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TUESDAY/WEDNESDAY POSTERS

Tuesday, July 27, 2010

TUE-AM-P, Poster Session #1, Exhibit Hall

Chair: John Archer, Retired
Co-Chair: Francesco de Paulis, University of L'Aquila
Meet and Greet Authors 8:30 to 9:30 am Tuesday.
Display of papers from 9:30 am Tuesday to Noon Wednesday.

8:30 am **A Guide for Selecting and Designing Your Method to Measure NSA** 16
Ed Blankenship *(Independent Researcher, Vancouver, WA, United States)*;
David Arnett *(Hewlett Packard Company, Vancouver, WA, United States)*;
Sidney Chan *(Hewlett Packard Company, Vancouver, WA, United States)*

Presentation Chart

Abstract–This paper compares different methods of performing Normalized Site Attenuation. All of these methods can be used in labs today, and are compliant with published standards. Each method has advantages and disadvantages which, if understood, can help labs improve their systems or show compliance with the standard requirements.

8:30 am **Near-Field Coupling Model between Electronic Systems and a Transmission Line** 22
Christelle Leseigneur *(IRSEEM / ESIGELEC, Saint Etienne du Rouvray, France)*; Priscila Fernández López *(IRSEEM / ESIGELEC, Saint Etienne du Rouvray, France)*; Christian Arcambal *(CEA, Saclay, France)*; David Baudry *(IRSEEM / ESIGELEC, Saint Etienne du Rouvray, France)*; Anne Louis *(IRSEEM / ESIGELEC, Saint Etienne du Rouvray, France)*

Presentation Chart

Abstract–This paper presents an analysis of radiated electromagnetic disturbances between electronic devices (parasitic emission source) and a transmission line. The study aims to model the coupling and for this purpose, two concepts are combined: the emission source is modelled by an array of elementary dipoles (electric and magnetic) and the induced voltage in the transmission line is calculated from the equivalent sources' radiation by two different approaches. The first one is totally analytical and is based on the transmission line theory and Taylor model. The second one only uses the insertion of the equivalent sources into an electromagnetic simulation tool. To validate our model we apply it for two cases: a passive system and an active one disturbing a transmission line.

8:30 am **Suppression of Power/Ground Noise using Meshed-Planar Electromagnetic Bandgap (MP-EBG) Structure for Ultra-Wideband (UWB) System-in-Package (SiP)** 28
Myunghoi Kim *(KAIST, Daejeon, Republic of Korea)*; Changwook Yoon *(KAIST, Daejeon, Republic of Korea)*; Kyoungchoul Koo *(KAIST, Daejeon, Republic of Korea)*; Chulsoon Hwang *(KAIST, Daejeon, Republic of Korea)*; Hajin Sung *(KAIST, Daejeon, Republic of Korea)*;
Joungho Kim *(KAIST, Daejeon, Republic of Korea)*

Presentation Chart

Abstract–In this paper, we propose the meshed-planar electromagnetic bandgap (MP-EBG) structure with a meshed planar surface embedded in the package power plane to suppress a power/ground noise in the frequency range from 3.1GHz to 10.6GHz, also known as the frequency band of Ultra-Wideband (UWB). The MP-EBG structure has two different EBG surfaces. One surface is a mushroom-like surface embedded between a package power and a ground plane and the other surface is a meshed planar structure embedded in a package power plane. The MP-EBG structure enables to enhance the bandwidth of the stopband in the limited package area and achieve the 8.7GHz stop bandwidth with -30dB isolation.

8:30 am **Design and Evaluation of a Novel AC Line Filter "Pentaleads®" having Quasi-Distributed Constant Structure** 32
K. Harada *(NEC TOKIN Co., Shiroishi-shi, Miyagi, Japan)*; Y. Takase *(NEC TOKIN Co., Sendai-shi, Miyagi, Japan)*; H. Ono *(NEC TOKIN Co., Sendai-shi, Miyagi, Japan)*; M. Takahashi *(NEC TOKIN Co., Sendai-shi, Miyagi, Japan)*; F. Tsuda *(NEC TOKIN Co., Shiroishi-shi, Miyagi, Japan)*; S. Yoshida *(NEC TOKIN Co., Sendai-shi, Miyagi, Japan)*

Presentation Chart

Abstract–A novel common-mode AC line filter "Pentaleads®" having five leads including an extra lead for grounding was developed. In order to realize an effective insertion loss in wide frequency range without using Y-capacitors, simple and unique quasi-distributed constant structure was adopted. The novel filter shows broad-band attenuation characteristics beyond 10 MHz which is nearly equal to a filter circuit consisted of a conventional line filter with Y capacitors of 3300pF. The novel filter enables not only realizing its attenuation characteristics broad, but also extremely low leakage current which is approximately only 1/20 of that of an equivalent L-C structured filter.

8:30 am **Estimating Radiated Emissions from Printed Circuit Boards and Cables Inside EMC Chambers** 36

Garrett McCormick *(University of Toledo, Toledo, OH, United States)*; Zulfiqar A. Khan *(University of Toledo, Toledo, OH, United States)*; Vijay Devabhaktuni *(University of Toledo, EECS, Toledo, OH, United States)*; Mansoor Alam *(University of Toledo, Toledo, OH, United States)*; Aihua Wood *(Air Force Institute of Technology, Wright–Patterson Air Force Base, OH,)*

Presentation Chart

Abstract–This paper presents a new approach to modelling radiated emissions from electronic systems inside EMC compliance chambers. The proposed approach exploits the fact that manufacturers prefer reusing circuits/layouts in new products with minor geometrical modifications to the existing designs. The available data from previous EMC testing, therefore, may contain certain features/patterns that may be extracted and employed to predict EMC performance of similar products. Motivated by this observation, the proposed method develops accurate models for radiated emissions inside the EMC testing environment. Specifically, radiated emissions from various geometrical configurations of a PCB-cable structure are employed to develop artificial neural network models. These developed models are tested to predict radiated emissions from a given PCB-cable structure configuration. Results show that very accurate estimates of the radiated emissions can be made using the developed models without requiring the time-consuming simulations and expensive prototype testing in the compliance chambers.

8:30 am **A Study of the use of a Low Order Reverberation Chamber for Shielding Measurements** 40

Colin E. Brench *(Southwest Research Institute, San Antonio, Texas, United States)*; David A. Smith *(Southwest Research Institute, San Antonio, Texas, United States)*

Presentation Chart

Abstract–The benefits of using the mode stir paddle in a reverberation chamber at low frequencies to enhance the dynamic range available for shielding measurements were studied. The high VSWR of the test antenna, when placed in a shielded room, show a number of deep nulls in the frequency response. The use of the paddles was seen to change the room geometry sufficiently to vary the match of the antennas and so minimize these nulls.

8:30 am **The Effect of a Horizontally Stratified Ground on Lightning Electromagnetic Fields** 45

F. Delfino *(University of Genoa, Genova, Italy)*; R. Procopio *(University of Genoa, Genova, Italy)*; M. Rossi *(University of Genoa, Genova, Italy)*; A. Shoory *(Swiss Federal Institute of Technology, Lausanne, Switzerland)*; F. Rachidi *(Swiss Federal Institute of Technology, Lausanne, Switzerland)*

Presentation Chart

Abstract–This paper proposes a formulation for the evaluation of the lightning electromagnetic fields in presence of a horizontally stratified soil. The formulation is based on a suitable mathematical modification of the Sommerfeld's exact formulas for the case of a homogeneous ground, in order to account for the dependence of the ground conductivity and permittivity on the vertical coordinate. Numerical simulations are presented to analyse the influence of the soil stratification on the above-ground lightning electromagnetic field components. The results obtained for a two-layered ground configuration are compared with those related to a homogeneous soil.

TUESDAY TECHNICAL PAPERS

TUE-AM-1, Antennas 1 (Sponsored by TC2), Room 223/222

Chair: Cliff Hauser, Raytheon Missile Systems

10:30 am **Influence of Antenna Pattern on Site Validation above 1 GHz for Site VSWR Measurements** 51

Jochen Riedelsheimer *(Albatross Projects GmbH, Team Technik, Nattheim, Germany)*; Friedrich-Wilhelm Trautnitz *(Albatross Projects GmbH, Team Technik, Nattheim, Germany)*

Presentation Chart

Abstract–With the experience of dozens of site VSWR validation measurements in SAC's and FAR's, special attention should be focused on the influence of the receiving antenna. Since the radiation pattern is determined in the standard and the used antennas (POD16 and POD618) are verified by measurements, the characteristic of the available receive antennas were investigated in detail at the band limits (1 GHz, 6 GHz, 18 GHz). The radiation pattern will be presented and analysed regarding the influence on site VSWR and measurement uncertainty. Also, the influences of coupling effects between receive antennas and masts were analysed during site VSWR testing.

11:00 am **A Reference Antenna Method for Non-Resonant Electrically Short Monopole Antennas** 56
Masanori Ishii *(National Institute of Advanced Industrial Science & Technology, National Metrology Institute of Japan, Tsukuba, Ibaraki, Japan)*; Yozo Shimada *(National Institute of Advanced Industrial Science & Technology, National Metrology Institute of Japan, Tsukuba, Ibaraki, Japan)*

Presentation Chart

Abstract–In order to measure the electric field strength in low-frequency bands, monopole antennas are generally used. When carrying out EMI measurements, the antenna factor is an important and well-known characteristic. Generally, absolute calibration methods are commonly used for monopole antenna calibrations. However, establishing and keeping the traceability to standard quantities in absolute calibration methods are time consuming. In this paper, a new reference antenna method for non-resonant electrically short monopole antennas is proposed and investigated through a numerical simulation. Since the target frequency band is less than 30 MHz, the monopole antennas work as electrically short monopole antennas. The measurements are performed under the near-field condition. The results show that the proposed reference antenna method is available and effective in obtaining the antenna factor of a non-resonant electrically short monopole antenna.

11:30 am **Aperture Coupling Near-Field Cavity Effects for Electromagnetic Testing with Measurements on a Slotted Circular Cylinder** 62
Marsellas L. Waller *(US Army Redstone Test Center, Redstone Arsenal, AL, United States)*; Thomas H. Shumpert *(US Army Redstone Test Center, Redstone Arsenal, AL, United States)*; Robert W. Scharstein *(University of Alabama, Tuscaloosa, AL, United States)*

Presentation Chart

Abstract–Electric field measurements for an electromagnetic wave excited from a log-periodic dipole array at two separation distances on a finite slotted circular cylinder are compared to an analytical model of a plane wave on an infinite slotted circular cylinder. The four foot diameter cylinder cross section is used to represent the cross section (1/2 scale) of an Army Blackhawk helicopter. The frequency range of interest is in the Very High Frequency (VHF) band where the first resonances of the cavity occur. Transverse Magnetic (TM) and Transverse Electric (TE) polarizations are considered.

TUE-AM-2, Power Supply Noise Control (Sponsored by TC4), Room 221/220

Chair: Noel Sargent, NASA
Co-Chair: John Kraemer, Rockwell-Collins

10:30 am **Impact of PCB Design on Switching Noise and EMI of Synchronous DC-DC Buck Converter** 67
Kyoungchoul Koo *(KAIST, Daejeon, Republic of Korea)*; Jiseong Kim *(KAIST, Daejeon, Republic of Korea)*; Myunghoi Kim *(KAIST, Daejeon, Republic of Korea)*; Joungho Kim *(KAIST, Daejeon, Republic of Korea)*

Presentation Chart

Abstract–Synchronous DC-DC buck converters operate under a few MHz but generate broadband noise up to GHz range due to its switching operation. The noise causes EMI problem through radiation and switching noise at the converter output from direct conduction. To control EMI and switching noise at the converter output, proper PCB design plays a critical role. This paper evaluates three types of GND plane layout and three types of high-voltage AC node layout for synchronous DC-DC buck converter test benches with 4-layer stack-up PCB. A transverse electromagnetic (TEM) cell measurement and a time-domain measurement of switching noise at the converter output were performed for the evaluation. The source of EMI, switching noise and magnitude difference over layouts were analyzed by the impedance measurement on the test benches.

11:00 am **Switching Voltage Regulator Noise Coupling to Signal Lines in a Server System** 72
Gong Ouyang *(Intel Corp., Dupont, WA, United States)*; Xiaoning Ye *(Intel Corp., Hillsboro, OR, United States)*; Trung-Thu Nguyen *(Intel Corp., Dupont, WA, United States)*

Presentation Chart

Abstract–This paper studies a real-world signal Integrity problem due to switching voltage-regulator (VR) noise coupling in a multi-processor server system. The fast switching of the VR FETs causes significant performance degradation on signal lines in proximity. The major source of the degradation is the high di/dt noise induced by FETs switching. The coupling mechanism is mutual inductive coupling between the VR transient current loop and the loop of differential signal pair. Solutions were identified by decreasing di/dt of the aggressor and optimizing component layout to reduce mutual inductance. General VR design methodology improvements are also discussed to address signal integrity concerns.

11:30 am **Investigation of Noise Coupling from Switching Power Supply to Signal Nets** 79
Songping Wu *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Keong Kam *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; David Pommerenke *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Bill Cornelius *(Apple Inc., Cupertino, CA, United States)*; Hao Shi *(Apple Inc., Cupertino, CA, United States)*; Matthew Herndon *(Apple Inc., Cupertino, CA, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Noise coupled from switched-mode power supply to signal nets can cause severe signal integrity problems because of the existence of fast switching voltages and currents in the circuit. In this paper, noise coupling mechanism from a synchronous buck converter to a nearby signal trace is studied using a hybrid non-linear model, which combines the synchronous buck converter circuit model and the passive electromagnetic model of the PCB coupling. General design guidelines to mitigate the noise coupling in practical printed circuit board (PCB) designs are provided based on the modeling results.

TUE-AM-3, Special Session – Evolving Trends in Spectrum Management and Engineering (Sponsored by TC6), Room 209/210

Chair: Larry Cohen, Naval Research Labs

10:30 am **High-Resolution Propagation Measurements using Biconical Antennas and Signal Processing** 85
Robert T. Johnk *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; John D. Ewan *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Nicholas DeMinco *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Ronald L. Carey *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Paul M. McKenna *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Christopher J. Behm *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Timothy J. Riley *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Steven Carroll *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; Mark A. McFarland *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*; James W. Leslie *(Institute for Telecommunication Sciences, Boulder, Colorado, United States)*

Presentation Chart

Abstract–This paper describes how commercially-available EMC biconical antennas can be used to perform high-resolution propagation measurements. A measurement procedure and signal processing sequence is described that greatly improves the range resolution and fidelity of transmission measurements using a pair of biconical antennas. Measurement results are provided for a number of different scenarios both indoors and outdoors. Direct comparisons are also provided with the Numerical Electromagtics Code (NEC).

11:00 am **Filter Technology for Spectrum Management** 91
Douglas R. Jachowski *(Naval Research Laboratory, Washington, DC, United States)*; Andrew C. Guyette *(Naval Research Laboratory, Washington, DC, United States)*

Presentation Chart

Abstract–Recent advances at the Naval Research Laboratory in filter technology applicable to spectrum management will be described.

TUE-AM-4, Special Session – EM Information Leakage (Sponsored by TC5), Room 207/208

Chair: Dr. William Radasky, Metatech Corporation
Co-Chair: Dr. Tetsuya Tominaga, NTT Corporation

10:30 am **Electromagnetic Information Leakage for Side-Channel Analysis of Cryptographic Modules** 97

Naofumi Homma *(Tohoku University, Sendai, Miyagi, Japan)*; Takafumi Aoki *(Tohoku University, Sendai, Miyagi, Japan)*; Akashi Satoh *(National Institute of Advanced Industrial Science & Technology, Chiyoda-ku, Tokyo, Japan)*

Presentation Chart

Abstract–A new class of physical attacks against cryptographic modules, which is called the side-channel attack, is now drawing much attention. Side-channel attacks exploit information leakage from a physical implementation, such as power consumption and electromagnetic (EM) radiation. This paper presents an overview of the recent trends in side-channel attacks, including EM analysis attacks, and related activities in the security evaluation of cryptographic modules.

11:00 am **Development of an On-Chip Micro Shielded-Loop Probe to Evaluate Performance of Magnetic Film to Protect a Cryptographic LSI from Electromagnetic Analysis** 103

Masahiro Yamaguchi *(Tohoku University, Sendai, Japan)*; Hideki Toriduka *(Tohoku University, Sendai, Japan)*; Shoichi Kobayashi *(Tohoku University, Sendai, Japan)*; Takeshi Sugawara *(Tohoku University, Sendai, Japan)*; Naofumi Homma *(Tohoku University, Sendai, Japan)*; Akashi Satoh *(Advanced Industrial Science & Technology, Chiyoda-ku, Tokyo, Japan)*; Takafumi Aoki *(Tohoku University, Sendai, Japan)*

Presentation Chart

Abstract–Measurement of electromagnetic near-field of a cryptographic LSI provides data on its instantaneous circuit operation. Therefore magnetic near field can be a target for side channel attack to steal secret key of encryption. In this paper, two types of miniature shielded-loop type magnetic probes were used to analyze RF magnetic near field on the ISO/IEC 18033-3 Standard Cryptographic LSI made by 0.13 μm CMOS process with clock frequency of 24 MHz. The 180x180 μm2-size on-chip shielded loop probe we developed was applied to scan the magnetic near field on the LSI and clarified that the magnetic filed is strong not only on the targeting cryptographic circuit. Such a detailed map was depicted for the first time for cryptographic LSI. Then the differential electromagnetic analysis (DEMA) was performed with the shielded-loop probe (1000 x 500 μm2, CP-2S, NEC). All the BITEs of 16-BYTEs long secret key are decrypted by using only 1x104 waveform data in case the waveform is measured closely to the cryptographic circuit whereas the error rate does not converge to zero until the waveform number reaches 3x10^4 if the data were extracted far away from the circuit. As the countermeasure against DEMA, 25μm thick magnetic film (μr=50 at 1MHz, NEC Tokin Co, type E25) was attached on top of bare LSI chip to suppress magnetic field intensity by 6 dB, which can be a good candidate to protect cryptographic LSI from side channel attack.

11:30 am **Information Leakage from Cryptographic Hardware via Common-Mode Current** 109

Yu-ichi Hayashi *(Tohoku University, Sendai, Japan)*; Takeshi Sugawara *(Tohoku University, Sendai, Japan)*; Yoshiki Kayano *(Akita University, Akita, Japan)*; Naofumi Homma *(Tohoku University, Sendai, Japan)*; Takaaki Mizuki *(Tohoku University, Sendai, Japan)*; Akashi Satoh *(National Institute of Advanced Industrial Science & Technology, Chiyoda-ku, Tokyo, Japan)*; Takafumi Aoki *(Tohoku University, Sendai, Japan)*; Shigeki Minegishi *(Tohoku Gakuin University, Tagajyo, Japan)*; Hideaki Sone *(Tohoku University, Sendai, Japan)*; Hiroshi Inoue *(Akita University, Akita, Japan)*

Presentation Chart

Abstract–Recently, it has been known that electromagnetic radiation from electrical device leaks internal information. That is, electromagnetic radiation contains information. Especially, it causes serious problem for cryptographic modules if electromagnetic radiation contains secret information. Therefore many studies have been made on power/electromagnetic analysis attacks, which extract secret keys from cryptographic modules by analyzing waveforms of currents, voltage or electromagnetic field. The attacks assume that the waveforms should contain the information leakage in some way. However, there are few studies discussing about "mechanisms" of the information leakage via electromagnetic field. In this paper, we will give the leakage model caused by common-mode currents, which are one of dominant factors of radiation. If the common-mode currents contain the secret information, it might be possible to obtain the information from far field. In order to verify the leakage model, we implement cryptographic hardware on an FPGA board, and reveal the secret information from common-mode currents measured by using EMC measurement techniques.

