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Tuesday, August 4, 2020

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Chair: Kaisheng Hu, Ciena, Ottawa, ON, Canada

2:30 pm **Simulation and Measurement of a Power Distribution Network Including Point-of-Load Regulation** 16

Matteo Cocchini; Luke Jenkins; Wiren D. Becker
IBM Corporation, Poughkeepsie, NY, USA

Abstract: In this paper, a power distribution network analysis of a system card integrating a circuit model of a voltage regulator, an extracted printed circuit board power distribution, and a packaged ASIC with a circuit model and power specification is presented. In a typical power integrity analysis, these components are analyzed separately. Behavior models have been previously proposed to create end-to-end simulation models. In this work, we integrate the analysis of the components to explore the interaction between the voltage regulation and the passive power distribution network using transistor models in the circuit simulator. The conclusions on the additional capability this provides to the power integrity engineer are presented.

3:45 pm **Decoupling Capacitor Placement Optimization with Lagrange Multiplier Method** 22

Zhifei Xu[1]; Jun Wang[2]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Xidian University, Xi'an, China

Abstract: This paper proposes a decoupling capacitor placement optimization method based on the cavity model and Lagrange multiplier. The variable conditions associating with coordinates (x,y) of input impedance expression based on the cavity model are combined with the Lagrange multiplier method. The decoupling capacitor optimum placement within a defined area of the board can be found through the proposed analytical method. The example of finding an optimum location of the decoupling capacitor within a defined area of the power delivery network is exposed, the results are compared to the brute-force method to prove the effectiveness of the proposed method.

W1_TU_PM_B Computational Modeling (Sponsored by TC-9) 1:00 pm - 4:15 pm

Chair: Scott Piper, General Motors Corp., Detroit, MI, USA

1:30 pm **Conductive EMI Analysis in Transmission Lines Generated from ESD** 26

Maksim M. Tomilin
Moscow Aviation Institute (National Research University), Moscow, Russia

Abstract: The problem that was studied in the paper is calculation of conductive electromagnetic interferences generated from ESD in transmission lines or PCBs with MATLAB.

2:00 pm **Analysis of FDTD Crosstalk of Multiconductor Overhead Transmission Lines with a Frequency-Varying Ground Impedance Loss** 29

Yaxiu Sun; Jing Liu; Zhen Su; Xinkai Wang; Fei Liang
Harbin Engineering University, Harbin, China

Abstract: In the study of crosstalk of multiconductor overhead transmission lines, the traditional model is often established on a perfectly conducting ground, ignoring the influence of the ground as a poor conductor on the transmission voltage and current. In this paper, the influence of being placed on the ground with a frequency-varying ground impedance loss is studied, and the contribution of ground impedance loss to crosstalk is added into the classical multiconductor transmission line (MTL) equation. For the parasitic parameters of overhead lines with insulating medium, a simple analytical method of hierarchical series method is adopted. According to the updated equation and the boundary condition derived by finite difference time-domain (FDTD) method, the accurate crosstalk solution is obtained. In this paper, considering the influence of non-uniform medium and ground impedance loss and combining with MTL time-domain analysis method, the crosstalk can be calculated accurately, which is of great significance for the research on crosstalk of multiconductor overhead transmission lines.

2:30 pm **The Impact of Solar Panel Cutouts on the Electromagnetic Interference from Solar Panels for Space Vehicles** 34

David Norte
Ball Aerospace, Boulder, CO, USA

Abstract: Conventional solar panels for industrial applications are comprised of a given number of rows and columns of solar cells such that the overall array of solar cells forms a balanced rectangular pattern. In space applications of solar panels, it is sometimes necessary to modify this rectangular pattern such that one or more corners of the panel are bevelled or chamfered in order to prevent the obstruction of the field of view from an on-board antenna, for example. In space applications, the bevel can be rather large and can cause a significant imbalance of the distribution of the solar cells.

3:15 pm **The Effects of Cable Routing and Length on the Resonant Frequencies in a Shielding Box** 40
Mehdi Bahadorzadeh; Charles F. Bunting; James C. West
Oklahoma State University Stillwater, OK, USA

Abstract: The effects of cable routing within a shielding box has been evaluated using a numerical electromagnetic package. Different cable paths with both constant and varying lengths have proposed. The cable-feed port reflection coefficient and radiated electric field were considered for different test cases. The influence of slot apertures in the enclosure itself, gaps between external structures and the enclosure body, and cable route on radiated electric field and excited slot resonances are examined. The coupling between enclosure and cable resonances and their effects radiation emission are presented. The effect of the wire path on the slot resonances is also shown. The simulations for representative cases were empirically verified through comparison with laboratory measurement.

3:45 pm **Approximate Direct Inverse for Embedded Domain Decomposition Method** 45
Jiaqing Lu; Jin-Fa Lee
The Ohio State University, Columbus, OH, USA

Abstract: The embedded domain decomposition method (DDM) is a powerful tool for analyzing complex electromagnetic applications. It can decompose a computational domain into nonconformal subdomains and provide great flexibility in modeling and optimizing add-on components. However, convergence issues are found for embedded DDM, particularly at low frequencies. To overcome the problem, we propose approximate direct inverse (ADI) based on the principle component analysis (PCA) of the system equations. The ADI is utilized as an effective preconditioner ensuring robust convergence of the embedded DDM system.

Best EMC Paper Finalist

W1_TU_PM_C Emissions and Reverberation Chambers (Sponsored by TC-2) 1:00 pm - 4:15 pm

Chair: Tom Fagan, Aerospace Corporation, El Segundo, CA, USA

1:00 pm **Effect of Measurement Probe Configuration in Undermoded Nested Cavity Tests** 50
James C. West; Mehdi Bahadorzadeh; Charles F. Bunting
Oklahoma State University, Stillwater, OK, USA

Abstract: A study of the effect of the field-sampling probe configuration used in nested-cavity measurements has been performed. The outer cavity was an overmoded reverberation chamber and the inner cavity was a small conducting enclosure that included a coupling aperture. Mechanical stirring within both the external and internal cavities was combined with frequency stirring to yield the mean received signal. Monopole, meanderline, and log-periodic probes were evaluated. The three-dimensional meanderline probes overall showed the best performance, better sampling the low-frequency signals where the inner cavity is undermoded. Despite the advantages, the mean signals levels still show a dependence on the specific configuration of the meanderline used, particularly at low frequency, and care must be used in interpreting the measured levels.

1:30 pm **Validation and Use of a Vibrating Intrinsic Reverberation Chamber for Radiated Immunity Tests** 56
Danilo Izzo[1,2]; Alexander Rommel[1], Robert Vogt-Ardatjew[2]; Frank Leferink[2,3]
[1]Daimler Truck AG Stuttgart, Germany; [2]University of Twente, Enschede, The Netherlands; [3]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: A superposition of plane waves can be used to model the complex structure of the electromagnetic field in a reverberation environment. The total number of plane waves is, for resonant cavities with irregular shapes, unknown. Thus, the effect of different numbers of plane waves on the field uniformity is investigated through a comparison between simulated and empirical data. The experimental samples have been taken in a Vibrating Intrinsic Reverberation Chamber using fast field probes. Finally, some conclusions on the actual number of the wave fronts to use in a simulation model are drawn for different frequencies close and above the LUF.

Best EMC Student Paper Finalist

2:00 pm **Durations of Power Excursions in a Monostirred Reverberation Chamber** 61

Luk R. Arnaut
Queen Mary University of London, United Kingdom

Abstract: A theoretical and experimental analysis of the probability distributions and statistics of level crossing excursions for the power received inside a mode-stirred reverberation chamber is presented, under the assumption of a stationary mode-stirring process. Measurement results obtained across a wide range of stir speeds and excitation frequencies show good agreement with theoretical predictions for asymptotically high and low levels of exceedance in overmoded regime. Stir velocity and frequency characteristics of the fundamental second spectral moment of the stir process are determined empirically. The results are relevant to immunity, fading, and reliability testing in reverberation chambers.