TUE-PM-4, Special Session – EM Information Leakage (Sponsored by TC5), Room 207/208

Chair: Dr. William Radasky, Metatech Corporation
Co-Chair: Dr. Tetsuya Tominaga, NTT Corporation

1:30 pm **ElectroMagnetic Attacks Case Studies on Non-Protected and Protected Cryptographic Hardware Accelerators** 115

Laurent Sauvage *(Telecom ParisTech / Secure-IC S.A.S., Paris, France)*; Olivier Meynard *(TELECOM ParisTech / DGA CELAR, Paris, France)*; Sylvain Guilley *(Telecom ParisTech / Secure-IC S.A.S., Paris, France)*; Jean-Luc Danger *(Telecom ParisTech / Secure-IC S.A.S., Paris, France)*

Author Unavailable for Presentation

Presentation Chart

Abstract–Electromagnetic analysis (EMA) is an important class of attacks against cryptographic devices. In this article, we present two attacks to disclose the key of cryptographic implementations in FPGAs by taking advantage of EMA. The first one shows how the Correlation-based on EMA (CEMA) on a non-protected hardware AES module is possible from a distance as far as 50 cm. An analysis of the leakage structure shows that the Hamming distance model, although suitable for small distances gets more and more distorted when the antenna is displaced far from the device. We pre-characterized a physical model using a first order templates construction which allowed us to enhance the CEMA by a factor up to ten. Therefore, we conclude that EMA at large distance is feasible with our amplification strategy coupled to an innovative training phase. The second case is about a 3DES cryptoprocessor protected with Dual-rail with Precharge Logic (DPL). We experimentally show that this countermeasure can be broken by an EMA method which relies on two stages, the first being a localisation phase by means of cartography, and the second being the EMA attack itself on the most relevant area.

2:00 pm **An Improved Technique to Discover Compromising Electromagnetic Emanations** 121

Martin Vuagnoux *(EPFL, Lausanne, Switzerland)*; Sylvain Pasini *(EPFL, Lausanne, Switzerland)*

Presentation Chart

Abstract–The techniques generally used to detect compromising emanations are based on a wide-band receiver tuned on a specific frequency or a spectral analyzer with a limited bandwidth. However, these methods may not be optimal since a significant amount of information is lost during the signal acquisition. In this paper, we propose a straightforward but efficient approach which acquires raw signal directly from the antenna and processes the entire captured electromagnetic spectrum thanks to the computation of short time Fourier transforms. We applied this approach to detect potential compromising electromagnetic emanations radiated by modern keyboard. Since keyboards are often used to transmit confidential data such as passwords, these emanations could remotely reveal sensitive information such as keystrokes. Thanks to this method, we detected four different kinds of compromising electromagnetic emanations generated by wired and wireless keyboards. These emissions lead to a full or a partial recovery of the keystrokes. We implemented these side-channel attacks and our best practical attack fully recovered 95\% of the keystrokes of a PS/2 keyboard at a distance up to 20 meters, even through walls.

2:30 pm **Information Leakage of Input Operation on Touch Screen Monitors caused by Electromagnetic Noise** 127

Hidenori Sekiguchi *(Osaka University, Osaka, Japan)*

Presentation Chart

Abstract–It is known that the display image on a personal computer with a monitor can be reconstructed by receiving the electromagnetic noise. Recently, the concern about information leakage in the display image caused by the electromagnetic noise has increased from the aspect of information security. In the present study, the information leakage of input button key operations on touch screen monitors was investigated experimentally in the reconstructed display image using the received electromagnetic noise. The experimental results revealed that the touched button image on the touch screen monitor can be identified in the reconstructed display image. In addition, the information leakage origin was discussed based on the reconstruction principle of the display image.

3:30 pm **Jamming Technique to Prevent Information Leakage Caused by Unintentional Emissions of PC Video Signals** 132

Yasunao Suzuki *(NTT Energy & Environment Systems Laboratories, Musashino-shi, Tokyo, Japan)*; Yoshiharu Akiyama *(NTT Energy & Environment Systems Laboratories, Musashino-shi, Tokyo, Japan)*

Presentation Chart

Abstract–A working personal computer (PC) and/or PC display monitor usually emits unintentional radiated electromagnetic waves, and it has been known that the information from a video display unit could be reconstructed by intercepting such emissions at a distance. This can be a potential information security threat, and proper measures are needed to prevent information leakage. In this paper, we propose a suitable jamming scheme for protect information

managed in a PC against such eavesdropping. We have developed a prototype portable countermeasure device using a jamming scheme, and experimentally evaluated its performance. The jamming signal of the countermeasure device synchronizes to the original video signal, so it is suitable for individual PCs and effective even when the video-frame averaging technique is used by the eavesdroppers.

4:00 pm **Countermeasure for Electromagnetic Screen Image Leakage based on Color Mixing in Human Brain** 138
Takashi Watanabe *(Hitachi Ltd., Tokyo, Japan)*; Hiroto Nagayoshi *(Hitachi Ltd., Tokyo, Japan)*; Takehiro Urano *(Hitachi Ltd., Tokyo, Japan)*; Toshirou Uemura *(Hitachi-Omron Terminal Solutions, Corp., Aichi-ken, Japan)*; Hiroshi Sako *(Hitachi Ltd., Tokyo, Japan)*

Presentation Chart

Abstract–The security problem of screen image leakage from a display unit has received wide interest of security researchers since the Van Eck's paper. As for the industry side, the problem is considered a security risk; especially for the computers that are used in the sensitive business fields, i.e. banking, data center. To solve this problem, reduction of the emanating signals' S/N ratio is important. Therefore, signal reduction and noise generation methods have been investigated as countermeasure. We present a method that imposes noise on displayed screen images, while keeping the quality of the image. This is realized by utilizing the human characteristic that is known as "Additive color mixing", which occurs when the eyes are continuously exposed to quickly changing colors. By implementing this method on hardware and software in an ordinary computer system, we confirmed the effectiveness of our method as a countermeasure for the electromagnetic screen image leakage.

TUE-AM-5, Cavities and Statistics (Sponsored by TC9), Room 203/204

Chair: Dr. Chris Holloway, NIST
Co-Chair: Dr. Marina Koledintseva, Missouri University of Science and Technology

10:30 am **Maximum Levels Inside an Electromagnetic Shielded Cavity** 143
Magnus Höijer *(Swedish Defence Research Agency FOI, Linköping, Sweden)*

Presentation Chart

Abstract–We present analytic expressions to quickly calculate the maximum electric field and power levels inside an electromagnetic shielded cavity. Typical maximum values are 9-11 dB larger than the corresponding average values. The method is applicable to both worst case estimates in e.g. an avionics bay, as well as to calculate the test quantity when performing a radiated susceptibility test in the reverberation chamber.

11:00 am **Statistics use for Radiated High Frequency Failures** 147
Emmanuelle Garcia *(EADS ASTRIUM Space Transportation, Les Mureaux, France)*

Presentation Chart

Abstract–After presenting a global process of EMC (ElectroMagnetic Compatibility) physics and risk analysis, this paper deals with the specific failure mode of radiated high frequencies. For realistic complex systems with partial unavailability of the data, peak amplitude frequency and observable spatial localisation sensibility, we detail the advantages of four main types of statistical results. The potential of using statistics in simulation coupled with experimental tests is also highlighted.

11:30 am **On Radiated Susceptibility Testing of Highly Directive Devices** 153
Vignesh Rajamani *(Oklahoma State University, Stillwater, OK, United States)*; Charles Bunting *(Oklahoma State University, Stillwater, OK, United States)*

Presentation Chart

Abstract–Radiated susceptibility testing of a highly directive device is challenging. To ensure the worst case coupling test in an anechoic chamber, an exhaustive measurement scheme is required which usually is not a viable option. When a test is performed with minimal requirements, the potential to miss susceptibilities are high and the uncertainty worsens when directivity is a function of frequency. Reverberation chambers assure best case susceptibility tests due to the nature of complex cavities but the potential to under test is also present as the directivity of the EUT are smoothed out. In this study, simulations are performed on a box with apertures to calculate directivity. An anechoic chamber test and reverb like tests are simulated to calculate the coupling. The differences in maximums of the induced fields are shown as a comparison.

TUE-PM-1, Measurements 1 (Sponsored by TC2), Room 223/222

Chair: Don Heirman, Don Heirman Consultants

1:30 pm **Radiated Spurious Emissions Measurement by Substitution Method** 159

Qin Yu *(Alcatel-Lucent, Columbus, OH, United States)*

Presentation Chart

Abstract–The total power substitution method is a measurement approach preferred by FCC and other authorities for evaluating the radiated spurious emissions of an RF product. This paper reviews and discusses the setup and procedures for conducting radiated spurious emissions measurement by using this approach. Two estimation methods, the free space path loss (FSPL) method and the site attenuation method, are also presented and elaborated in the paper. With a given field strength of a spurious signal at the receiving antenna, its effective radiated power (ERP) and the required input power to the substitution antenna can be estimated beforehand to save testing time and efforts. The calculated results are compared with the measured ones from both broadband EMC antennas and tunable dipoles. The pros and cons of each method are addressed as well.

2:00 pm **A New Stripline Measuring Setup for the Characterisation of Conductive Gaskets up to 18 GHz** 165

Johan Catrysse *(MICAS/ESAT, KULeuven, Heverlee-Leuven, Belgium)*; Filip Vanhee *(KHBO, Flanders Mechatronics Engineering Center, Oostende, Belgium)*; Davy Pissoort *(KHBO, Flanders Mechatronics Engineering Center, Oostende, Belgium)*; Christian Brull *(Schlegel Electronic Materials, Leffinge, Belgium)*

Presentation Chart

Abstract–Due to the impact of higher and higher frequencies, the SE characterisation of shielding gaskets at frequencies above 1 GHz is needed for on board shielding applications. Although the standard IEEE Std 1302™ – 2008 is covering the characterisation of shielding gaskets up to 18 GHz, the methods proposed in this standard are not applicable for these type of thin and small gaskets. A method overcoming this problem is proposed in this paper.

2:30 pm **Reduction of Noise in Near-Field Measurements** 171

Christopher Osterwise *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Steven L. Grant *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Daryl Beetner *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Near-field measurements are sometimes corrupted by ambient noise from either far- or near-field sources. Far-field noise can be removed by performing measurements in a shielded room, but this option is not always available. An adaptive noise cancellation technique is proposed for cancelling ambient electromagnetic interference from measurements taken in a noisy environment. A time-domain, non-recursive, block-processing algorithm was selected to generate the adaptive linear filter. Measurements in the near field of a clocked-logic electronic device in a noisy environment are compared with measurements of the same device in a noise-free environment to demonstrate that the algorithm properly removes ambient electromagnetic noise from the recorded signals. Electromagnetic noise signals in the frequency range of 10 to 700 MHz are reduced in magnitude by 20 dB or more, often to the level of thermal noise.

3:30 pm **A Critical Assessment of the Closed-Loop Bulk Current Injection Immunity Test Performed in Compliance with ISO 11452-4** 177

Paolo S. Crovetti *(Politecnico di Torino, Torino, Italy)*; Franco Fiori *(Politecnico di Torino, Torino, Italy)*

Presentation Chart

Abstract–In this paper, the closed-loop Bulk Current Injection (BCI) method, that is employed to measure the immunity to Electromagnetic Interference (EMI) of an electronic equipment in compliance with the ISO 11452-4 standard, is critically assessed on the basis of an experimental characterization of its test setup. In particular, it is highlighted that the injected bulk current estimated by the calibration procedure described in the standard is significantly different from the actual bulk current injected into the EUT connector during BCI tests above 100MHz. Such a discrepancy gives rise to unreliable BCI immunity test results highlighting susceptibility issues that are not related with the actual susceptibility of the equipment under test. The characterization technique considered in this paper could be adopted to define an alternative procedure to estimate the EUT-level injected bulk current in BCI tests.

4:00 pm **Frequency Phenomenon and Algorithms for Arc Detection** 183
Kermit Phipps *(Electric Power Research Institute, Knoxville, Tennesee, United States)*;
Thomas Cooke *(Electric Power Research Institute, Knoxville, Tennesee, United States)*;
Doug Dorr *(Electric Power Research Institute, Knoxville, Tennesee, United States)*;
Philip Keebler *(Electric Power Research Institute, Knoxville, Tennesee, United States)*

Presentation Chart

Abstract–Successful detection of power line arcing requires various algorithms from frequency domain to time domain analysis. This paper explores frequency phenomenon that when analysed with a defined set of algorithms can distinguish between arcing noise and typical power line noise associated with distribution hardware and various noise-generating loads. These techniques may be applied to measuring conducted and radiated emissions in the electromagnetic environment. They may also be applied to H and E fields resulting from the spreading of distribution lines within a secondary power-distribution down inside a manhole. The promising quick detection and identification from laboratory and actual field measurements is necessary and critical to ensure life-safety for manhole workers during maintenance activities.

4:30 pm **New Radiated Immunity/Susceptibility Test Method using Rotating FM-EM Field** 189
Kimitoshi Murano *(Tokai University, Hiratsuka-shi, Kanagawa, Japan)*; Majid Tayarani *(Iran University of Science & Technology, Narmak, Tehran, Iran)*; Fengchao Xiao *(University of Electro-Communications, Chofu-shi, Tokyo, Japan)*; Yoshio Kami *(University of Electro-Communications, Chofu-shi, Tokyo, Japan)*

Presentation Chart

Abstract–A new radiated radio-frequency immunity/susceptibility test method using a frequency-modulated rotating electromagnetic field (rotating FM-EM field) is described. By using the field as an incident-EM field in an immunity/susceptibility test, the immunity/susceptibility characteristics of an equipment under test for a polarization angle of the field with time-varying frequency spectra can be easily obtained. In this paper, a generation method and basic characteristics of the rotating FM-EM field for the radiated immunity/susceptibility test are clarified. Moreover, measured susceptibility of an FM receiver is shown as an example.

TUE-PM-2, Nanotechnology and Advanced Materials (Sponsored by TC11), Room 221/220

Chair: Dr. Chris Holloway, NIST
Co-Chair: Dr. Marina Koledintseva, Missouri University of Science and Technology

1:30 pm **EMI Shielding Effects of Carbon Nanotubes on Traditional EMI Plastics** 194
Ned Bryant *(RTP Company, Winona, MN, United States)*

Presentation Chart

Abstract–Carbon Nanotubes (CNTs) were added to several Polycarbonate (PC) based plastic shielding compounds and the resulting composites were measured for Shielding Effectiveness (SE). It was discovered that at relatively low loading levels the addition of CNTs with the Stainless Steel (SS) and Nickel-Coated Carbon Fiber (NCCF) fibrous additives resulted in a significant increase in the SE of the composites. The entire SE percolation curve shifted to lower loading levels requiring less SS or NCCF to manifest useful shielding results. These results will allow future designs to be lighter weight and more cost effective.

2:00 pm **EMI Shielding Effects of Carbon Nanotube Cellulose Nanocomposite** 198
Pasi Moilanen *(University of Jyväskylä, Jyväskylä, Finland)*; Marko Luukkainen *(Nokia Corporation, Tampere, Finland)*; Jari Jekkonen *(IT'IS Foundation, Zürich, Switzerland)*; Veijo Kangas *(University of Jyväskylä, Jyväskylä, Finland)*

Presentation Chart

Abstract–Electromagnetic interference shielding is important aspect of modern communication and computer technology. Carbon nanotube cellulose nanocomposite (CNTCNC) provides a novel material for EMI shielding. Especially promising is use of layered solution where CNTCNC paper is combined with existing commercial materials. The effect of CNTCNC layer is surprising and it is not yet sure, what causes the significant raise in shielding. CNTCNC is essentially paper like in properties, thus it is flexible and if needed it can be modified in many ways.

2:30 pm **Electromagnetic Absorbing Nanocomposites including Carbon Fibers, Nanotubes and Graphene Nanoplatelets** 202

G. De Bellis *(Sapienza University of Rome, Rome, Italy)*; I.M. De Rosa *(Sapienza University of Rome, Rome, Italy)*; A. Dinescu *(National Institute for Research & Development in Microtechnologies, Bucharest, Romania)*; M.S. Sarto *(Sapienza University of Rome, Rome, Italy)*; A. Tamburrano *(Sapienza University of Rome, Rome, Italy)*

Presentation Chart

Abstract–Nanocomposites loaded with different types of micro/nanofillers are developed and characterized for use in electromagnetic radar absorbing materials with minimum thickness. It is demonstrated that the tailoring of the desired EM properties can be achieved by the proper choice and combination of both the filler and the matrix. In particular, graphene Nanoplatelets dispersed in a bisphenol-A based epoxy matrix feature a loss tangent lower than a few percent and tailored dielectric permittivity. The designed bilayer absorbers entirely made with nanocomposites have thicknesses of 2 mm and 1.5 mm for the X-band and Ku-band respectively.

3:30 pm **Broadband Characterization of Carbon Nanotube Networks** 208

Emmanuel Decrossas *(University of Arkansas, Fayetteville, Arkansas, United States)*; Mahmoud A. EL Sabbagh *(University of Arkansas, Fayetteville, Arkansas, United States)*; Victor Fouad Hanna *(University Pierre et Marie Curie, Paris, France)*; Samir M. El-Ghazaly *(University of Arkansas, Fayetteville, Arkansas, United States)*

Presentation Chart

Abstract–In this paper, the complex permittivity of carbon nanotube networks is extracted over a broadband of frequencies using a non destructive, simple, and low-cost procedure. The structure holding the material under test is a hollow circular waveguide shorted at one end and connected through precision adapter to the 1.85 mm-50-Ohms coaxial cable of performance network analyzer. In this testing configuration, discontinuities between different transmission lines are modeled based on the full-wave mode matching technique. In this modeling, all higher-order modes propagating and evanescent are considered in the computation which produces generalized scattering matrices (GSMs). A gradient-optimization method is used to solve the inverse problem and extract the complex permittivity of material under test from the measured magnitude and phase of reflection coefficient. The technique is general and requires only a small fraction of material under test which can be in liquid, pulverized or solid form.

4:00 pm **Comparative Analysis of TL Models for Multilayer Graphene Nanoribbon and Multiwall Carbon Nanotube Interconnects** 212

M.S. Sarto *(Sapienza University of Rome, Rome, Italy)*; A. Tamburrano *(Sapienza University of Rome, Rome, Italy)*

Presentation Chart

Abstract–The multiconductor transmission line model of a multilayer graphene nanoribbon (MLGNR) interconnect is proposed for the analysis of current distribution and signal propagation at radio frequency (RF) up to 100 GHz. The equivalent single conductor model is also developed in order to analyse the common mode propagation. The comparison of the RF performances of a MLGNR interconnect and a multi-wall carbon nanotube (MWCNT) interconnect is also performed. The obtained results show that the MLGNR interconnect has a higher current carrying capability than an MWCNT nanoline having the same dimension and configuration above the ground.

TUE-PM-3, PCB Concerns (Sponsored by TC4), Room 209/210

Chair: John Archer, Retired
Co-Chair: Philip Keebler, EPRI

1:30 pm **Spurious Emission from Microstrip Oscillator Circuit** 218

Han-Chang Hsieh *(National Taiwan University, Taipei, Taiwan)*; Jay-San Chen *(Bureau of Standards, Metrology & Inspection, Taipei City, Taiwan)*; Chi-Hsueh Wang *(National Taiwan University, Taipei, Taiwan)*; [illegible] *(National Taiwan University, Taipei, Taiwan)*; Ming-Shing Lin *(National Yunlin University of Science & Technology, Yunlin, Taiwan)*; Chun Hsiung Chen *(National Taiwan University, Taipei, Taiwan)*

Author Unavailable for Presentation

Presentation Chart

Abstract–The previously developed fast model is adopted to characterize the electric field radiated from the microstrip oscillator circuit. The oscillator circuit is nonlinear and autonomous, and may cause a large amount of spurious emission. In this paper, both simulated and measured results are presented and good agreement between them is observed. Being based on the field-expressions-incorporated circuit solver, the adopted fast model would be very useful and efficient in

predicting the field radiated from the whole oscillator circuit as well as that from each microstrip element. Specifically, this model has demonstrated to be suitable for locating the main emission sources on PCB.

2:00 pm **On Chip Filtering versus Layout Techniques to Reduce RF Coupled Disturbances** 222
Philipp Schröter *(Technical University of Ilmenau / Infineon Technologies AG, Neubiberg, Germany)*; Frank Klotz *(Infineon Technologies AG, Neubiberg, Germany)*

Presentation Chart

Abstract–This paper investigates techniques to improve the performance of analog circuits and reduce their sensitivity to coupled electromagnetic interferences (EMIs). A bandgap has been chosen for these analyses. RF noise is injected into an aggressor line couples and causes circuit functional failure. The efficiency of design techniques as an increase of bias currents, different filters and layout techniques as an increase of distances, different shieldings were compared. Performance improvements of the circuit and required additional chip size for the modifications were considered. The investigations have been done by measurements. Therefore various circuits were designed and manufactured. A model of the bandgap was derived that predicts correctly the susceptibility of the circuit.

2:30 pm **Simulation and Design of Printed Circuit Boards Utilizing Novel Embedded Capacitance Material** 228
Yu Xuequan *(Huawei Technologies Co., Ltd, Shanghai, China)*; Yan Hang *(Huawei Technologies Co., Ltd, Shanghai, China)*; Zhang Gezi *(Huawei Technologies Co., Ltd, Shanghai, China)*; Wang Haisan *(Huawei Technologies Co., Ltd, Shanghai, China)*

Presentation Chart

Abstract–The effects of a novel embedded capacitance material on PI-Power integrity, SI-Signal integrity and EMC-Electro Magnetic Compatibility were simulated and measured by comparing a multilayer board with embedded capacitance to a conventional multilayer board utilizing conventional FR-4 material. SIwave software was used to simulate electrical properties and EMC of the embedded capacitance material board and conventional FR-4 material board up to a frequency of 4 GHz. Finally, the application prospects of embedded capacitance materials are analysed.

3:30 pm **Limit and use of Near-Field Scan for Platform RFI Analysis** 233
Jayong Koo *(Intel Corporation, Hillsboro, Oregon, United States)*; Jason Mix *(Intel Corporation, Hillsboro, Oregon, United States)*; Kevin Slattery *(Intel Corporation, Hillsboro, Oregon, United States)*

Presentation Chart

Abstract–A near-field scan procedure for approximating the radio frequency (RF) current within an integrated circuit (IC) chip or printed circuit board (PCB) is suggested, and is examined for characterizing the radio frequency interference (RFI) of a mobile internet device research platform. The equivalent RF current obtained from the procedure serves as a model for the noise source and is used to estimate the near field distribution above a small micro processor. Comparison of the predicted near field distribution is made with measurements and the limitations of the approach is also discussed.

4:00 pm **Reduction of Heatsink Emissions by Application of Lossy Materials** 239
Eric Chikando *(IBM Corporation, Durham, North Carolina, United States)*; Samuel Connor *(IBM Corporation, Durham, North Carolina, United States)*; Bruce Archambeault *(IBM Corporation, Durham, North Carolina, United States)*

Presentation Chart

Abstract–This paper investigates the benefits of high permittivity and permeability RF materials on electromagnetic interference (EMI) performance of integrated circuit (IC) heatsinks. An analysis of lossy materials using Finite-Difference Time-Domain (FDTD) simulations is presented and findings are supported by experimental measurements carried out in both reverberation chamber (RC) and Semi-Anechoic Chamber (SAC) environments.

TUE-PM-5, High Power and Time Domain Simulation (Sponsored by TC9), Room 203/204

Chair: Sam Connor, IBM
Co-Chair: Dr. Alan Roden, Aerospace Corp

1:30 pm **Investigation on Electromagnetic Responses of Double Objects Illuminated by a High-Power EMP using Hybrid TDIE-TDPO Method** 244

Ming-Da Zhu *(Shanghai Jiao Tong University, Shanghai, China)*; Xi-Lang Zhou *(Shanghai Jiao Tong University, Shanghai, China)*; Wen-Yan Yin *(Zhe Jiang University / Shanghai Jiao Tong University, Hangzhou, China)*

Presentation Chart

Abstract–An efficient and stable hybrid method, based on time-domain integral equation (TDIE) and time-domain physical optics (TDPO), is proposed for investigating electromagnetic responses of double 3-D objects illuminated by a high-power EMP. The planar triangular patches are used to model the conductive surface with RWG basis functions implemented, while the temporal basis functions of weighted Laguerre polynomials are also employed. A set of hybrid TDIE-TDPO equations are solved by marching-on-in-order scheme (MOO) for the sake of stability. Under such circumstances, compared with the full TDIE solver, the computational complexity of our developed hybrid TDIE-TDPO method is reduced greatly. Several examples are presented to demonstrate its validity and efficiency. In particular, transient electromagnetic responses of different double 3-D conductive objects, illuminated by a HP- EMP, are captured and compared for different pulse waveforms and pulse parameters.

2:00 pm **Analysis of Radio Interference due to Corona along 1000kV AC Transmission Lines** 248

Yang Zou *(North China Electric Power University, Baoding, Hebei, China)*; Tiebing Lu *(North China Electric Power University, Baoding, Hebei, China)*; Zhibin Zhao *(North China Electric Power University, Baoding, Hebei, China)*; [illegible] *(North China Electric Power University, Baoding, Hebei, China)*; Gaolin Xiong *(North China Electric Power University, Baoding, Hebei, China)*

Author Unavailable for Presentation

Finalist for Best Student Paper Award

Presentation Chart

Abstract–The excitation function method is used to analyze radio interference (RI) generated from the corona of power transmission lines. RI from different transmission line arrangements is calculated. The effect of different line parameters is analyzed, including the height of the lines, soil resistivity and radius of sub-conductors. From the analysis we can see that the height and soil resistivity can significantly influence RI, but the radius of the conductor has little effect. The research is helpful to the design and operation of 1000kV AC transmission lines in China.

2:30 pm **Fast Calculation of Dielectric Substrate Losses in Microwave Applications by the FD2TD Method using a New Formalism** 253

C. Buccella *(University of L'Aquila, L'Aquila, Italy)*; V. De Santis *(University of L'Aquila, L'Aquila, Italy)*; M. Feliziani *(University of L'Aquila, L'Aquila, Italy)*; F. Maradei *(Sapienza University of Rome, Rome, Italy)*

Presentation Chart

Abstract–The paper deals with the electromagnetic characterization of dielectric substrate by a numerical analysis. The electromagnetic analysis is performed by a frequency-dependent finite difference time domain (FD2TD) method with a new formulation. A multi-pole Debye dispersive relation is used to model frequency-dependent properties of dispersive dielectrics. The proposed method is suitable to predict efficiently substrate dielectric loss in EMC, microwave and RF applications.

3:30 pm **Transient FDTD Simulation Validation** 257

Ricardo Jauregui *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Pere J. Rui *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Ferran Silva *(Universitat Politècnica de Catalunya, Barcelona, Spain)*

Presentation Chart

Abstract–In computational electromagnetic simulations, most validation methods have been developed until now to be used in the frequency domain. However, the EMC analysis of the systems in the frequency domain many times is not enough to evaluate the immunity of current communication devices. Based on several studies, in this paper we propose an alternative method of validation of the transients in time domain allowing a rapid and objective quantification of the simulations results.

4:00 pm **Transient Perturbation Analysis in Digital Radio** 263
Ricardo Jauregui *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Marc Pous *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Mireya Fernández *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Ferran Silva *(Universitat Politècnica de Catalunya, Barcelona, Spain)*

Presentation Chart

Abstract–This paper presents a new simulation methodology to study the effect of radiated transient disturbances on digital communication systems. The procedure is divided in two stages. In the first one, FDTD numerical simulation is used to determine the transient levels coupled to the antennas. In the second stage, these levels are analyzed by means of a signal processing simulation software to determine the degradation caused in the system. The procedure is applied to a DAB system in car when a radiated interference is generated by a transient in a vehicle cable. The results show that the amplitude of the radiated transient coupled signal is a key parameter, but it is also essential to take into account other parameters such as burst duration and frequency.

4:30 pm **Evaluation of Propagation Characteristics for PCB Traces with Periodic Roughness using ASM-FDTD Method** 269
Minshen Wang *(University of Houston, Houston, Texas, United States)*; Rui Qiang *(University of Houston, Houston, Texas, United States)*; Ji Chen *(University of Houston, Houston, Texas, United States)*; Marina Koledintseva *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Amendra Koul *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; James Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–This paper presents an efficient technique to evaluate the propagation characteristics of PCB traces with periodic roughness. This technique is based on the application of the array-scanning-method finite-different time-domain technique in which only one single periodic element need to be modeled. Numerical examples are used to demonstrate the effectiveness and efficiency of this approach.

WEDNESDAY/THURSDAY POSTERS

Wednesday, July 28, 2010

WED-PM-P, Poster Session #2, Exhibit Hall

Chair: John Archer, Retired
Co-Chair: Francesco de Paulis, University of L'Aquila
Meet and Greet Authors Noon to 1:00 pm Thursday.
Display of papers from 1:30 pm Wednesday to Noon Thursday.

1:30 pm **The Laboratory Stand for Conducted Emissions Measurement in Accordance with the Military Standard** 275
Leszek Nowosielski *(Military University of Technology, Warsaw, Poland)*; Rafał Przesmycki *(Military University of Technology, Warsaw, Poland)*; Marian Wnuk *(Military University of Technology, Warsaw, Poland)*

Presentation Chart

Abstract–This paper concerns the problems of electromagnetic compatibility of military equipment. There were presented the measurement methodology and a description of the laboratory stand for measuring conducted emissions from military equipment in frequency bandwidth from 10kHz to 10MHz in accordance with the procedure CE 102 of MIL STD 461E standard. The laboratory stand mentioned above is used to do research in scope of accreditation for Electromagnetic Compatibility Laboratory WEL WAT granted by Polish Centre for Accreditation.

1:30 pm **A Two-Layer Board Intellectual Property to Reduce Electromagnetic Radiation** 279

Nansen Chen *(MediaTek Inc., Hsinchu, Taiwan)*; Hongchin Lin *(National Chung-Hsing University, Taichung, Taiwan)*

Presentation Chart

Abstract–A non-ideal return path in the printed circuit board (PCB) with a split reference plane will increase electromagnetic interference (EMI) that is encountered in the digital LCD-TV system using a 2-layer PCB. An innovative layout skill using the surface mounted jumpers or zero ohm resistors to connect the power nets in the PCB and DDR SDRAM can avoid the split reference plane in the bottom layer. From the S-parameters simulation, the proposed PCB design induces less signal insertion loss, which is expected to have less radiation. The radiated emission measurement was also performed to verify the 2-layer PCB with the solid reference plane achieving less electromagnetic radiation from 0.36 dB to 8.65 dB (μV/m) in the range of DDR operating and harmonic frequencies.

1:30 pm **Improvement of Simultaneous Switching Noise Simulation Considering On-Chip Capacitance** 284

Kunio Ota *(Toshiba Corporation, Yokohama, Kanagawa, Japan)*; Kazuhisa Matsuge *(Toshiba Corporation, Yokohama, Kanagawa, Japan)*; Yo Takahashi *(Shibaura Institute of Technology, Tokyo, Japan)*; Toshio Sudo *(Shibaura Institute of Technology, Tokyo, Japan)*

Presentation Chart

Abstract–Simultaneous switching noise (SSN) causes signal degradation to the high-speed interfaces among CMOS VLSIs. To achieve SSN simulation with a high accuracy, accurate models for chips, packages and printed circuit boards (PCBs) are required. However, such accurate simulation models are not currently available, since chip vendors do not release the value of on-chip capacitance and the detailed package model with mutual inductances. This paper presents our approach for establishing an accurate model without detailed information on the chip and package. The three key points of our approach are the measurement of on-chip capacitance using a vector network analyzer (VNA), the measurement of quad flat package (QFP) dimensions using X-ray photographs, and the application of 3-D electromagnetic field solver to extract a detailed equivalent circuit model for the package from a geometrical structure. The simulated SSN time-domain waveforms showed an extremely good agreement with the measured results.

1:30 pm **Development of Equivalent Circuit Model with Transmission Line Model for Designing Filter Formed on Printed Circuit Boards** 289

Keisuke Matsumoto *(Okayama University, Okayama, Japan)*; Yoshitaka Toyota *(Okayama University, Okayama, Japan)*; Kengo Iokibe *(Okayama University, Okayama, Japan)*; Ryuji Koga *(Okayama University, Okayama, Japan)*

Presentation Chart

Abstract–Slit pattern formed on return plane of printed circuit boards behaves like a passive element. A defected ground structure (DGS) is one of them. The characteristics of DGS easily varies with the slit pattern so that it is expected for various applications. Since a design method has not been developed, however, we need to establish the method to design a slit pattern. Some equivalent circuit models have been used but they consist of lumped elements and require full-wave simulation. In addition, value of the lumped elements have no relation to physical parameters. So it is not useful for filter designing. In this report, we proposed equivalent circuit model with transmission line model for DGS with filter function. Transmission characteristic was calculated by both full-wave simulator and circuit simulator with the proposed equivalent circuit model and the first stop-band width calculated by circuit simulator was in agreement with full-wave simulator.

1:30 pm **Optimization of Heat Sink EMI using Design of Experiments with Numerical Computational Investigation and Experimental Validation** 295

S. Manivannan *(Anna University, Chennai, Tamil Nadu, India)*; R. Arumugam *(SSN College of Engineering, Chennai, Tamil Nadu, India)*; S. Prasanna Devi *(Anna University, Chennai, Tamil Nadu, India)*; S. Paramasivam *(ESAB, Chennai, Tamil Nadu, India)*; P. Salil *(CEM-Sameer, Chennai, Tamil Nadu, India)*; B. Subbarao *(CEM-Sameer, Chennai, Tamil Nadu, India)*

Presentation Chart

Abstract–This paper presents a technique for the minimization of electromagnetic radiation from the flat plate heat sink by optimizing the heat sink geometry parameters using Taguchi Design of Experiments technique. The heat sink is modelled and simulated using numerical method via Ansoft HFSS software. Experimental investigation on the heat sink was performed in a shielded semi anechoic chamber confirming to FCC/CISPR requirements for EMC measurements. The experimental results were found to have good concurrence with the simulated results. The L27 combinations (6 factors, 3 levels) were generated by the Taguchi's Design of Experiments with orthogonal array method using Minitab software. The L27 combinations generated were analysed for radiated emission via simulation. The parameters considered for optimization are the Length and Width of the heat sink, Fin height, Base height, Number of fins and Fin

thickness. With the results available for each of the 27 combinations, ANOVA test was carried out for finding out the contribution and impact of each heat sink design parameter towards the radiated emission by the heat sink.

1:30 pm **Diagnosis of EMI to Laptop WWAN Device from TFT-LCD Driver using Non-Contact Measurement-Based Transfer Function Technique** 301

K.-S. Chen *(National Sun Yat-sen University, Kaohsiung, Taiwan)*; T.-S. Horng *(National Sun Yat-sen University, Kaohsiung, Taiwan)*; C.-Y. Ho *(National Sun Yat-sen University, Kaohsiung, Taiwan)*; J.-M. Wu *(National Kaohsiung Normal University, Kaohsiung, Taiwan)*; K.-C. Peng *(National Kaohsiung First University of Science & Technology, Kaohsiung, Taiwan)*

Presentation Chart

Abstract–This paper presents a novel non-contact measurement technique for electromagnetic interference (EMI) diagnosis. The proposed technique uses vector network analyzer with antenna and near-field probes to measure the transfer function for an EMI path without interrupting the operation of device under test. As an example, with the help of the measured transfer function and equivalent source in the proposed technique, the EMI to laptop wireless wide area network (WWAN) device caused by a thin film transistor-liquid crystal display (TFT-LCD) driver is accurately diagnosed and appropriately treated. In addition, an easy-to-follow procedure is given for applying the presented non-contact measurement technique to the demonstrated example.

1:30 pm **Multichannel Pseudo-Differential Links** 305

Frédéric Broydé *(Excem, Maule, France)*; Evelyne Clavelier *(Excem, Maule, France)*

Presentation Chart

Abstract–In this paper, we study multichannel pseudo-differential transmission schemes which use a common conductor or a return conductor. Combining 4 architectures with compatible types of termination circuit, we find that 12 multichannel pseudo-differential transmission schemes are possible. They provide a reduced external crosstalk compared to multiple single-ended links, using fewer conductors than multiple differential links.

1:30 pm **Mobile Phones Electromagnetic Interference in Medical Environments: A Review** 311

Mireya Fernández-Chimeno *(Universitat Politècnica de Catalunya, Barcelona, Spain)*; Ferran Silva *(Universitat Politècnica de Catalunya, Barcelona, Spain)*

Presentation Chart

Abstract–This paper presents a review of the effect of electromagnetic interferences of mobile phones in medical environment. The review is focussed in two areas, EMI in implantable devices like pacemakers or ICD, and EMI in medical equipment in hospital areas with life supporting equipment like intensive care units (ICU) or operating rooms (OR). The applied methodology for interference testing is different for all the analyzed studies, and the results range from 100% of interfered devices to no effect. The majority of authors recommend maintaining a safety distance both between cellular phones and medical devices. Also, it is necessary to establish clear policies for the use of mobile phones in critical areas in hospitals. Finally, it is necessary to develop a family of EMC standards for testing in-situ the effects of non-medical devices inside medical facilities. This will permit medical staff to take profit from new technologies in their daily work in a safe way.

1:30 pm **Extracting Physical IC Models using Near-Field Scanning** 317

Zhenwei Yu *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jayong Koo *(Intel Corporation, Hillsboro, Oregon, United States)*; Jason A. Mix *(Intel Corporation, Hillsboro, Oregon, United States)*; Kevin Slattery *(Intel Corporation, Hillsboro, Oregon, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Accurate modeling of chip and chip-package is critical for EMI (Electromagnetic Interference) and RFI (RF Interference) analysis and prediction. In this paper, a model based on an array of dipoles from near-field measurement is proposed. A simple active circuit is simulated in a 3-D full-wave simulation tool, and the dipole model is calculated from the near-field data in the simulation using inverse method with regularization technique. This model has clear physical meaning, and it is validated using field at other place.

WEDNESDAY TECHNICAL PAPERS

WED-AM-1, Antenna 2 (Sponsored by TC2), Room 223/222

Chair: Werner Schaefer, Cisco

8:30 am **Quantum-Based SI Traceable Electric-Field Probe** 321

Joshua A. Gordon *(NIST, Boulder, Colorado, United States)*; Christopher L. Holloway *(NIST, Boulder, Colorado, United States)*; Steve Jefferts *(NIST, Boulder, Colorado, United States)*; Tom Heavner *(NIST, Boulder, Colorado, United States)*

Presentation Chart

Abstract–We are presently investigating the feasibility of developing a technique that will allow direct traceable microwave electric field (E-field) measurements. The new approach is based on atomic rf-resonance spectroscopy, where an applied electrical field causes a transition between high-lying Rydberg states of an atom. The new technique will allow direct E-field measurements traceable to fundamental physical constants and SI units. If successful, this self calibrating probe will provide more accurate field measurements along with better sensitivity than do present techniques. Direct traceable E-field measurements with sensitivities below 0.1 V/m could be possible.

9:00 am **Simulated Characteristics of Optical Electric Field Probe** 325

Tomokazu Ikenaga *(National Institute of Information & Communications Technology, Sendai, Miyagi, Japan)*; Hiroyasu Ota *(National Institute of Information & Communications Technology, Sendai, Miyagi, Japan)*; Ken Ichi Arai *(National Institute of Information & Communications Technology, Sendai, Miyagi, Japan)*

Presentation Chart

Abstract–To perform electric near-field measurements with high accuracy in the gigahertz frequency range, we are developing an optical electric field probe by employing an electrooptic crystal and a laser beam for signal transmission. In this paper, we report the results of a FDTD (Finite Difference Time Domain) simulation of the invasiveness of probes when measuring the electric field distribution above a microstrip line (MSL). The purpose is to verify the measurement accuracy and clarify the design guidelines for optical electric filed probes. Key words: Electric field distribution, Optical electric field probe, Microstrip line, FDTD.

9:30 am **Field Injection Probes for Field Coupled Electrostatic Discharge Sensitivity Database of ICs** 329

Zhen Li *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jiang Xiao *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Byongsu Seol *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jongsung Lee *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; David Pommerenke *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–An ESD sensitivity database gives a guidance in estimating if, for given ESD scenario and IC location soft-error problems are likely to occur or not. The paper describes on the field probes used.