2:30 pm **Asymmetry in Log-Periodic Dipole Antennas and Hybrid Antennas due to the Infinite Balun** 67

James S. McLean
TDK R&D Corp., Cedar Park, TX, USA

Abstract: A Log-Periodic Dipole Antenna (LPDA) employing an infinite balun feed mechanism does not typically exhibit pronounced radiation pattern asymmetry. Similarly, a hybrid LPDA-broadband-dipole antenna does not exhibit significant asymmetry in the frequency range in which the constituent LPDA acts alone in producing radiation. Nevertheless, a slight pattern asymmetry exists in such antennas due to the unbalanced excitation of the exposed center conductor of the internal coaxial line at the feed point where is emerges from the boom. That is, this small portion of the center conductor is driven against the remainder of the LPDA. The small asymmetry can be discerned in the primary lobe of the principal plane patterns but manifests itself in a less subtle manner in the antenna symmetry tests called for in several contemporary EMC standards. Perhaps surprisingly, the effect is observable at frequencies well below those at which the active region is located near the feed point. It is worthwhile to note that this behavior can exist with no common mode (CM) current on the feed transmission line, rather only on the LPDA booms. We examine this behavior in some detail using full-wave analysis of a typical LPDA antenna including a detailed feed model. We also provide measured data showing clearly similar behavior.

Best EMC Paper Finalist

3:15 pm **Dominant Timing Direct Identification for Radiation Noise due to Extended Double Pulse Test on Bare SiC MOSFET and Si RC-IGBT Chips** 73

Toshiya Tadakuma[1]; Michael Rogers[2]; Koichi Nishi[1]; Masahito Shoyama[3]
[1]Mitsubishi Electric Corporation, Fukuoka, Japan; [2]Mitsubishi Electric US, Inc., Monroeville, PA, USA; [3]Kyushu University, Fukuoka, Japan

Abstract: This paper describes a practical methodology to identify dominant switching timing directly with current dependency relative to radiation noise in switching power devices. Using an expanded double pulse test method on a half bridge circuit, it is possible to measure radiation noise as a switching characteristic the same as loss, time or switching speed. As a result, it is possible for power device makers to adjust in device development stage without building a total system. The methodology is introduced with results of power chips with different properties, SiC MOSFET and Si RC-IGBT. In future work, the results will be utilized to optimize not only the basic system but also power device structures.

3:45 pm **Measurement of the Amplitude and Phase Response of Harmonic Products in Protection Diodes** 79

Marcelo B. Perotoni[1]; Omid Hoseini Izadi[2]; David Pommerenke[3]
[1]Federal University of ABC, Santo Andre, Brazil; [2]University of Missouri-Rolla, Rolla, MO, USA; [3]Graz University of Technology, Graz, Austria

Abstract: This paper provides initial data from a measurement setup that captures not only the magnitude of unwanted harmonic signals created by TVS diodes but also measures their phase. Initial SPICE simulations are used for qualitative comparison. Goal is to use the phase information to gain in-sight into the mechanisms that create harmonics, not only for Transient Voltage Suppressor diodes, but also for imperfect metallic contacts.

WEDNESDAY TECHNICAL PAPERS – I

Wednesday, August 5, 2020

W1_WE_PM_A Passive Component Modeling and Measurement Techniques I (Sponsored by TC-10) 1:00 pm - 4:45 pm

Chair: Yunhui Chu, Intel Corp., Hillsboro, OR, USA

1:00 pm **A Development for Channel Loss Prediction based on Empirical Mode Decomposition Method and 2X-thru De-Embedding in High-Speed PCB System** 84

Kuan-Wei Chen[1]; Sheng-Chieh Lin[2]; Yi-Tang Chen[1]; Chi-Hsiang Hung[1]
[1]Wiwynn Crop., New Taipei City, Taiwan (ROC); [2]Elite Material Co., Ltd., Taoyuan City, Taiwan (ROC)

Abstract: Channel loss dominated the performance of the high speed I/O signals. The loss budget affects the ratio of cost and price directly. Owing to the above reasons, the exact correction of the de-embedded result can make this ratio more readable for the platform design guide. Due to the systematization, an algorithm is presented, which comprises a 2X-thru de-embedding method and an empirical mode decomposition (EMD) in this article. This 2Xthru de-embedding system includes a mix-mode calculation for differential mode S-parameters extraction, a time-domain channel characterization (TCC) for the midpoint of time sifting, and a Tmatrix cascading elimination for DUT extraction. The curve fitting method consists of an EMD or an ensemble empirical mode decomposition (EEMD) algorithm. This EMD/EEMD techniques have been applied for the elimination of ripple in the measure S21 of transmission line with small impedance mismatches. This work also does the correction for SMA and D-probe measurement fit by EMD and EEMD algorithm. This systematized topology can propose a criterion for a commercially printed circuit board (PCB) system and can also extend to the high-speed PCB system such as PCIe-5 and 6.