10:30 am **Dependence of the Time- and Frequency-Domain Response of BCI Injection Probes on the Common-Mode Characteristic Impedance of the Cable Bundle** 334

James McLean *(TDK R&D Corp., Cedar Park, Texas, United States)*; Robert Sutton *(TDK R&D Corp., Cedar Park, Texas, United States)*

Presentation Chart

Abstract–The common-mode characteristic impedance of a typical cable bundle has been suggested to be approximately 150 Ohms. However, standard test fixtures for BCI probes employ 50 Ohm coaxial ports. Here a representative injection probe (transformer) intended for bulk current injection applications is characterized experimentally in the frequency domain using a 2-port vector network analyzer and a standard (50 Ohm) test fixture as described in the IEC 61000-4-6 standard. The full 3-port scattering representation of the probe in the test fixture is then de-embedded and renormalized such that the coaxial ports of the test fixture are changed to 150 Ohms. The time-domain step response of the representative transformer is then computed from the renormalized frequency-domain scattering matrix. It is seen that changing the impedance level from 50 Ohms to 150 Ohms significantly alters both the frequency and time domain performance of the transformer. Thus, the standard test fixture does not accurately predict the frequency and time

performance of a typical BCI transformer. It is shown that the dependence of performance on port impedance can, to some extent, be anticipated by examining the equivalent network for the transformer.

11:00 am **Improvements in GMI Probe Design for Time-Domain Transient Current Measurements** 340
Fan Zhou *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Songping Wu *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; David Pommerenke *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Yoshiki Kayano *(Akita University, Akita, Japan)*; Hiroshi Inoue *(Akita University, Akita, Japan)*; Kenji Tan *(Akita Research & Development Center, Akita, Japan)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Measurement techniques for time-domain transient currents are widely needed in many EMC applications. Demonstrated to have a lot of potential for this purpose, giant magnetio-impedance (GMI) probes are studied in this paper. Improvements in the probe design, including a balanced circuit for increased signal to noise ratio and an on-probe magnetic-field bias circuit, are proposed. These improvements in the probe design make the GMI probes more suitable for practical applications of time-domain transient current measurements

11:30 am **Characterization of the Bulk Current Injection Calibration-Jig for Probe-Model Extraction** 344
Flavia Grassi *(Politecnico di Milano, Milano, Italy)*; Sergio A. Pignari *(Politecnico di Milano, Milano, Italy)*

Presentation Chart

Abstract–In this paper, a circuit model of the jig used for calibration of bulk current injection (BCI) probes is derived. The jig model is used to develop a procedure for probe-model extraction, based on measurement data, with the injection device mounted onto the calibration jig. This allows to exploit a device, i.e., the calibration jig, belonging to standard equipment of every EMC laboratory, and provides precise indications on how to adapt the probe parameters to the characteristics of the actual wiring harness to be tested.

WED-AM-2, HPEM (Sponsored by TC5), Room 221/220

Chair: Dr. William Radasky, Metatech Corporation
Co-Chair: Michael McInerney, U.S. Army Engineer Research

8:30 am **Systematic Design Technique for Improvements of Mobile Phone's Immunity to Electrostatic Discharge Soft Failures** 348
Ki Hyuk Kim *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*; Jeong-Hoi Koo *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*; Bong-Gyu Kang *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*; Soon Jae Kwon *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*; Yongsup Kim *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*; Joongho Jeong *(Samsung Electronics, Co., Ltd., Suwon, Gyeonggi, Republic of Korea)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–A systematic design technique for the improvements of the mobile phone's immunity to the electrostatic discharge (ESD) soft failures is proposed. The design technique consists of two parallel processes; one is the ESD simulation and the other is the ESD characterization. The modeling methods of the mobile phone, the ESD gun and the ESD testing setup for the ESD simulations are also developed. The proposed technique is applied to design the countermeasures against the ESD soft failure of the slide-type mobile phone and the root causes of the ESD soft failure are analyzed based on the proposed technique. The RC low pass filters are designed to improve the ESD immunity of the mobile phone and the ESD simulation results of the improved mobile phone show more than 82% voltage level reductions of the signals which cause the ESD soft failure. The improved mobile phone's ESD immunity is characterized again and no ESD soft failure is detected.

9:00 am **Model for ESD LCD Upset of a Portable Product** 354

Jiang Xiao *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
David Pommerenke *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Fan Zhou *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
James L. Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Hideki Shumiya *(Sony Company, Tokyo, Japan)*; Takashi Yamada *(Sony Company, Tokyo, Japan)*;
Kenji Araki *(Sony Company, Tokyo, Japan)*

Presentation Chart

Abstract–A hybrid method is developed to model Electrostatic Discharge (ESD) LCD (Liquid Crystal Display) upset in a portable product. It combines ESD scanning, full-wave simulation and circuit simulation. This methodology is applied in the investigation of system-level ESD problem of the LCD of the portable product by the following steps. First, the sensitive area of the portable product causing the failure is located by ESD scanning. Using the local injection measurement currents, a behavioural SPICE model is then developed to simulate the ESD failure. Third, a full wave block-level model is used to extract the current densities at the sensitive regions; those current densities are imported into the SPICE model to predict ESD upset levels. The combined model is verified by testing its ability to simulate the upset level of 4 system level ESD test conditions, leading to satisfactory results.

9:30 am **Effects of High-Power and Transient Disturbances on Wireless Communication Systems Operating Inside the 2.4 GHz ISM Band** 359

Christian Klünder *(Hamburg University of Technology, Hamburg, Germany)*;
Jan Luiken ter Haseborg *(Hamburg University of Technology, Hamburg, Germany)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–This paper deals with special HPEM sources and their effects on wireless communication systems operating inside the 2.4 GHz ISM band. Different measurements have been performed to investigate the effect of UWB and radar pulses on the receiver of a digital wireless communication system. First the coupling of UWB and radar pulses into a typical bar antenna usable for the 2.4 GHz ISM band has been measured. Based on the coupling measurements the effects in the baseband of a typical wireless receiver is being investigated for different radar and UWB pulses. Finally a worst-case analysis by using a HF switch is being investigated for a WLAN and Bluetooth system. The results show how possible interferences with different interference durations and interference repetition rates can cause effects on the performance of a wireless communication system.

10:30 am **The Investigation of Measurement Method for HPM Radiation to the Analog Switch Chip** 364

Minkyun Yoo *(University of Seoul, Dondaemoon-gu, Seoul, Republic of Korea)*; Wonkyu Kim *(University of Seoul, Dondaemoon-gu, Seoul, Republic of Korea)*; Yoon-Mi Park *(Seoul National University, Kwanak-gu, Seoul, Republic of Korea)*; Min-Hyuk Kim *(Seoul National University, Kwanak-gu, Seoul, Republic of Korea)*; Young-Seek Chung *(Kwangwoon University, Nowon-gu, Seoul, Republic of Korea)*; Hyun-Kyo Jung *(Seoul National University, Kwanak-gu, Seoul, Republic of Korea)*; Changyul Cheon *(University of Seoul, Dondaemoon-gu, Seoul, Republic of Korea)*

Presentation Chart

Abstract–In this paper we suggest a special measurement system using an optical transformation when an analog switch chip is exposed by an external High Power Microwave(HPM). The proposed measurement system can compare a normal operation with a malfunction of the chip, analyzed signals at each pin of the chip when the HPM radiates to the chip. To analyze accurately the operation of the chip proposed measurement system uses an optical communication method. An electrical signal of the chip is modulated to an optical signal by a laser diode(LD) within the range of the HPM. After that, the modulated optical signal is demodulated to the electrical signal by a photo diode(PD) beyond the range of the HPM and then signal is measured. Because this system has no interference between frequency of microwaves and optical waves, an accurate analysis is possible.

11:00 am **Effect of Ionosphere to Lightning Radiation Field** 370

Zhibin Zhao *(North China Electric Power University, Beijing, China)*;
Tiebing Lu *(North China Electric Power University, Beijing, China)*

Author Unavailable for Presentation

Abstract–The effect of ionosphere to the lightning radiation magnetic field is investigated in this paper. Supposing that the ionosphere is perfect conductor layer, the expressions of magnetic field are obtained. Based on the engineering model, the obtained expression is applied to analyzing the characteristics of lightning radiation magnetic field. The

analysis indicates that the reflection from the ionosphere result in multiple peaks in lightning radiation magnetic field. At last, some measured results are presented to be analysed.

11:30 am **Effects of Channel Length on Calculation Accuracy of Lightning Return Stroke Electromagnetic Fields** 374

Tongyu Ding *(Harbin Institute of Technology, Harbin, Heilongjiang, China)*;
Shaoqing Zhang *(Harbin Institute of Technology, Harbin, Heilongjiang, China)*;
Qun Wu *(Harbin Institute of Technology, Harbin, Heilongjiang, China)*

Presentation Chart

Abstract–In order to save the computation time of lightning electromagnetic pulse in FDTD, we shorten the lightning discharge channel length to 1000m, calculate the electromagnetic fields at flat ground. To compare the results with those of H=2500m, we found the error caused by the shortening only occurs in the descending period of the lightning waveforms, and the relative error of Ez is about 3% for near field, while the computation time is only 1/3 of that calculated with H=2500m.

WED-AM-3, Special Session – Hybrid Techniques for EMC Analysis (Sponsored by TC9), Room 209/210

Chair: Dr. Albert Ruehli, Missouri University of Science and Technology
Co-Chair: Dr. Guilio Antonini, University of L'Aquila

8:30 am **Parameterized Model Order Reduction with Guaranteed Passivity for PEEC Circuit Analysis** 378

Francesco Ferranti *(Ghent University, Gent, Belgium)*; Tom Dhaene *(Ghent University, Gent, Belgium)*; Luc Knockaert *(Ghent University, Gent, Belgium)*; Giulio Antonini *(Università degli Studi dell'Aquila, L'Aquila, Italy)*

Finalist for Best Student Paper Award

Presentation Chart

Abstract–We present a novel parameterized model order reduction technique applicable to the Partial Element Equivalent Circuit analysis that provides parametric reduced order models, stable and passive by construction, over a user defined design space. We treat the construction of parametric reduced order models on scattered design space grids. This new parameterized model order reduction technique is based on the hybridization of traditional passivity-preserving model order reduction methods and interpolation schemes based on a class of positive interpolation operators, in order to guarantee overall stability and passivity of the parametric reduced order model. Pertinent numerical examples validate the proposed approach.

9:00 am **Efficient Signal and Power Integrity Analysis by using Modal Decomposition and Integral Equations** 384

Xing-Chang Wei *(Institute of High Performance Computing, A*STAR, Singapore, Singapore)*;
Er-Ping Li *(Institute of High Performance Computing, A*STAR, Singapore, Singapore)*;
En-Xiao Liu *(Institute of High Performance Computing, A*STAR, Singapore, Singapore)*

Presentation Chart

Abstract–In this paper, we propose a novel field-circuit method for the signal and power integrities simulation of power distribution networks. The electromagnetic field inside the power distribution network is expressed in the modal field distribution. The modal field is then decomposed into the parallel plate mode and transmission mode, which are related to the power-ground planes and signal traces respectively. Integral equations are created for these two modes. During the discritization of the integral equations, network ports are defined between the power-ground planes and signal traces. In this way, their equivalent networks are extracted through the moments method solution of the integral equations. Finally, the two equivalent networks are combined to provide the whole circuit model of the power distribution network. This circuit model can be used for the signal and power integrities analysis. Through numerical examples, the accuracy and efficiency of the proposed method is verified.

9:30 am **Efficient Macromodeling of Power-Bus Structures based on 2D-Integral Equation Approach** 390

M. Leone *(OvG-University Magdeburg, Magdeburg, Germany)*;
O. Kröning *(OvG-University Magdeburg, Magdeburg, Germany)*

Presentation Chart

Abstract–A numerically very efficient simulation method for the analysis of arbitrarily shaped power-bus structures on printed-circuit boards is presented. It is based on a 2D contour integral-equation method in combination with a subsequent macromodeling step, for simulation in time- and frequency domain. For this purpose a vector-fitting approach is applied, yielding a SPICE-compatible equivalent circuit representation of the power bus. The presented approaches allow us to embed the power planes as a linear N port into a circuit simulator, in order to perform a complete analysis of a power-bus system with active and passive components and the complete decoupling circuitry. The accuracy of the suggested method is validated by independent 3D-full wave simulations and experimental results.

10:30 am **An Electromagnetics-Based Parallel Transient Simulator of Linear Complexity for the Analysis of Very Large-Scale Integrated Circuits and Packages** 396

Duo Chen *(Purdue University, West Lafayette, Indiana, United States)*; Dan Jiao *(Purdue University, West Lafayette, Indiana, United States)*

Presentation Chart

Abstract–A parallel transient electromagnetic simulator of linear complexity and linear speedup is developed to simulate very large-scale integrated circuits and packages from DC to very high frequencies. In this simulator, through suitable basis functions and linear algebraic techniques, we directly and rigorously decompose the original 3-D system matrix into multiple 1-D matrices with negligible computational overhead. Each one-dimensional matrix is made tridiagonal, and hence can be solved readily in linear complexity. We then achieve an almost embarrassingly parallel implementation of the linear-complexity electromagnetic solver with a low communication-to-computation ratio. Numerical experiments on very large-scale integrated circuits and packages have demonstrated superior performance and linear speedup of the proposed parallel transient simulator. It successfully simulates a large-scale combined die-package system from a real product, which involves more than 3.5 billion unknowns, in fast CPU run time.

11:00 am **Hybrid Method used to Model via Transitions** 401

Hanfeng Wang *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Albert E. Ruehli *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–A hybrid approach to solve via impedance and model via transitions is presented in the paper. The method is a combination of via-plane capacitance extraction and the impedance matrices calculation of parallel plane pair. A new formulation of the integral equation method for axially symmetric geometry is used for the capacitance extraction. The method is validated with other model results.

11:30 am **Next-Generation Three-Dimensional Full-Wave Electromagnetic Solver Hybridization for Large-Scale Signal Integrity, Power Integrity, and EMI Modeling** 407

Vikram Jandhyala *(University of Washington, Seattle, Washington, United States)*;
Swagato Chakraborty *(Physware Inc., Bellevue, Washington, United States)*;
Dipanjan Gope *(Physware Inc., Bellevue, Washington, United States)*

Presentation Chart

Abstract–This paper introduces a new methodology and conceptual framework for implementation of automated hybrid solver technology. Specifically, it addresses the challenges and approaches to automated solver hybridization, whereby a three-dimensional full-wave simulation technology may adapt automatically to geometric redundancies and significantly reduce cost while maintaining high accuracy. The proposed method is one step towards the grand goal of an adaptive error-controllable solver that embodies all aspects of 3D full-wave, 3D quasi-static, and various semi-analytic and analytic approximations within a unified automated framework.

WED-AM-4, Radiation Coupling and EMI (Sponsored by TC4), Room 207/208

Chair: David Larrabee , East Stroudsburg University
Co-Chair: Kermit Phipps, EPRI

8:30 am **Prediction of EMI from Two-Channel Differential Signaling System based on Imbalance Difference Model** 413

Tohlu Matsushima *(Kyoto University, Kyoto, Japan)*; Tetsushi Watanabe *(Industrial Technology Center of Okayama Prefecture, Okayama, Japan)*; Yoshitaka Toyota *(Okayama University, Okayama, Japan)*; Ryuji Koga *(Okayama University, Okayama, Japan)*; Osami Wada *(Kyoto University, Kyoto, Japan)*

Presentation Chart

Abstract–In a differential transmission line, a large common mode radiation is excited due to asymmetry. To suppress the radiation, the differential line must be designed electrically symmetric. In this paper, the imbalance difference model, which was proposed by the authors for estimation of common-mode radiation, is extended to apply the differential signaling system. The authors focus on two pairs of differential transmission lines with asymmetric property, which consists of an adjacent return plane and signal lines which are placed close to an edge of the return plane. The authors define five transmission modes; two normal modes, two primary common modes and a secondary common mode. In these transmission modes, the secondary common mode radiation is dominant, and the authors evaluate the radiation using the imbalance difference model. To reduce the common-mode radiation, placing a guard trace which has the same potential as that of the return plane, we can control the imbalance and reduce common-mode radiation even the transmission line has asymmetry. The reduction of common mode radiation can be estimated quantitatively by calculation of the imbalance of the transmission line.

9:00 am **Study of Mutual Coupling on Mobile Phone PCB with Shielding using FDTD** 419

Chung-Huan Li *(ETH Zurich, Zurich, Switzerland)*; Jari Jekkonen *(ETH Zurich, Zurich, Switzerland)*; George Tudosie *(Schmid & Partner Engineering AG, Zurich, Switzerland)*; Nicolas Chavannes *(Schmid & Partner Engineering AG, Zurich, Switzerland)*; Niels Kuster *(ETH Zurich, Zurich, Switzerland)*

Presentation Chart

Abstract–The coupling mechanisms between the active traces and a victim trace with two victim ports on a real phone PCB model was investigated with FDTD simulation in this paper. The studied scenarios include the PCB with a full shielding, perforated shielding and no shielding. Firstly, the coupling performance of the real phone PCB was reproduced with numerical simulations. According to the simulation results, a simplified PCB model was developed based on the real phone PCB to study the coupling mechanisms with different geometries of the shielding, including the dimensions and perforated shielding. The understanding from the investigation were applied to interpret the performance in the real phone PCB.

9:30 am **Knowledge-Based Approach to Interference Mitigation for EMC of Transceivers on Unmanned Aircraft** 425

Ilteris Demirkiran *(Embry-Riddle Aeronautical University, Daytona Beach, Florida, United States)*; Donald D. Weiner *(Syracuse University, Syracuse, New York, United States)*; Andrew Drozd *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*; Irina Kasperovich *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*

Presentation Chart

Abstract–This paper discusses the results of exploratory research and development to apply and demonstrate a heuristics, knowledge-based approach for analyzing the electromagnetic compatibility (EMC) of co-located radio frequency (RF) spread spectrum frequency hopping transceivers mounted on an unmanned airborne vehicle (UAV) platform.

10:30 am **New Insights on Loop Radiation Efficiency** 431

Dheena Moongilan *(Bell Laboratories, Alcatel-Lucent, Murray Hill, New Jersey, United States)*

Presentation Chart

Abstract–Circuit loop area reduction is a frequently used EMC technique for minimizing differential mode current radiations and improving the overall immunity of products from electrical noise. The efficiency characteristics of loop radiation are studied and new facts on loop radiation are described. The relationship of the radiation amplitude efficiency and frequency of the first radiation-peak with the size and shape of the loop area is explained. A mathematical model is presented for calculating radiations first peak and its frequency from the loop area. The effect of loop area shape on peak radiation frequency is experimentally verified. Experimental data is also provided to demonstrate that the radiation amplitude efficiency peak shifts to higher frequencies when the loop area is minimized.

11:00 am **Polarization Extraction through the Linear Component Method** 437
J.A. Nascimento *(Federal University of Campina Grande, Campina Grande, Paraiba, Brazil)*; G. Fontgalland *(Federal University of Campina Grande, Campina Grande, Paraiba, Brazil)*; R.M. Valle *(Federal University of Campina Grande, Campina Grande, Paraiba, Brazil)*

Presentation Chart

Abstract–In this article is proposed a measurement technique to the electromagnetic polarization for completely polarized waves, using the linear component method, in order to obtain the magnitude and phase of the radiated electric field by one or many sources. Through these parameters the characteristics of the electromagnetic wave emitted by antennas, including the type and miniaturized RFID, will be defined more precisely.

11:30 am **Effects of a Wire beneath the Ground Plane on Antenna Coupling through a Slot** 440
Takehiro Morioka *(National Institute of Advanced Industrial Science & Technology, Tsukuba, Ibaraki, Japan)*; Kazuhiro Hirasawa *(University of Tsukuba, Tsukuba, Ibaraki, Japan)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–Antenna characteristics, such as input impedance are considerably deviated from those in free space when another antenna is located in the vicinity of the antenna. This often causes system degradation problems. In the present paper, effects of a parasitic wire located beneath the slotted ground plane are investigated on the coupling between monopole antennas above the ground plane. The method of moments is applied to the problem and a combined matrix formulation that includes mutual coupling effects between the elements located in both regions is newly introduced. It is shown that a wire beneath the ground plane considerably affects coupling characteristics between two monopoles above the ground plane when the slot resonates.

WED-AM-5, Signal Integrity I (Sponsored by TC10), Room 203/204

Chair: Dr. Marina Koledintseva, Missouri University of Science and Technology
Co-Chair: Dr. Jianmin Zhang, Cisco

8:30 am **Improved Target Impedance and IC Transient Current Measurement for Power Distribution Network Design** 445
Jingook Kim *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Songping Wu *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Hanfeng Wang *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Yuzo Takita *(Sony Corporation, Tokyo, Japan)*; Hayato Takeuchi *(Sony Corporation, Tokyo, Japan)*; Kenji Araki *(Sony Corporation, Tokyo, Japan)*; Gang Feng *(Research In Motion, Waterloo, Ontario, Canada)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–An improved definition of target impedance is proposed in this paper, which is derived from the time-domain waveforms of the IC transient current and the allowable voltage fluctuation. The proposed target impedance removes the unnecessary constraint in the original definition and allows for more cost-effective power distribution network (PDN) designs for consumer electronic products. A measurement procedure to obtain IC transient current waveforms is also developed for the PDN designs utilizing power traces. The proposed target impedance and the measurement procedure have been validated using practical functioning designs.

9:00 am **Differential Signal via Shield with Narrow via Pitch Partial Electromagnetic Bandgap Structure** 451
Chulsoon Hwang *(KAIST, Deajeon, Republic of Korea)*; Minchul Shin *(KAIST, Deajeon, Republic of Korea)*; Jun So Pak *(KAIST, Deajeon, Republic of Korea)*; Joungho Kim *(KAIST, Deajeon, Republic of Korea)*

Presentation Chart

Abstract–This paper presents a signal via shielding method in a printed circuit board (PCB) with the narrow via pitch partial electromagnetic bandgap (NVP-PEBG) structure. The NVP-PEBG structure was developed to shield a small area such as a signal via with wideband isolation and compact size. This NVP-PEBG structure showed excellent noise isolation for a single-ended signal via. In this paper, the NVP-PEBG structure is applied to a differential signal via and its performance with the differential signal via is demonstrated in coupling against the noise in a power and ground plane.

9:30 am **Equivalent Transmission-Line Model for Vias Connected to Striplines in Multilayer Print Circuit Boards** 455

Siming Pan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jianmin Zhang *(Cisco Systems, Inc., San Jose, California, United States)*; Qinghua B. Chen *(Cisco Systems, Inc., San Jose, California, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Finalist for Best Student Paper Award

Presentation Chart

Abstract–Vias are typical discontinuities for high-speed signal transmission in printed circuit boards. Previous work has studied the through-hole via connections from the top layer to the bottom between microstrip traces and proposed an equivalent transmission-line model for impedance matching between traces and vias. In this paper, the equivalent transmission-line model is extended for the via structures connected to striplines based on modal decomposition. Both single-ended and differential cases are discussed, and the effects of the model parameters on the performance of signal transition are also investigated. The extended equivalent transmission-line model is accurate and fast to be embedded in circuit simulators for via and link-path analysis. Further, it could provide straightforward criteria to design and optimize via structures for better signal integrity.

10:30 am **Off-Phase Crosstalk Behaviour and Design Considerations for High-Speed Memory Buses** 461

Amy J. Chen *(Intel Corporation, Santa Clara, California, United States)*; Hao Wang *(Intel Corporation, Santa Clara, California, United States)*

Presentation Chart

Abstract–The interconnect margins shrink rapidly at higher speed due to reduced bit width and increased noise level. Crosstalk impact remains the biggest concern for the single-ended memory busses such as DDR3 and GDDR5 interconnect. The phase relationship of the xtalk coupling plays an important role on interconnect performance. This paper outlines several types of off-phase crosstalk and their impact to system margin. It also provides the methodology to analyse their effects and design considerations to mitigate their impact.

11:00 am **Design and Modeling for Chip-to-Chip Communication at 20 Gbps** 467

Jianmin Zhang *(Cisco Systems, Inc., San Jose, California, United States)*; Qinghua B. Chen *(Cisco Systems, Inc., San Jose, California, United States)*; Kelvin Qiu *(Cisco Systems, Inc., San Jose, California, United States)*; Antonio C. Scogna *(CST of America, Framingham, Massachusetts, United States)*; Martin Schauer *(CST of America, Framingham, Massachusetts, United States)*; Gerardo Romo *(CST of America, Framingham, Massachusetts, United States)*; James L. Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Antonio Orlandi *(University of L'Aquila, L'Aquila, Italy)*

Presentation Chart

Abstract–This paper presents the design of serial chip-to-chip communication at 20 Gbps including modeling and correlation for PCBs (Printed Circuit Boards) with FR4 substrate materials. The entire channel under investigation includes two packages, a 21-layer ceramic and a 12-layer organic, and a 22-layer PCB. A probing station, microprobes and a VNA are used to measure the entire channel S-parameters and the measurement is correlated to the simulation up to 20 GHz. Extended study for the channel with low loss PCB substrate material is simulated. Time-domain eye comparisons for the FR4 channel, low loss channel, and the FR4 channel with equalization are given. A general design rule as well as new technologies for the high-speed channel design at 20 Gbps and beyond are discussed and given in the conclusion.

11:30 am **An Evaluation of the Immunity Characteristics of an LSI with Capacitors Embedded in an Interposer** 473

Chie Sasaki *(Panasonic Corporation, Kadoma City, Osaka, Japan)*; Yoshiyuki Saito *(Panasonic Corporation, Kadoma City, Osaka, Japan)*; Eiji Takahashi *(Panasonic Corporation, Kadoma City, Osaka, Japan)*; Yasuhiro Sugaya *(Panasonic Electronic Devices Co., Ltd., Kadoma City, Osaka, Japan)*; Hideki Kobayashi *(Panasonic Electronic Devices Co., Ltd., Kadoma City, Osaka, Japan)*

Presentation Chart

Abstract–To improve the electrical characteristics of LSIs, we are developing technology for embedding chip capacitors into interposers for LSIs. In this paper, we applied an interposer with embedded capacitors to an image-processing LSI and compared its electrical characteristics with that of a conventional LSI. We confirmed improvements in the timing margin, signal integrity, and immunity characteristics of the LSI.

WED-PM-1, Measurement 2 (Sponsored by TC2), Room 223/222

Chair: Bob Hofmann, Hofmann EMC Engineering

1:30 pm **Time-Domain Measurement Method to Guard against Preamplifier Saturation** 479

Matthew J. Jackson *(DENSO International America, Inc., Southfield, Michigan, United States)*

Presentation Chart

Abstract–This paper investigates the cause of preamplifier saturation, discusses the 1 dB compression point and considers the ramifications of collecting data with a saturated amplifier. Two common saturation analysis methods, the attenuator check and band-pass filter, are considered as ways to guard against preamplifier saturation. After a brief discussion on the amplifier's input signal and its composition, a time-domain measurement method, consisting of seven steps, is introduced as another way to prevent preamplifier saturation.

2:00 pm **Modeling of the Immunity of ICs to EFTs** 484

Ji Zhang *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Jayong Koo *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Daryl Beetner *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Richard Moseley *(Freescale Semiconductor, Inc., Austin, Texas, United States)*;
Scott Herrin *(Freescale Semiconductor, Inc., Austin, Texas, United States)*;
David Pommerenke *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Investigation of the immunity of ICs to EFTs is increasingly important. In this paper, an accurate model of a microcontroller is developed and verified. This model consists of two parts: a passive Power Distribution Network (PDN) model and an active I/O protection network model. Measurement methods are designed to extract the parameters of the passive PDN model. The accuracy of the overall model of the IC is verified using both S parameter tests and EFT injection tests. The model is able to accurately predict the voltage and current at power-supply and I/O pins and correctly accounts for the active components of the I/O protection network.

2:30 pm **Spectral Analysis of Conducted Emissions of DC/DC Converters** 490

Diego Bellan *(Politecnico di Milano, Milano, Italy)*; Filippo Marliani *(European Space Agency, Noordwijk, Netherlands)*; Sergio A. Pignari *(Politecnico di Milano, Milano, Italy)*;
Giordano Spadacini *(Politecnico di Milano, Milano, Italy)*

Presentation Chart

Abstract–This paper investigates spectral properties of conducted emissions (CE) of DC/DC converters used in space applications (e.g., onboard space vehicles). This is done in order to improve the accuracy of prediction models, recently developed, which foresee measurement of CE in the time-domain and subsequent time-to-frequency transformation. In particular, two phenomena are addressed in this work: (a) The time-variant behavior of CE, due to the instability of the DC/DC converter switching frequency; (b) the finite sensitivity of the measurement system resulting from the related noise floor. Proper signal processing procedures are proposed in order to bound the effects of such phenomena, and comparison of predictions versus experimental measurements are used to assess the effectiveness of the proposed approach.

3:30 pm **Impact of RF Interference between a Passive RFID System and a Frequency Hopping Communications System in the 900 MHz ISM Band** 495

Michael R. Souryal *(National Institute of Standards & Technology, Gaithersburg, Maryland, United States)*; David R. Novotny *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; Daniel G. Kuester *(University of Colorado, Boulder, Colorado, United States)*; Jeffrey R. Guerrieri *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; Kate A. Remley *(National Institute of Standards & Technology, Boulder, Colorado, United States)*

Presentation Chart

Abstract–We present experimental measurements and analysis of RF interference between a passive RFID system and a generic frequency hopping communications system in the 902 MHz to 928 MHz ISM radio band. Interference in both directions is considered, RFID to communications and vice-versa, and interference mitigation strategies are assessed. Variables of interest include transmission power, antenna locations and polarization, and frequency hopping channel bandwidth and dwell time. Among the findings are the susceptibility of the RFID backscatter link to sources operating within regulatory limits, characterization of the performance asymmetry between the systems, and the constructive effect of interference to RFID at low powers.

4:00 pm **Influence of Planar Sampling Techniques of Near Field Magnitude-Only Data on Predicting Far Field Radiation of PCBs by Genetic Algorithms** 501

Hongmei Fan *(University of Western Australia, Crawley, Western Australia, Australia)*; Franz Schlagenhaufer *(University of Western Australia, Crawley, Western Australia, Australia)*

Presentation Chart

Abstract–Near field data planar sampling techniques, including plane coverage angle, data type and number of observation points, are investigated with respect to a Near Field-Far Field conversion. For a PCB with a loop above a finite ground plane, an equivalent set of dipoles are searched by Genetic Algorithms to approximate the near field data, and then predict the far field. Magnetic near field peak magnitudes are obtained by a Method-of-Moments simulation, and far field prediction is compared with simulated data.

4:30 pm **Measurement of RF Current Waveform of a Source Driver Chip used in a Liquid Crystal-TV Display Panel** 505

Shoichi Kobayashi *(Tohoku Univiersity, Sendai, Miyagi, Japan)*; Hideki Torizuka *(Tohoku Univiersity, Sendai, Miyagi, Japan)*; Sandeep Dhungana *(Tohoku Univiersity, Sendai, Miyagi, Japan)*; Masahiro Yamaguchi *(Tohoku Univiersity, Sendai, Miyagi, Japan)*

Presentation Chart

Abstract–Instantaneous RF current waveform of the power line for a source driver chip used in a typical colour active matrix type liquid crystal-TV display panel has been evaluated for the first time based on magnetic near field measurement. A 16-inch panel set was opened to bare the 10 parallelly-connected source driver chips. Each chip is with 2.7 mm x 12.0 mm in size, and drives 207 liquid crystal cells with nominally 100 pF for each at 16 Vmax with common voltage level of 8 V, which corresponds to the maximum charge of 0.17 μC. A shielded-loop probe (CP-2S, window size: 0.2 mm x 1.0 mm) was used to measure the induced voltage waveform. The analogue power line was identified as the major source of RF magnetic field noise. Then RF current waveform was calculated based on the Faraday's low, using the size and geometry of measurement system. It is known the cells are fully charged when all the panel cells display "white." The measured corresponding peak current was 130 mA with rise time of less than 10 ns at the turned-off of clock pulse, followed by a triangular-like decrease for 1.7 μs. The corresponding electric charge was 0.14 μC, which is closely to the maximum possible charge of 0.17 μC. The spectrum of RF current has significant intensity even around 1 GHz. Such quantitative analysis leads a new tool to analyze flat display panel noise especially for the large panels.

5:00 pm **Designing Shielding Boxes made of Conductive Plastics using a new Joining Structure** 509

Johan Catrysse *(KULeuven, Heverlee-Leuven, Belgium)*; Filip Vanhee *(KHBO, Oostende, Belgium)*; Davy Pissoort *(KHBO, Oostende, Belgium)*; Rik Dewitte *(Bekaert Fibre Technologies, Zwevegem, Belgium)*; Dieter Hellert *(Bekaert Faser Vertriebs GmbH, Idstein, Germany)*

Presentation Chart

Abstract–When designing shielding boxes made of conductive plastics, the problem is how to contact both parts of the box together, and how to fit filters and cable entries in a conductive way to the chassis. A new low-cost joining structure has been developed and characterized, as well as the importance of fixing filters and cable entries.

WED-PM-2, Reverberation 1 (Sponsored by TC2), Room 221/220

Chair: Diane Kempf, NAVAIR
Co-Chair: Dr. William Radasky, Metatech Corporation

1:30 pm **Evaluation of Uncorrelation and Statistics Inside a Reverberation Chamber in Presence of Two Independent Stirrers** 515

Franco Moglie *(Università Politecnica delle Marche, Ancona, Italy)*; Valter Mariani Primiani *(Università Politecnica delle Marche, Ancona, Italy)*

Presentation Chart

Abstract–The paper analyzes the stirrer performances in a reverberation chamber (RC). The independent positions (N) of the stirrers are computed when one or two stirrers rotate inside the chamber. In the case of two operating stirrers, they are moved in both synchronized and interleaved tuned modes showing that this second modality yields a larger independent position number. In the case of one stirrer and two synchronized stirrers, the independent positions are computed using the classical autocorrelation function, whereas in the case of two completely independent stirrers a two dimensional autocorrelation is proposed. It is shown that this procedure does not depend on the order followed to move the stirrers. The stirrer performances are also verified checking the ratio between the maximum and the averaged received power inside the chamber. Finally, the statistics of the received power analyzed applying the severe Anderson Darlington (AD) test to discover the departure from the expected distribution.

2:00 pm **Studying the Pulse Regime in a Reverberation Chamber with a Model based on Image Theory** 520

Emmanuel Amador *(INSA Rennes, Rennes, France)*; Christophe Lemoine *(INSA Rennes, Rennes, France)*; Philippe Besnier *(INSA Rennes, Rennes, France)*; Alexandre Laisné *(CEAT, DGA-ATU, Balma, France)*

Presentation Chart

Abstract–In this article, we propose a time-domain model of a reverberation chamber. This very straightforward model based upon image theory allows to simulate the behavior of a reverberation chamber in the pulse regime. After a brief introduction of the model, results with different pulse lengths and different loading configurations are presented and compared to measurements made in the reverberation chamber of our laboratory.

2:30 pm **Stirrer Blade Separation Experiment in Reverberation Chambers** 526

Olof Lundén *(Swedish Defence Research Agency FOI, Linköping, Sweden)*;
Niklas Wellander *(Swedish Defence Research Agency FOI, Linköping, Sweden)*;
Mats Bäckström *(Combitech AB, Linköping, Sweden)*

Presentation Chart

Abstract–It is often claimed that it is the volume swept by the stirrers in relation to the reverberation chamber volume that is of importance for the efficiency of the stirrers. The impact of a change of the stirrer diameter is however approximately cubic compared with the change of the stirrer height. In this paper it is shown that it is mainly the periphery of the stirrers that contribute in the tuning of reverberation chambers.

3:30 pm **Examining the True Effectiveness of Loading a Reverberation Chamber: How to Get Your Chamber Consistently Loaded** 530

Jason B. Coder *(University of Colorado, Denver, Colorado, United States)*; John M. Ladbury *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; Christopher L. Holloway *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; Kate A. Remley *(National Institute of Standards & Technology, Boulder, Colorado, United States)*

Presentation Chart

Abstract–In this paper we explore how placing the same amount of absorber in different locations within a reverberation chamber can have different loading effects. This difference can have a significant impact on measurement reproducibility, both for measurements in the same chamber and measurements between chambers (i.e., round robin style testing). We begin by discussing some of the theories behind this and show some experimental results from different absorber placements in a reverberation chamber. We conclude with some suggestions to ensure absorber is placed consistently.

4:00 pm **Yet Another Antenna Efficiency Measurement Method in Reverberation Chambers** 536

Hans Georg Krauthäuser *(TU Dresden, Dresden, Germany)*;
Markus Herbrig *(emv GmbH, Taufkirchen, Germany)*

Presentation Chart

Abstract–Radiation efficiency is one of the most difficult to measure quantities of antennas. Established methods are mostly either based on the Weehler-Cap-Method and limited to small antenna, or require a full 3D scan around he antenna under test. We present an alternative method for the measurement of antenna efficiency in the reverberation chamber. The measurement is based on an emission measurement method presented in [1]. Using this method, antenna efficiencies can be estimated along with the emission measurement of the equipment under test (EUT). This can help to reduce the uncertainty during radiated emission testing in the reverberation chamber. Of course, the method can also be used without an EUT present in the chamber to characterize the antenna only. [1] H. Krauthaeuser, "On the measurement of total radiated power in uncalibrated reverberation chambers," Electromagnetic Compatibility, IEEE Transactions on, vol. 49, no. 2, pp. 270–279, May 2007.

4:30 pm **Double-Weibull Distributions of the Re-Emission Spectra from a Non-Linear Device in a Mode Stirred Chamber** 541

Chen Jiaqi *(University of York, York, United Kingdom)*; Andy Marvin *(University of York, York, United Kingdom)*; Ian Flintoft *(University of York, York, United Kingdom)*; John Dawson *(University of York, York, United Kingdom)*

Presentation Chart

Abstract–A Double-Weibull distribution of the mean normalised field strength is used to formulate the statistical aspects of the re-emission spectra of an EUT in a reverberation chamber. Cumulative distributions of mean normalised

measurement results are used to quantify the degrees of interaction between EUT and RF interference levels. This research is a precursor to digital device immunity diagnostic methodology on the statistics aspects independent from absolute magnitudes.

5:00 pm **Determination of Reverberation Distance using Frequency and Time Domain** 547
Vignesh Rajamani *(Oklahoma State University, Stillwater, Oklahoma, United States)*;
Charles F. Bunting *(Oklahoma State University, Stillwater, Oklahoma, United States)*

Presentation Chart

Abstract–With the advent and abundance of wireless devices and the confined spaces in which they are installed, the exposure dominance of the direct path and the scattered path needs to be studied. Wireless connectivity and reliability of wireless routers installed in industrial environments, deployment of RFID tags on concrete structures for structural monitoring, safe operation of various sensors coexisting in ad-hoc networks are examples of wireless systems that are encountered every day. The metallic nature of the installation environment reflects EM energy which can constructively or destructively aid the performance of wireless systems. When there is a line of sight between the transmitter and the receiver, the direct path seems to dominate and the received power varies as square of the distance. When the environment is reflective, the multipath contribution is dominant over the direct path even for small distances of separation. In this paper, a method to measure the distance at which the direct and the scattered path are equal is proposed and measurements in both frequency domain and time domain are presented.

WED-PM-3, Special Session – Multi-Gbps Interconnect Simulation and Measurement (Sponsored by TC10), Room 209/210

Chair: Dr. Xiaoning Ye, Intel
Co-Chair: Dr. Antonio Ciccomancini, CST

1:30 pm **Analyzing via Impedance Variations with a Stochastic Collation Method** 552
Jianxiang Shen *(University of Houston, Houston, Texas, United States)*; Hanfeng Wang *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Ji Chen *(University of Houston, Houston, Texas, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–In this paper, we describe a systematic approach to optimize and analyze the equivalent characteristic impedance of practical via structures. The procedure consists of (a) optimizing via structures for impedance matching using a Genetic algorithm, and (b) numerically characterize, by stochastic collocation method, the sensitivity of the equivalent characteristic impedance to the manufacturing uncertainties in the various geometrical parameters of a via structure. Such procedure naturally leads to a rigorous methodology for EM design/control in the presence of multiple sources of uncertainty.

2:00 pm **DC Blocking via Structure Optimization and Measurement Correlation for SerDes Channels** 557
Jianmin Zhang *(CISCO Systems, Inc., San Jose, California, United States)*; Qinghua B. Chen *(CISCO Systems, Inc., San Jose, California, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; James L. Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Antonio Orlandi *(University of L'Aquila, L'Aquila, Italy)*; Bruce Archambeault *(IBM Corp., Research Triangle Park, North Carolina, United States)*

Presentation Chart

Abstract–SerDes (Serializer/DeSerializer) is widely used in gigabit Ethernet systems, fiber-optic communication systems, and storage applications for high-speed data transmission between different ASICs (application-specific integrated circuit) with the significant advantage of saving package pin numbers. The channel connecting the Serializer/DeSerializer in two different ASICs on a PCB (Printed Circuit Board) is the SerDes channel defined in the paper. Since DC biases in different ASICs are usually different for their Serializer/DeSerializer circuits, DC blocking capacitors are then necessary to block the DC path for signal transmission through the SerDes channel. It is known that the trace impedance on a PCB can be well controlled in manufacturing while it is difficult for a DC blocking via structure. Therefore, the blocking via structure is the main discontinuity contributor of the SerDes channel. In this paper, two different DC blocking via structures are studied. The performances of the two structures are compared and correlated up to 20 GHz with full-wave modelling and measurements. This study reveals the advantages/disadvantages of the two via blocking structures. A via optimization tool, which is based on the cavity resonance algorithm to speed up the optimization, is used to obtain the optimized parameters for the two blocking via structures, and the following full-wave simulations give further performance explorations of the two via structures.

2:30 pm **Efficient Time-Domain Vector Fitting for Broad-Band Interconnect Modelling** 563

Se-Jung Moon *(Intel, Hillsboro, Oregon, United States)*; Xiaoning Ye *(Intel, Hillsboro, Oregon, United States)*; Andreas Cangellaris *(University of Illinois at Urbana-Champaign, Urbana, Illinois, United States)*

Presentation Chart

Abstract–This paper introduces a new methodology toward the efficient and robust whole channel simulation using the TDVF algorithm which is supported by an efficient order estimation method in order to reduce the computational resources and enhance the accuracy of the model. An application of the method is presented in this paper for modelling a socket component in muti-Gbps interconnects.

3:30 pm **Stressed Jitter Analysis for Physical Link Characterization** 568

Nitin Radhakrishnan *(Cisco Systems, Inc., San Jose, California, United States)*; Brice Achkir *(Cisco Systems, Inc., San Jose, California, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; James L Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–A link-path analysis approach is introduced in this paper based on the frequency-domain S-parameters of the link path. Different jitter components are also modelled and can be injected into the analysis to characterize the link responses to different types of jitter input. Stressed link path analysis can be very useful in practical engineering designs in terms of link path optimization, device selection and qualification, etc.

4:00 pm **Analysis of Coupling-Induced Jitter in FPGA Transceiver** 573

Kundan Chand *(Altera Corporation, San Jose, California, United States)*; Geping Liu *(Nvidia Corporation, Santa Clara, California, United States)*; Daniel Chow *(Nvidia Corporation, Santa Clara, California, United States)*

Presentation Chart

Abstract–This paper analyses jitter increase mechanism due to parallel IO simultaneous switching noise (SSN), while FPGA transceiver operates at multi-gigabit data rates or higher. Several jitter measurement methods and relevant simulations are used to diagnose noise sources and coupling paths. This paper illustrates that transmitter jitter profile is related to power supply noise and inductive crosstalk characteristics. These findings helped improve PDN design resulting in better device jitter performance.

4:30 pm **Modeling the Impact of Return-Path Discontinuity on Interconnects for Gb/s Applications** 579

Ivan Ndip *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Kai Löbbicke *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Christian Tschoban *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Michael Töpper *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Stephan Guttowski *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Herbert Reichl *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*;
Klaus-Dieter Lang *(Fraunhofer Institute for Reliability and Microintegration IZM, Berlin, Germany)*

Presentation Chart

Abstract–Return-path discontinuity (RPD) has a huge impact on the performance of interconnects carrying high-speed signals for Gb/s applications. In this contribution, we quantify the effects of RPD on both planar and vertical interconnects. For planar interconnects, we focus on the impact of slits on reference planes of embedded microstrip lines in thin-film re-distribution layers, considering the lossy nature of silicon. For vertical interconnects, we propose a circuit model that accurately captures the impact of RPD which occurs when signal vias transit power-ground plane pairs. This model can be used in the pre-layout stage to develop design guidelines to minimize the impact of RPD for Gb/s applications.

5:00 pm **Enabling Terabit per Second Switch Linecard Design through Chip/Package/PCB Co-Design** 585

Qinghua Bill Chen *(Cisco Systems, Inc., San Jose, California, United States)*; Jianmin Zhang *(Cisco Systems, Inc., San Jose, California, United States)*; Kelvin Qiu *(Cisco Systems, Inc., San Jose, California, United States)*; Darja Padilla *(Cisco Systems, Inc., San Jose, California, United States)*; Zhiping Yang *(Cisco Systems, Inc., San Jose, California, United States)*; Antonio C. Scogna *(CST of America, Framingham, Massachusetts, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Widespread use of the Web 2.0 Internet applications such as video streaming and social networking are continuously demanding higher bandwidth network equipment. Electrical designers increasingly face more and more challenges to deliver higher speed products within short development cycle due to design complexity and new multi-GHz signal integrity problems. This paper presents a modeling and simulation methodology through chip/package/PCB (printed circuit board) co-design and co-optimization to enable a terabit per second network switch linecard design. Channel design techniques such as BGA (Ball Grid Array) pin backdrill, via tuning, and low loss interconnects are outlined. Full wave 3D modelling techniques with optimal model segmentation, model cascading and model optimization are discussed. At the end, correlation between lab measurement and simulation in both frequency and time domains are investigated.

WED-PM-4, Filtering, Automotive and Cable Concerns (Sponsored by TC4), Room 207/208

Chair: John Archer, Retired
Co-Chair: Kermit Phipps, EPRI

1:30 pm **Noise Mitigation Analysis of a π-Filter for an Automotive Control Module** 591

Cyrous Rostamzadeh *(Robert Bosch LLC, Farmington Hills, Michigan, United States)*; Flavio Canavero *(Politecnico di Torino, Torino, Italy)*; Feraydune Kashefi *(Khavaran Institute of Science & Technology, Mashhad, Iran)*

Presentation Chart

Abstract–Electromagnetic interference (EMI) filters are often used on automotive 13.8 VDC power networks to reduce high-frequency noise from being conducted off the printed circuit boards (PCB) and resulting into EMI problems. The filter performance is difficult to predict and often compromised at high frequencies due to parasitics associated with the filter itself, or the PCB layout. The power line filters with Surface Mount Technology ferrite and Multi Layer Ceramic Capacitors are attractive solutions for mitigation of RF noise in high-density automotive PCBs. A lumped-element SPICE model is introduced for optimized Pi-filter design, including frequency-dependent ferrite component model. The PCB implementation of EMI filter is outlined for optimum filter performance.

2:00 pm **High Speed Data Cables with Lossy Material Coating** 597

Eric Chikando *(IBM Corporation, Durham, North Carolina, United States)*; Jay Diepenbrock *(IBM Corporation, Durham, North Carolina, United States)*; Sam Connor *(IBM Corporation, Durham, North Carolina, United States)*; Bruce Archambeault *(IBM Corporation, Durham, North Carolina, United States)*

Presentation Chart

Abstract–High Speed unshielded differential cables will often have unwanted, but unavoidable, common mode energy in the low GHz frequency range. This work examines a coating of lossy material on the cables and quantifies the amount of loss, and the frequency range of the loss using reverberation chamber measurements

2:30 pm **Full-Wave Investigation of EFT Injection Clamp Calibration Setup** 602

Spartaco Caniggia *(EMC Consultant, Bareggio, Milano, Italy)*; Eric Dudenhoeffen *(Teseq AG, Luterbach, Switzerland)*; Francescaromana Maradei *(Sapienza University of Rome, Rome, Italy)*

Presentation Chart

Abstract–The paper deals with a full-wave investigation of the capacitive coupling clamp that is used in electrical fast transient (EFT) immunity test to inject disturbances to nominal signals. The analysis is performed by using the software tool MicroWave Strudio (MWS) based on the finite integration technique. The model of the injection clamp is validated by comparison with measurements and with the results obtained by SPICE. The full-wave model is used to investigate EFT injection clamp calibration setup, such as that proposed in section "6.4.2 Calibration of the capacitive coupling clamp" of the new Edition (the 3rd) of IEC 61000-4-4.

3:30 pm **The Designing, Realization and Testing of a Network Filter used to Reduce Electromagnetic Disturbances and to Improve the EMI for Static Switching Equipment** 608

Petre-Marian Nicolae *(University of Craiova, Craiova, Dolj, Romania)*; George Mihai *(University of Craiova, Craiova, Dolj, Romania)*; Ileana-Diana Nicolae *(University of Craiova, Craiova, Dolj, Romania)*

Presentation Chart

Abstract–The paper deals with the designing, realization and testing of a network filter used to reduce the electromagnetic disturbances produced by static switching equipment. The tests were done according to the CISPR 17 standard for the determination of the insertion loss for each cell, and the verifications concerning the filter's efficiency with respect to the conducted and radiated disturbances produced by a static switching equipment revealed the obeying of the CISPR 11 standard. One presents the experimental determinations previous to the network filter use. After the filter's designing and realization experimental data were gathered relative to the conducted emissions. The assembling and case shielding were improved in order to obey the limits imposed to the radiated emissions according to the CISPR 11 standard, and consequent experimental determinations revealed significant improvements from the EMI point of view.

4:00 pm **Rapid Simulation of the Statistical Variation of Crosstalk in Cable Harness Bundles** 614

Xiang Li *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Meilin Wu *(Amphenol Corporation, Nashua, New Hampshire, United States)*;
Daryl Beetner *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Todd Hubing *(Clemson University, Clemson, South Carolina, United States)*

Presentation Chart

Abstract–Accurate assessment of crosstalk problems in cable harnesses requires simulation methods that account for statistical variation in harness parameters. Use of the T-parameter method to rapidly estimate the statistical variation of crosstalk in cable harness bundles is outlined in the following paper. Crosstalk is calculated by segmenting the harness into a cascade of equal length multi-conductor transmission lines (MTLs). Methods to test the influence of the statistical variation in wire positions, height, and number of twists are proposed using both simulation and analytical methods. The analytical method uses the mean and variance of crosstalk estimated for fixed harness parameter values to estimate the mean and variance when parameters vary with known probability density functions. The analytic method may thus save additional computational resources, since simulations are only required at a relatively small number of fixed parameter values. A comparison of the simulation results and the analytical results shows the analytical method may accurately estimate statistical variation for the parameters studied.

4:30 pm **Automotive EMC Case Study: HMI Graphics Influence on Radiated Emissions** 620

Steven Mainville *(Johnson Controls, Inc., Holland, Michigan, United States)*

Presentation Chart

Abstract–A case study describing the influence of TFT LCD graphics on automotive radiated emissions testing and its impact to the FM band receiver. The underlying root-cause of the EMI issue is determined using a novel technique that decodes the display's graphics into the transmitted RGB data and predicts the data's impact to radiated emissions. The countermeasure implemented to resolve the issue is equally novel and does not involve any hardware optimizations. The use of test images to be used in component level EMC testing is also discussed.

5:00 pm **Low Frequency Electromagnetic Field Reduction Techniques for the On-Line Electric Vehicle (OLEV)** 625

Seungyoung Ahn *(KAIST, Daejeon, Republic of Korea)*; Junso Pak *(KAIST, Daejeon, Republic of Korea)*; Taigon Song *(KAIST, Daejeon, Republic of Korea)*; Heejae Lee *(KAIST, Daejeon, Republic of Korea)*; Jung-Gun Byun *(KAIST, Daejeon, Republic of Korea)*; Deogsoo Kang *(KAIST, Daejeon, Republic of Korea)*; Cheol-Seung Choi *(KAIST, Daejeon, Republic of Korea)*; Eunjung Kim *(KAIST, Daejeon, Republic of Korea)*; Jiyun Ryu *(KAIST, Daejeon, Republic of Korea)*; Mijoo Kim *(KAIST, Daejeon, Republic of Korea)*; Yumin Cha *(KAIST, Daejeon, Republic of Korea)*; Yangbae Chun *(KAIST, Daejeon, Republic of Korea)*; Chun-Taek Rim *(KAIST, Daejeon, Republic of Korea)*; Jae-Ha Yim *(KAIST, Daejeon, Republic of Korea)*; Dong-Ho Cho *(KAIST, Daejeon, Republic of Korea)*; Joungho Kim *(KAIST, Daejeon, Republic of Korea)*

Presentation Chart

Abstract–In this paper, we introduce the On-line Electric Vehicle (OLEV) system and its non-contact power transfer mechanism and propose some techniques for the reduction of electromagnetic fields (EMFs) from the power line and the vehicle itself. By applying a metallic plate shield, horizontal/vertical shield, and connecting wire for loop cancellation, the low frequency EMFs have been significantly reduced. Simulation and measurement results for application to vehicles currently in service are also given.

WED-PM-5, PCB Simulation (Sponsored by TC9), Room 203/204

Chair: Vignesh Rajamani, Oklahoma State University
Co-Chair: Dr. Antonio Ciccomancini, CST

1:30 pm **Network Model for the Analysis of Radiated Emissions from Horizontal PCB Submodules** 631
M. Friedrich *(Otto-von-Guericke University Magdeburg, Magdeburg, Germany)*;
M. Leone *(Otto-von-Guericke University Magdeburg, Magdeburg, Germany)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–The radiation behaviour of motherboard subboard structures on printed-circuit boards is investigated.The analysis is based on an equivalent circuit including the connector inductance network and the radiating antenna structure. A special focus is put on the calculation of the mutual and self inductances of the connector pins. For this purpose simple closed-form expressions are developed for the central board region and validated by accurate cavity-model reference results. The final validation of the predicted radiated-emission characteristics by numerical 3D field simulations and by measurement shows a good agreement with respect to engineering purposes.

2:00 pm **High Speed Interconnects of Multi-Layer PCB Analysis by using Non-Conformal Domain Decomposition Method** 637
Yang Shao *(Ohio State University, Columbus, Ohio, United States)*; Zhen Peng *(Ohio State University, Columbus, Ohio, United States)*; Jin-Fa Lee *(Ohio State University, Columbus, Ohio, United States)*

Presentation Chart

Abstract–A non-conformal domain decomposition method (DDM) is proposed to investigate signal integrity (SI) of high-speed interconnects on multi-scale, multi-layer printed circuit board (PCB) in this paper. The accuracy and robustness of the proposed method is first demonstrated by a 4-layer differential pair. Then we studied a 14-layer 16 traces interconnect model to demonstrate the efficiency of the method. Eye diagrams of the two models are studied for time domain SI.

2:30 pm **EMI Circuit Modeling of a Power Train on Composite Ground Plane** 643
N. Doorgah *(Ecole Centrale de Lyon, Ecully, France)*; C. Vollaire *(Ecole Centrale de Lyon, Ecully, France)*; F. Costa *(University Paris Est Creteil, St. Denis, France)*; N. Gazel *(Hispano-Suiza, Moissy-Cramayel, France)*; R. Meuret *(Hispano-Suiza, Moissy-Cramayel, France)*

Presentation Chart

Abstract–Aeronautics world is in continuous evolution. Actually, the tendency is to substitute the hydro mechanical actuators with electrical ones. However, this means introducing more power electronics and in doing so, the systems become more and more vulnerable to electromagnetic noise emitted. Moreover, the introduction of composite material based structures modifies EMI behavior in airplanes. The aim of this study is to be able to predict, via modeling for frequencies going from 10 kHz to some MHz, the propagation pathways and the amount of common and differential mode current. Thus the model developed as well as the optimization methods can benefit the aeronautical industry during preliminary phases of development of different equipments.

3:30 pm **On the Radiated Electromagnetic Emission Modelling of On-Chip Microwave Components** 647
Abhishek Ramanujan *(IRSEEM, Saint Etienne du Rouvray, Haute Normandie, France)*;
Zouheir Riah *(IRSEEM, Saint Etienne du Rouvray, Haute Normandie, France)*;
Anne Louis *(IRSEEM, Saint Etienne du Rouvray, Haute Normandie, France)*;
Bélahcène Mazari *(IRSEEM, Saint Etienne du Rouvray, Haute Normandie, France)*

Presentation Chart

Abstract–A radiated emission model, scaled, optimized, and compatible to modelling "on-chip" microwave devices is presented in this paper. The model has been inspired from a previously existing model at IRSEEM, which predicts only the radiated magnetic field. The proposed model predicts the radiated electromagnetic (EM) emissions of components of very small form factor. An optimization procedure has been implemented in order to extract the model parameters, taking into account their physical sense. The model is applied to an "on-chip" microstrip patch antenna, designed and simulated in Ansoft HFSS. The antenna is built on a High Resistivity Silicon substrate and resonates at 20 GHz. Promising and encouraging results have been obtained for the modelled radiated EM fields. Our model is proven suitable to apply on System-in-package and System-on-Chip devices integrating wireless system within itself.

4:00 pm **An Equivalent Three-Dipole Model for IC Radiated Emissions based on TEM Cell Measurements** 652

Siming Pan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jingook Kim *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Sungnam Kim *(LG PRI, Pyungtaek-si, Kyunggi-do, Republic of Korea)*; Jaesu Park *(LG PRI, Pyungtaek-si, Kyunggi-do, Republic of Korea)*; Heoncheol Oh *(LG PRI, Pyungtaek-si, Kyunggi-do, Republic of Korea)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–An equivalent dipole model is proposed in this paper to represent the source of radiated electromagnetic emissions from an integrated circuit (IC). The height of an IC is usually much smaller than its length and width, so only three dipole moments are sufficient to characterize an IC in terms of its electromagnetic emissions. The dipole moments can be extracted from three TEM cell measurements. The radiated fields from the IC can then be calculated based on the extracted dipole sources. This IC emission model with three dipole moments is validated using the far-field measurements in a semi anechoic chamber for a test IC. For complex structures, it is desirable that the extracted dipole moments can be incorporated into a commercial full-wave tool as equivalent sources to simulate the radiations from an IC. This is demonstrated using an approach developed in this paper.

THURSDAY TECHNICAL PAPERS

Thursday, July 29, 2010

THU-AM-1, Measurements 2 and Reverberation 3 (Sponsored by TC2), Room 223/222

Chair: Dr. Galen Koepke, NIST
Co-Chair: Bob Hofmann, Hofmann EMC Engineering

8:30 am **Conductive Fabric's SE Measurement in a Mode Stirred Reverberation Chamber** 657

Mario Pocai *(EMC Consultant, Pisa, Italy)*; Ivan Dotto *(CISAM, San Piero a Grado, Italy)*; Domenico Festa *(IBD, Chiari, Italy)*

Presentation Chart

Abstract–The new approach proposed by NIST for the measurements of the Shielding Effectiveness (SE) of materials in a Reverberation Chamber (MSRC), was applied in a lower frequency range 600 – 1000 MHz for testing a conductive fabric. The results here obtained have been compared to those recorded by measuring the SE of the same fabric following the ASTM 4935 Standard. The difference between ASTM results and the RC results – that ranges from 1 to 11 dB – is investigated to understand the reason of the disagreement between the two.

9:00 am **An Improved Model for Antennas in Reverberation Chambers** 663

John M. Ladbury *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; David A. Hill *(National Institute of Standards & Technology, Boulder, Colorado, United States)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–We present an improved model for antennas in a reverberation chamber. The derivation of this model is more rigorous than previous derivations and models, but is still, admittedly, overly simplistic. However, this model should be exact for a special class of antennas (those that can be modelled as an unknown 2-port network between the test port and an ideal antenna). For more realistic antennas, these models should still provide valuable insight into the possible behavior of any antenna. Using these models, we show that some previous assumptions regarding receiving characteristics (mismatch and efficiency) of an antenna are invalid: most significantly we show that there can be differences between the transmitting and receiving efficiency of an antenna, and also between the transmitting and receiving mismatch factors. However, we show that the errors are unimportant for most measurements. We also give justification for the assumption that the average reflection coefficient of an antenna in a reverberation chamber is simply the free-space reflection coefficient of the antenna.

9:30 am **On the use of a Reverberation Chamber to Test the Performance and the Immunity of a WLAN System** 668

Valter Mariani Primiani *(Università Politecnica delle Marche, Ancona, Italy)*;
Franco Moglie *(Università Politecnica delle Marche, Ancona, Italy)*;
Renzo Recanatini *(Università Politecnica delle Marche, Ancona, Italy)*

Presentation Chart

Abstract–The paper presents some results concerning the use of a reverberation chamber (RC) to test a wireless local area network (WLAN) system using the standard IEEE 802.11b/g. The whole link (access point and terminal) was operating inside the RC under different chamber loading conditions and varying the stirrer rotating speed. The effects of this multipath environment on system performances were checked measuring three transmission quality estimators: the ping average round trip time, the cyclic redundancy check (CRC) error, and the data retries. The behavior of these parameters, as function of the bitrate set for the link, was also analyzed. The same RC was used to carry out a radiated immunity test on the same WLAN. The undesired signal was both a modulated and continuous wave injected into the used channel and into adjacent channels. The modulated wave is that prescribed by the IEC 61000-4-3 standard.

10:30 am **Modern Vessels and their Problems in EMC – Examples in Practice** 674

Christian Klünder *(Hamburg University of Technology, Hamburg, Germany)*; Tobias Pilsak *(Hamburg University of Technology, Hamburg, Germany)*; Hermann Hanneken *(Meyer Werft GmbH, Papenburg, Germany)*; Jan Luiken ter Haseborg *(Hamburg University of Technology, Hamburg, Germany)*

Presentation Chart

Abstract–This paper describes the fundamental problems of EMC on vessels. During the lasts years the size of electronic integration package on modern vessels is increasing with every new built ship. Due to this fact the EMC becomes a more and more important part of the whole building process. In this paper three examples in practice will be discussed (AIS reception problem, DGPS reception problem and satellite TV reception problem). At the end general hints are stated to avoid or reduce EMC problems.

11:00 am **Forward and Reverse Link Constraints in UHF RFID with Passive Tags** 680

Daniel G. Kuester *(University of Colorado at Boulder, Boulder, Colorado, United States)*;
David R. Novotny *(NIST, Boulder, Colorado, United States)*; Jeffrey R. Guerrieri *(NIST, Boulder, Colorado, United States)*

Presentation Chart

Abstract–This paper examines the relative roles of the forward and reverse links in determining the operational range of passive UHF RFID systems. Simple free space examples in free space show when the forward or reverse link may be the main range constraint in practical systems, depending on reader and tag characteristics. Measurements of transmission and scattering off of a dipole in a real environment demonstrate showed different multipath effects; transmission power fading squared disagreed with backscattered fading in the test environment by up to 8 dB within a measurement range of 2 m.

11:30 am **Primary and Induced Currents from Cable Discharges** 686

Timothy J. Maloney *(Intel Corporation, Santa Clara, California, United States)*

Presentation Chart

Abstract–Analysis of cable discharge events (CDE) starts with the basic wire-to-ground pulse and continues, for shielded cables, with induced currents on the signal lines. These situations can be classified and analyzed through step response and impulse response. The essential behaviors can be derived from the uniformly charged shield being grounded to produce induced current on the data lines at the opposite end. This effect is called the W-pulse and is shown to be a kind of step response for both loads. From this and similar results, the effects on shielded cable lines of the commonly-applied IEC 61000-4-2 platform pulse are derived by convolution. Finally, the induced currents resulting from a charged shielded cable above a ground plane are deduced. Because the coupling from shielded cables to internal lines is almost all inductive, we have bipolar induced pulses with zero charge integral. Thus the bipolar data line response to these shielded cable pulses is a significant hazard for pulsed latchup. We discuss adequacy of the low-voltage IEC direct pin pulse (often called direct pin zap or DPZ) for assessing pulsed latchup on external ports, shielded in particular. Finally, it is shown why having connected cables as part of the regular IEC platform test also helps to test for cable discharge latchup hazards.

THU-AM-2, Capturing the Electromagnetic Environment 1 (Sponsored by TC3), Room 221/220

Chair: Dr. Randy Jost, University of Utah
Co-Chair: David Hilton

8:30 am **Multi-Band Microstrip Antenna with Minimalization of Radiation Towards Head** 692
Marian Wnuk *(Military University of Technology, Warsaw, Poland)*

Presentation Chart

Abstract–Intensive development of cellular personal communications system has been observed lately. Thus, protection of a man, and especially protection of his head against non-ionizing electromagnetic radiation generated by cellular telephones is becoming one of the most important problems. The results of elaborated microstrip antennas which have minimized radiation towards the user's head are presented in this paper.

9:00 am **Assessment of Emissions from Electrical Equipment regarding Human Exposure – Approaches for Application of the Generic Standard IEC 62311** 697
Bernd W. Jaekel *(Siemens AG, Erlangen, Germany)*; Ana Mladenovic *(University of Nis, Nis, Yugoslavia)*; Mirjana Peric *(University of Nis, Nis, Yugoslavia)*; Dusan Vuckovic *(University of Nis, Nis, Yugoslavia)*; Nenad Cvetkovic *(University of Nis, Nis, Yugoslavia)*; Slavoljub Aleksic *(University of Nis, Nis, Yugoslavia)*

Presentation Chart

Abstract–In a lot of countries and regions there are requirements regarding electromagnetic emissions from electrical equipment. Such emissions can be looked at under two aspects: the emissions might interfere with other equipment in the vicinity causing potential malfunction (EMC aspect), or might be considered with regard to human exposure (EMF aspect). Limitation of such emissions related to the EMC aspect is part of EMC activities and is mostly due to the need to protect radio services from being interfered. Applicable limits depend on the type of equipment under concern and of the locations where equipment is intended to be operated. However, more and more such emissions are looked at also under a human exposure point of view within the frame of EMF regulations. As both aspects deal with entirely different objective targets consequently different limits, different measurement procedures and different assessment methods are to be applied. This could mean in practice that basically two kinds of measurements have to be carried out. This paper introduces an approach how to use results obtained by means of EMC measurements for the purpose of EMF assessments. As an example for an assessment the EMC data in the frequency range between 30 MHz and 230 MHz are used as part of an EMF assessment.

9:30 am **Low Frequency Electromagnetic Field Exposure Study with Posable Human Body Model** 702
X.L. Chen *(IT'IS Foundation, Zurich, Switzerland)*; S. Benkler *(SPEAG Schmid & Partner Engineering AG, Zurich, Switzerland)*; C.H. Li *(IT'IS Foundation, Zurich, Switzerland)*; N. Chavannes *(SPEAG Schmid & Partner Engineering AG, Zurich, Switzerland)*; N. Kuster *(IT'IS Foundation, Zurich, Switzerland)*

Presentation Chart

Abstract–This paper investigates the electric field and current density induced in a human body when exposed to low frequency electromagnetic fields. A numerical technique based on the Finite Element Method and electromagnetic quasi-static approximations is employed to compute both the fields generated by low frequency sources and the fields induced inside a human body due to exposure or contact. Case study is conducted to investigate exposure situations pertaining to the safety of human being in the vicinity of high intensity low frequency electromagnetic fields.

10:30 am **Specific Absorption Rate Evaluation for People using Wireless Communication Device in Vehicle** 706
K.H. Chan *(City University of Hong Kong, Hong Kong, China)*; S.W. Leung *(City University of Hong Kong, Hong Kong, China)*; Y.M. Siu *(City University of Hong Kong, Hong Kong, China)*

Presentation Chart

Abstract–In this paper, a specific absorption rate (SAR) evaluation on human exposure from wireless communication devices inside a vehicle is investigated. A finite-difference time-domain method (FDTD) is used for simulating the electromagnetic field distribution inside the vehicle. Results have shown that the maximum SAR induced for a mobile phone user in the vehicle is only increased by 5% when compared to free space. Results have also indicated that other passengers in the vehicle are also inducing various levels of the SAR values in their bodies. The induced SAR values can be as high as about 40% of the maximum SAR value induced in the mobile phone user.

THU-AM-3, Special Session – Modeling/Simulation Validation (Sponsored by TC9), Room 209/210

Chair: Dr. Andy Drozd, Andro Consulting
Co-Chair: Dr. Bruce Archambeault, IBM

8:30 am **Antenna Co-Site Performance Analysis for Complex Systems using Feature Selective Validation** 712

Irina Kasperovich *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*; Andrew L. Drozd *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*; Clifford E Carroll, Jr. *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*; Adrienne A. Croneiser *(ANDRO Computational Solutions, LLC, Rome, New York, United States)*

Presentation Chart

Abstract–This paper illustrates the application of a new technique called the Feature Selective Validation (FSV) to assist in an antenna siting problem for a complex aircraft vehicle. The FSV is based on the IEEE 1597.1 Standard for the Validation of CEM Computer Modeling and Simulations. In practice, various antenna configurations must be analyzed in order to localize antenna placement to meet both performance and co-site EMC requirements. The results of a limited sensitivity analysis are presented using canonical models of an airframe wing structure to identify the best placement of a simple dipole. The FSV facilitates comparisons between sets of electromagnetic observables to determine the impact of antenna placements. The results of hybrid MoM/UTD simulations at high frequencies approaching 1 GHz are compared to validate results and demonstrate the efficacy of the FSV method, which can be used to conduct sensitivity analyses for virtually any co-site problem.

9:00 am **Applying Feature Selective Validation (FSV) as an Objective Function for Data Optimization** 718

Siming Pan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Hanfeng Wang *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Feature Select Validation (FSV) is a widely used validation method for data comparison. FSV provides a quantitative standard to describe the similarity between two sets of data. In this paper, the application of the FSV technique is extended to data optimization. The raw data obtained from simulations or measurements are often non-ideal for further processing. Several techniques, such as data perturbation, can be used to improve the data quality in certain aspects. However, after modifications the new data could be very different to the original one. Using FSV as an objective function for the optimization process is discussed in this paper, in an example of causality enforcement, to ensure the enforced casual data has the minimum deviations from the original data. The results demonstrate that the proposed approach in this paper is effective for data modification and optimization.

9:30 am **Quantifying the Quality of Agreement between Simulation and Validation Data for Multiple Data Sets** 722

Bruce Archambeault *(IBM, Durham, North Carolina, United States)*; Joseph Diepenbrock *(IBM, Durham, North Carolina, United States)*

Presentation Chart

Abstract–The FSV is used to compare multiple data sets. These data sets may be comparing modeled data for model validation purposes, or may be multiple measurements of related data, to determine the agreement between them.

10:30 am **Challenges in Developing a Multidimensional Feature Selective Validation Implementation** 726

Bruce Archambeault *(IBM, Raleigh, North Carolina, United States)*; Alistair Duffy *(De Montfort University, Leicester, United Kingdom)*; Hugh Sasse *(De Montfort University, Leicester, United Kingdom)*; Xin Kai Li *(De Montfort University, Leicester, United Kingdom)*; Mark Scase *(De Montfort University, Leicester, United Kingdom)*; Mohammed Shafiullah *(De Montfort University, Leicester, United Kingdom)*; Antonio Orlandi *(University of L'Aquila, L'Aquila, Italy)*; Danilo De Febo *(University of L'Aquila, L'Aquila, Italy)*

Presentation Chart

Abstract–Feature Selective Validation (FSV) was incorporated as core component of IEEE Std 1597.1. Recently, discussions have moved from 'is quantitative comparison of data needed?' to 'how can this be applied to

multidimensional data?' The purpose of this paper is to present some of the latest thinking about the key challenges in developing a 1D model to unlimited dimensionality. In particular, the paper will present: (1) a revised mathematical framework for FSV, e.g. using tensor notation to simplify the mathematical representation. (2) A discussion on how the performance of n Dimensional FSV can be verified against human perception. (3) A review on the effects of data that oscillates between positive and negative data points, e.g. transients.

11:00 am **Comparison of Measured and Computed Near and Far Fields of a Heatsink using the Feature Selective Validation (FSV) Method** 732
Alpesh Bhobe *(Cisco Systems, Inc., San Jose, California, United States)*;
Philippe Sochoux *(Cisco Systems, Inc., San Jose, California, United States)*

Presentation Chart

Abstract–In this paper we outline the comparison of near and far fields a Heatsink using the Frequency Selective Validation (FSV) method. Numerical simulations are performed using several 3D-EM tools like Ansoft HFSS, CST MWS and CST Microstripes. The FSV method will be used to compare the data between these three different numerical approaches as well as with the measured data. This study also focuses on establishing a heat sink design flow from an EMC perspective. The current EMC design on heat sinks is reactive rather than proactive. Mechanical engineers design heat sinks based on thermal constraints. The EMC team only becomes involved when there is a resonance problem in testing weeks or months later. In this paper, we develop a methodology including pre-design guidelines, post-design simulation, and correlation with lab measurements. An example is also provided to illustrate the methodology.

11:30 am **Validating the FSV Method using Reverberation Chamber Measurements** 737
Genvevieve J. Hankins *(The Boeing Company, Seattle, Washington, United States)*;
Dennis M. Lewis *(The Boeing Company, Seattle, Washington, United States)*

Presentation Chart

Abstract–The Feature Selective Validation (FSV) Method was originally developed as a standard technique to mimic an expert's opinion of concurrence between CEM and measurement datasets. It has recently expanded as a method to quantify agreement between various types of datasets. This paper presents a comparison of measurements obtained from different antenna positions in an overmoded cavity. Based on the field distributions within the usable area of the reverberation chamber these datasets should appear statistically similar. The objective is to present a credible evaluation of the FSV method using standard reverberation chamber theory.

THU-AM-4, Transmission Line Noise Concerns (Sponsored by TC4), Room 207/208

Chair: Michael McInerney, U.S. Army Engineer Research

8:30 am **Modeling Connector Contact Condition using a Contact Failure Model with Equivalent Inductance** 743
Yu-ichi Hayashi *(Tohoku University, Sendai, Miyagi, Japan)*; Songping Wu *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Takaaki Mizuki *(Tohoku University, Sendai, Miyagi, Japan)*; Hideaki Sone *(Tohoku University, Sendai, Miyagi, Japan)*

Presentation Chart

Abstract–It is found from previous studies on the immunity issues of CATV coaxial cables due to contact failure that, when contact resistance is small, the contact distribution and the number of contact points become factors that affect the degradation in immunity of the cables. However, when contact resistance is relatively large, the effects of the contact distribution and the number of contact points are negligible. In this paper, the physics of this phenomenon is further studied. Simulation results, validated by measurement, reveal that the contact distribution and the number of contact points contribute to parasitic inductances that could change the current distribution among the contact points, and further affect the immunity performance of the cables. Using a contact failure model proposed in this paper, cable contact scenarios at the connectors with different contact distributions and numbers of contact points can be simply simulated by changing the inductance term in the model.

9:00 am **Predicting CM Radiation from Strip Line Structure by Equivalent Circuit Model** 748
Yoshiki Kayano *(Akita University, Akita, Japan)*; Hiroshi Inoue *(Akita University, Akita, Japan)*

Presentation Chart

Abstract–In recent years, effective methods for predicting and suppressing EMI over a broad band are required. In this paper, we newly focus on prediction of EM radiation from a strip line structure by an equivalent circuit model. Firstly, frequency responses of common-mode (CM) current on the PCB and EM radiation are studied experimentally and

compared with FDTD modeling. It was demonstrated that the ground plane of the PCB is the dominant radiation factor at low frequencies. Secondly, an equivalent circuit model for predicting CM current was proposed. The equivalent circuit model is based on consideration of concepts of CM antenna impedance to current- and voltage-driven mechanisms. The good agreement between the predicted and full-wave results indicates the validity of the equivalent circuit model. The frequency response of EM radiation from microstrip/strip line structure can be identified using our proposed model.

9:30 am **A Lumped-Element Circuit Model of Ferrite Chokes** 754

Andrea Orlando *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Marina Y. Koledintseva *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Daryl G. Beetner *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Peng Shao *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Phil Berger *(John Deere, Waterloo, Iowa, United States)*

Presentation Chart

Abstract–An RLC model of ferrite chokes for suppressing common-mode (CM) currents is presented. The equivalent lumped-element circuit parameters are obtained from the frequency-dependent input impedance of a ferrite choke on a wire above the ground plane. This input impedance can be either measured (using vector network analyzer or impedance analyzer), or numerically modeled based on the known ferrite material properties (permittivity and permeability). An example of using both numerical modeling and measurements is provided. Results show good agreement at comparatively low frequencies (below 200 MHz). The upper frequency limit for the proposed equivalent lumped-circuit model is discussed.

10:30 am **Far-End Crosstalk Reduction in Adjacent PCB Traces Employing High/Low-Z Configurations** 760

Mohammad Almalkawi *(University of Toledo, Toledo, Ohio, United States)*; Zulfiqar Khan *(University of Toledo, Toledo, Ohio, United States)*; Vijay Devabhaktuni *(University of Toledo, Toledo, Ohio, United States)*; Charles Bunting *(Oklahoma State University, Stillwater, Oklahoma, United States)*

Presentation Chart

Abstract–This paper introduces a new High/Low-Z trace configuration to reduce far-end crosstalk in adjacent printed circuit board (PCB) interconnects. The emphasis is made to reduce crosstalk without using additional PCB components in the design. Specifically, we employ stepped impedance elements of uniform length on the victim traces to suppress high-frequency electromagnetic interference. The overall design is much simpler than the usual low-pass filter configurations which are difficult to implement in the prototype testing. The proposed approach shows remarkably better results as compared to conventional intervening guard trace schemes. Further, the proposed configuration can be combined with the conventional schemes to achieve even higher reduction in crosstalk.

THU-AM-5, Signal Integrity II (Sponsored by TC10), Room 203/204

Chair: Dr. Tzong-Lin Wu, National Taiwan University
Co-Chair: Dr. Joungho Kim, KAIST

8:30 am **Experimental Validation of Common-Mode Filtering Performances of Planar Electromagnetic Band-Gap Structures** 764

F. De Paulis *(University of L'Aquila, L'Aquila, Italy)*; L. Raimondo *(University of L'Aquila, L'Aquila, Italy)*; D. Di Febo *(University of L'Aquila, L'Aquila, Italy)*; B. Archambeault *(IBM, Research Triangle Park, North Carolina, United States)*; S. Connor *(IBM, Research Triangle Park, North Carolina, United States)*; A. Orlandi *(University of L'Aquila, L'Aquila, Italy)*

Finalist for the Best Technical Paper Award

Presentation Chart

Abstract–An experimental validation of an electromagnetic band-gap (EBG) based common mode filter is given in this paper. The proposed layout technique is based on planar EBG structures altered by removing the connecting bridges between adjacent patches. The patches are properly dimensioned for ensuring the presence of frequency notches at the frequencies that should be filtered in the common-mode transfer function. The notch frequency is associated with the first resonant mode of the patch.

9:00 am **Equivalent Circuit Models for Evaluation of Bandgap Limits for Planar Electromagnetic Bandgap Structures** 770

Francesco de Paulis *(University of L'Aquila, L'Aquila, Italy)*; Leo Raimondo *(University of L'Aquila, L'Aquila, Italy)*; Antonio Orlandi *(University of L'Aquila, L'Aquila, Italy)*; Liehui Ren *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–In this work different physic based equivalent lumped element circuits models representing planar EBG structures are developed. Their results, in terms of evaluation of the lower and upper limits of the bandgap, are compared with a three dimensional simulation considered as reference. Guidelines for the use of these models for their use in planar EBG design are developed.

9:30 am **An Ultra Compact Common-Mode Filter for RF Interference Control in 3G Wireless Communication Systems** 776

Iat-In Ao Ieong *(National Taiwan University, Taipei, Taiwan)*; Chung-Hao Tsai *(National Taiwan University, Taipei, Taiwan)*; Tzong-Lin Wu *(National Taiwan University, Taipei, Taiwan)*

Presentation Chart

Abstract–A miniaturized common-mode suppression filter for GHz differential signals is realized using LTCC fabrication technology. The filter is realized in SMD-typed package with the physical size of 1.6 mm x 1.6 mm. Its equivalent circuit model is established to illustrate the properties of the common mode suppression and the differential mode propagation. It is found in measurement that the common-mode noise can be reduced over 10 dB from 1.8 GHz to 2.4 GHz in frequency domain, which covers the band of universal mobile telecommunication system (UMTS) in 3G wireless communication, and can be reduced about 30% in time domain under 1.4 Gbps PRBS. More importantly, the differential signal integrity, in terms of insertion loss and transmission phase in frequency domain and eye diagrams in time domain, is not degraded up to 5 GHz. To our best knowledge, it is the first SMD-type common-mode filter designed for gigahertz differential signals using LTCC technology.

10:30 am **Radiating Emissions from the Planar Electromagnetic Bandgap (EBG) Structures** 780

Baharak Mohajer-Iravani *(EMWaveDev, Fayetteville, Arkansas, United States)*;
Omar M. Ramahi *(University of Waterloo, Waterloo, Ontario, Canada)*

Presentation Chart

Abstract–Electromagnetic bandgap (EBG) structures are considered as a viable solution for the problem of switching noise in printed circuit boards and packages. Less attention, however, has been given to whether or not the introduction of EBGs affect the EMI potential of the circuit to couple unwanted energy to neighboring layers or interconnects. In this paper, we show that the bandgap of EBG structures, as generated using the Brillouin diagram, does not necessarily correspond to the suppression bandwidth generated using S-parameters. In fact, we show that the slow modes which typically exist at the edges of the bandgap of periodic structures contribute to increased radiation, even within the suppression band obtained from the S-parameters. We validate this finding using numerical simulation. Based on this work, design guidelines for EBG structures can be drawn to insure not only suppression of switching noise but also minimization of EMI.

11:00 am **Systematic Analysis of the Signal Integrity Performances of Surface Integrated Waveguide Structures (SIWs)** 784

Antonio Ciccomancini Scogna *(CST of America Inc., Framingham, Massachusetts, United States)*;
Antonio Orlandi *(University of L'Aquila, L'Aquila, Italy)*

Presentation Chart

Abstract–In this work a systematic analysis of the signal integrity performances of substrate integrated waveguide structures (SIW) is reported. It is numerically demonstrated how the transmission of very high bit rate (frequency range 0-110 GHz) can be successfully achieved by using this type of structure and an equivalent stripline model is used as reference for the purpose. The numerical model of the SIW is validated by measured data available in literature. An extension of the single ended SIW structure is proposed and named as differential SIW. Crosstalk analysis of the two adjacent SIW and transmitting performance for a new configuration denoted as inverted-U is also carried out

11:30 am **Surface Impedance Approach to Calculate Loss in Rough Conductor Coated with Dielectric Layer** 790

Marina Koledintseva *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Amendra Koul *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Fan Zhou *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
James Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
Scott Hinaga *(CISCO Systems, Inc., San Jose, California, United States)*

Presentation Chart

Abstract–The analysis presented herein contains closed-form analytical expressions to calculate attenuation in a layered structure "rough metal-dielectric-dielectric", which is a practically important problem in separating dielectric loss from rough conductor loss in actual PCB stripline geometries, when measuring dielectric constant (Dk) and dissipation factor (Df) using traveling wave S-parameter methods. This approach is based on the surface impedance concept. It is shown that the presence of an epoxy layer on the conductor may affect extracted dielectric parameters, of a PCB substrate, especially the Df data.

THU-PM-1, Special Topics (Sponsored by TC1 and TC6), Room 223/222

Chair: Larry Cohen, Naval Research Labs

3:00 pm **Including EMC in Risk Assessments** 796

Keith Armstrong *(Cherry Clough Consultants, Stafford, Staffordshire, United Kingdom)*

Presentation Chart

Abstract–The reliability of electronic technologies (including the software and firmware that runs on them) can become critical, when the consequences of errors, malfunctions or other types of failure include significant financial losses, mission loss, or harm to people, domestic animals or property (i.e. functional safety). Electromagnetic interference (EMI) can be a cause of unreliabil-ity in all electronic technologies, so electromagnetic compatibility (EMC) must be taken into account when the risks caused by malfunctioning electronics are to be controlled. However, levels of reliability or safety risk can be three orders of magnitude beyond what could possibly be demonstrated with any practicable EMC testing regime. So it is necessary to ask how can we demonstrate confidence that electronic reliability will be sufficient, despite exposure to its operational electromagnetic environment over its lifetime? The solution [1] is to use well-proven EMC design techniques, and risk assessment that shows the overall design achieves toler-able risk levels, all verified and validated by a variety of tech-niques (including EMC testing). This paper addresses how to apply risk assessment techniques to issues of electromagnetic compatibility (EMC).

3:30 pm **Investigations of the EM-Coupling in the Near and Far Field of a Transmitting Antenna According to EUROCAE ED-130** 802

Tobias Dyballa *(Hamburg University of Technology, Hamburg, Germany)*;
Jan Luiken ter Haseborg *(Hamburg University of Technology, Hamburg, Germany)*

Presentation Chart

Abstract–In EUROCAE ED-130 two test procedures for radiated field EMC tests are pointed out. These procedures differ in the distance of the field transmitting antenna to the equipment under test. To cover the use of portable electronic devices next to the tested system, immunity tests are preformed in the near and far field region of the transmitting antenna. In this paper these tests are realized with exemplary test devices to obtain differences and similarities of these different test procedures.

4:00 pm **Analysis on Coexistence of UWB with IEEE802.11n** 807

Zhuo Li *(Beijing University of Posts & Telecommunications, Beijing, China)*; Feng Zhao *(Beijing University of Posts & Telecommunications, Beijing, China)*; Zheng Zhou *(Beijing University of Posts & Telecommunications, Beijing, China)*; Weixia Zou *(Beijing University of Posts & Telecommunications, Beijing, China)*; Bin Li *(Beijing University of Posts & Telecommunications, Beijing, China)*; Chong Zhao *(Beijing University of Posts & Telecommunications, Beijing, China)*

Presentation Chart

Abstract–Considering the potential interference of ultra-wideband (UWB) on narrowband communication systems, this paper studies coexistence issue between UWB with both impulse radio (IR) and multiband (MB) modulation and IEEE802.11n system, using physical layer model method. According to the physical characteristics of UWB and the victim system, entire physical layer models are set up. Based on the requirements of bit error rate (BER) and receiver sensitivity of IEEE 802.11n, the emission limits of UWB are obtained in the operating frequency band (5.18~5.805GHz) of 802.11n. Compared with a method based on interference to noise ratio (I/N) criteria, this method reflects the effect of

the actual systems, so the conclusion can provide the reference to formulating the frequency spectrum of UWB within the operating frequency band of 802.11n. Besides, we also reveal that IR-UWB should be more strictly regulated compared with MB-OFDM because of its time domain characteristic.

THU-PM-2, Systems Simulation (Sponsored by TC9), Room 221/220

Chair: Sam Connor, IBM
Co-Chair: Dr. Jun Fan, Missouri University of Science and Technology

3:00 pm **Vent Hole Size Analysis for High-Frequency Systems Chassis Design** 813
Eric Chikando *(IBM Corporation, Research Triangle Park, North Carolina, United States)*; Edward Bodette *(IBM Corporation, Research Triangle Park, North Carolina, United States)*; Samuel Connor *(IBM Corporation, Research Triangle Park, North Carolina, United States)*; Bruce Archambeault *(IBM Corporation, Research Triangle Park, North Carolina, United States)*

Presentation Chart

Abstract–This paper presents the electromagnetic interference shielding impact due to air vent holes on electronic systems chassis. In the study, finite-difference time domain (FDTD) simulations are used to investigate effects of aperture holes size on shielding performance. A numerical analysis is then proposed which enables mathematical quantification of expected shielding as function of holes number, size, depth and hole-to-hole separation distance.

3:30 pm **Analysis of the Shielding Performance of 2-D Periodic Screens Against Near Sources** 819
Rodolfo Araneo *(Sapienza University of Rome, Roma, Italy)*; Giampiero Lovat *(Sapienza University of Rome, Roma, Italy)*; Salvatore Celozzi *(Sapienza University of Rome, Roma, Italy)*

Presentation Chart

Abstract–The objective of this paper is to investigate the use of periodic artificial materials for shielding high-frequency high-impedance near fields produced by electric dipoles. The problem is handled numerically by applying the Array Scanning Method that reduces the problem of an aperiodic source close to a periodic screen to a superposition of phased-dipole-array problems (where the array periods are the spatial periods of the shield). As a result, the Floquet theory can be applied and the scattering problem is solved in the unit cell by means of a periodic space-domain Method of Moment, which employs the Ewald transformation to compute the involved Green's functions with accelerated performance. The exact solutions are compared with those derived by a spectral-domain approach with the use of homogeneous models and by the classical transmission-line approximation.

4:00 pm **Modeling the Near-Field Coupling of the EMC Filter Components** 825
S. Zangui *(Ecole Centrale de Lyon, Ecully, France)*; K. Berger *(Ecole Centrale de Lyon, Ecully, France)*; C. Vollaire *(Ecole Centrale de Lyon, Ecully, France)*; E. Clavel *(G2Elab, St. Martin d'Hères, France)*; R. Perrussel *(Ecole Centrale de Lyon, Ecully, France)*; B. Vincent *(Ecole Centrale de Lyon, Ecully, France)*

Presentation Chart

Abstract–EMC filters are increasingly integrated into power applications. To improve the filter performance it is important to model the electromagnetic interference between components to optimize their positions. In this paper, a method is proposed to construct the equivalent model of the filter components. The proposed method proposed is based on the multipolar expansion by representing the radiation emission of generic structures in a spherical reference (r, θ, φ). These models of the sources will be used to compute the mutual inductance between the components according to their layout.

4:30 pm **Efficient Mid-Frequency Plane Inductance Computation** 831
Fan Zhou *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Albert Ruehli *(Missouri University of Science & Technology, Rolla, Missouri, United States)*; Jun Fan *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–In power distribution networks (PDN), the modelling of the mid-frequency inductance for Zpp type plane pairs is very important. It is a key step for the placement of the decoupling capacitors. This paper gives an efficient approach for the calculation of the inductance for different capacitor placements. The PEEC based formulations takes advantage of the opposite currents in the planes. This leads to compute time reductions and memory savings for both the element calculation and the matrix solve step. We also use a formulation where placement of capacitors leads to only small changes in the circuit matrix. Comparisons with other models are made to validate our results.

THU-PM-3, Special Session – Nanomaterials and Nanodevices for EMC Applications (Sponsored by TC11), Room 209/210

Chair: Prof. Maria Sabrina Sarto, University of Rome
Co-Chair: Dr. Alessio Tamburrano, University of Rome

3:00 pm **The Partition Algorithm for Interconnect Analysis in Carbon Nanotube based ASICs** 837
Xi Zhang *(Tsinghua University, Beijing, China)*; Rong Luo *(Tsinghua University, Beijing, China)*

Presentation Chart

Abstract–Bundles of carbon nanotubes (CNTs) have been proposed as a promising replacement for copper interconnect due to their large conductivity and current-carrying capabilities. However, large resistance caused by imperfect metal contacts appears to be a significant problem in short CNT interconnects. Taking advantages of both CNT and copper becomes a good choice in ASIC. In this paper, an effective partition algorithm is proposed, which determines the partition length and makes reasonable allocation for CNT bundles and copper interconnect, thereby optimizing the performance of ASIC. Compared to copper based interconnect, the experiments report the critical delay is reduced to about 29%.

3:30 pm **Experimental Characterization of Electrical Properties of Carbon Nanotube Networks using Planar Transmission Lines** 841
Mahmoud A. EL Sabbagh *(Syracuse University, Syracuse, NY, United States)*

Presentation Chart

Abstract–This paper explores building planar transmission lines using carbon nanotube (CNT) networks. Transmission lines with carbon nanotube networks replacing the conventional metallic traces are presented. The experimental realization and the repeated two-port microwave measurements of the proposed transmission lines enable accurate extractions of the fundamental parameters showing percolation effects in CNT networks. The frequency-dependent phase velocity characteristics show a dramatic reduction compared to the speed of light in vacuum. The large magnitude of extracted complex permittivity for CNT networks also exhibits its percolation performance. The effects of CNTs' bulk density on measured and calculated parameters is explained.

4:00 pm **Skin-Effect Modeling of Carbon Nanotube Bundles: The High-Frequency Effective Impedance** 847
M. D'Amore *(Sapienza University of Rome, Rome, Italy)*; M.S. Sarto *(Sapienza University of Rome, Rome, Italy)*; A.G. D'Aloia *(Sapienza University of Rome, Rome, Italy)*

Presentation Chart

Abstract–A bundle of single wall carbon nanotubes (SWCNTs) with circular cross-section is treated as a homogeneous material with a.c. effective conductivity, which is evaluated by using the Drude's complex expression. The effective d.c. conductivity of the homogeneous bundle is obtained from the total d.c. resistance. The frequency-domain distribution of current density along radial direction of the bundle is utilized to obtain the expressions of the skin depth and the effective impedance. Applications of the proposed formulation to SWCNT bundles of different configurations are carried out. The obtained results show the saturation behaviour of the effective resistance and inductance above a critical frequency, which depends on the momentum relaxation time of the CNTs.

4:30 pm **Full-Wave Evaluation of Carbon Nanotubes as Microwave Interconnects** 853
Kichul Kim *(University of Colorado, Boulder, Colorado, United States)*; Paul Rice *(University of Colorado, Boulder, Colorado, United States)*; Pavel Kabos *(National Institute of Standards & Technology, Boulder, Colorado, United States)*; Dejan S. Filipovic *(University of Colorado, Boulder, Colorado, United States)*

Presentation Chart

Abstract–Microwave interconnect configurations composed of single wall carbon nanotubes (CNTs) are studied in this paper. Specifically, an atomic layer deposition (ALD) enabled nano-coaxial line with individual CNTs comprising the inner conductor, CNT Goubau line with ALD enabled alumina coating, a nano-coaxial line with inner conductor composed of CNT bundles, and Goubau lines of CNT bundles are discussed. The characteristic impedance and losses of these interconnects are compared with the similar size copper-based transmission lines. Full wave simulations with incorporated quantum effects are conducted using finite element and method of moments tools ANSYS HFSS and EMSS FEKO1, respectively. The thorough modeling validation, interconnect design and analysis are carried out over the wide microwave spectrum. Obtained results clearly show that although their inherent loss and impedance are high, the CNT interconnects can indeed outperform their copper counterparts with lower loss and impedance, that is reinforced with decreasing the radius of the CNTs.

5:00 pm **Predicting of Wideband Electromagnetic Responses of Composites Containing Magnetic Inclusions** 857

Konstantin N. Rozanov *(Russian Academy of Sciences, Moscow, Russia)*;
Marina Y. Koledintseva *(Missouri University of Science & Technology, Rolla, Missouri, United States)*;
James Drewniak *(Missouri University of Science & Technology, Rolla, Missouri, United States)*

Presentation Chart

Abstract–Engineering of absorbing bulk and sheet composite materials, including nanocomposites, for various EMI applications, requires adequate prediction of frequency and concentration behavior of these composites. This paper proposes two simple analytical formulations for effective permittivity and permeability of magneto-dielectric composites as functions of frequency and concentration. The first new proposed mixing rule is based on the Ghosh-Fuchs theory, which gives good agreement with the measured permittivity and permeability for composites containing magnetic alloy powders. This approach employs the Bergman-Milton concept of spectral function. Herein, the spectral function typical for the Bruggeman effective medium theory, also known as the Bruggeman symmetric rule (BSR), is chosen. This spectral function is composed using two fitting parameters: an averaged shape factor of inclusions, and the percolation threshold. These fitting parameters are found from the concentration dependence of permittivity, and then they are used to retrieve frequency dependence of permeability. The proposed mixing law is valid for nearly spherical inclusions in the composite, e.g., crumbs. Another analytical model proposed in this work can be applied to predict effective permeability of composites containing magnetic inclusions. It is based on the Bruggeman asymmetric rule (BAR), which has been modified in such a way that it takes into account shape factors of magnetic inclusions, in particular, randomly oriented platelets.

THU-PM-4, Capturing the Electromagnetic Environment 2 (Sponsored by TC3), Room 207/208

Chair: Dr. Randy Jost, University of Utah
Co-Chair: David Hilton

3:00 pm **An Automated Measurement System for Cosite Interference Analysis** 863

Matthew Young *(Delcross Technologies, Champaign, Illinois, United States)*;
Matt Miller *(Delcross Technologies, Champaign, Illinois, United States)*;
Fred German *(Delcross Technologies, Champaign, Illinois, United States)*

Presentation Chart

Abstract–Cosite electromagnetic interference can be accurately simulated when measured data characterizing the broadband behavior of individual RF systems operating in the cosite environment is available. In this paper, a measurement system is presented that performs the broadband transmitter and receiver characterizations necessary for analyzing the cosite problem. An overview of the system is provided along with resulting measurements and observations from a validation exercise.

3:30 pm **Simulation and Data Management for Cosite Interference Prediction** 869

Fred German *(Delcross Technologies, Champaign, Illinois, United States)*;
Kavitha Annamalai *(Delcross Technologies, Champaign, Illinois, United States)*;
Matthew Young *(Delcross Technologies, Champaign, Illinois, United States)*;
Matthew C. Miller *(Delcross Technologies, Champaign, Illinois, United States)*

Presentation Chart

Abstract–The accurate prediction of cosite electromagnetic interference (EMI) in complex radio frequency (RF) environments is often limited by the nature of the data available to describe the systems involved. Analysts attempting to predict cosite EMI are often faced with not only performing accurate simulations that yield useful results when using mixed data types, but also with managing a large amount of disparate data types in a way that allows straightforward predictions to be made and, just as importantly, allowing the accuracy of those predictions to be refined as more data becomes available to improve the description of the systems in the cosite scenario. In this paper, we address efficient approaches for both aspects of the cosite prediction challenge: simulation and data management.

4:00 pm **Off-Hull Radio Frequency Emissions from Below-Deck Spaces in Ships** 875

Gregory Tait *(Naval Surface Warfare Center Dahlgren, Dahlgren, Virginia, United States)*; Michael Slocum *(Naval Surface Warfare Center Dahlgren, Dahlgren, Virginia, United States)*; David R. Hilton *(Space & Naval Warfare Systems Center Pacific, San Diego, California, United States)*; Chris A. Dilay *(Space & Naval Warfare Systems Center Pacific, San Diego, California, United States)*; David F. Southworth *(Space & Naval Warfare Systems Center Pacific, San Diego, California, United States)*

Presentation Chart

Abstract–Measurement results and model analyses are presented for off-hull RF emissions caused by intentional transmitters radiating at 2.4 GHz and 5.8 GHz in enclosed, reflective spaces typically found within ships and aircraft. These transmissions can originate from shipboard wireless local area networks, radio frequency identification (RFID) tags and readers, handheld radios, and telemetry sources. Reverberant below-deck spaces with direct access to open air through windows and hatches exhibit surprisingly large off-hull signals detectable at substantial distances from the ship or aircraft. This situation occurs for total radiated power from the (multiple) transmitters at levels as low as 10 – 25 mW inside the below-deck space.

4:30 pm **Simulation and Measurement of Electromagnetic Radiation Absorption in a Finished-Product Warehouse** 881

Javier Ferrer Coll *(University of Gävle / KTH Royal Institute of Technology, Gävle, Sweden)*; Per Ängskog *(University of Gävle, Gävle, Sweden)*; Carl Karlsson *(University of Gävle, Gävle, Sweden)*; José Chilo *(University of Gävle, Gävle, Sweden)*; Peter Stenumgaard *(University of Gävle / Swedish Defence Research Agency, Gävle, Sweden)*

Presentation Chart

Abstract–Several studies have characterised industrial environments as being highly reflective. In this paper, we provide the data obtained from electromagnetic field measurements performed at the warehouse of a paper mill. The data is also compared to simulated data. This data proves the existence of non-reflective and very high absorption industrial environments where wireless communication is impossible at certain frequencies. Furthermore, in such environment, radio performance cannot be improved by multiple antenna solutions such as MIMO (Multiple Input Multiple Output) and diversity since multiple reflections are effectively absorbed. One advantage however is that electromagnetic interference from different process in the area will also be absorbed in this highly absorbing industrial area.