1:30 pm **Design and Characterization of Differential Signal Integrity Interconnects at Millimeter-Wave PCB** 90

Kaisheng Hu
Ciena, Ottawa, ON, Canada

Abstract: In this paper, a Signal Integrity test board is designed to evaluate differential calibration and de-embedding methods at millimeter-Wave frequency band: Differential Crosstalk TRL (Thru-Reflect-Line) and Differential 2x-Thru de-embedding. For DUT's result, S21 phase delay are same, but differential Crosstalk TRL shows non-causality issue together with higher error at S21 amplitude. Finally 2x-Thru is selected at several typical de-embedding scenarios: PCB parameters extraction (Dk, Df and Surface Roughness) up to 67 GHz; Ultra-low loss PCB material evaluation (Panasonic Meg 7, TUC TU933+, Nelco MW4000 and Isola Tachyon-100G); Multi-channel skew test (less than 1 ps) with one port de-embedding.

2:00 pm **Problem of the Slot Connector Model Extraction by De-Embedding Methodology** 96

Scott Lee; Eriksson Chuang; William Chang; Jerry Syue; Cooper Li
Quanta Computer Inc., Taoyuan City, Taiwan (R.O.C.)

Abstract: Problem of de-embedding methodology for slot connector model extraction had been studied in this paper. De-embedding is effective for linear subtraction of trace length effect for connector model extraction[1]. In slot connector, there is golden finger stub inside and it causes PCB material and contact point dependent reflection which are non-linear effect. This will cause gap between actual and simulated characteristics of slot connector and result in over-estimate of signal margin of system linkage.

2:30 pm **Meander Line Optimization for High-Speed Differential Transmission Lines** 100

Sangkyu Jin; SoYoung Kim

Abstract: Meander structures are often used to compensate signal skew in differential transmission lines in the Printed Circuit Board (PCB)s. However, it causes impedance discontinuity, which results in signal reflection. In this paper, we propose a design guideline to reduce signal reflection caused by impedance discontinuity. The best design was a loosely coupled differential transmission line with one large meander curve to reduce impedance mismatches. The proposed design is validated with measurement results.

W1_WE_PM_B Interference Control Methods (Sponsored by TC-4) 1:00 pm - 4:15 pm

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

2:30 pm **Direct Measurement and Representation of Common-Mode Sources in Cable Harnesses** 118
Sameer Walunj[1]; Tamar Makharashvili[1]; Brian Booth[2]; Kerry Martin[2];
Chulsoon Hwang[1]; Daryl Beetner[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Deere and Company, Moline, IL, USA

Abstract: Predicting common-mode currents in cable harnesses is essential for predicting radiated emissions early in the design process. Using component-level tests to predict system-level emissions is difficult, however, as the common mode current seen in the component-level test may differ dramatically from that seen in the system. A component-level measurement-based approach for characterizing common mode sources is proposed here which may be used to predict common-mode currents for a variety of harness configurations. Common-mode source measurements were made by grouping sources together by the size of the loads they drive and measuring the effective common-mode source voltage and impedance for the group through a characterization board. Common-mode currents were predicted using these sources and transmission line models of the harness. The method was validated by characterizing sources in an engine controller from 20 MHz to 200 MHz and then predicting common-mode currents on harnesses of a variety of lengths, and thus for different common-mode impedances looking into the harness. The worst error between the predicted and measured common mode current was less than 7 dB in the 20 MHz to 200 MHz frequency range.

W1_WE_PM_C RFI Issues and 5G Measurements I (Sponsored by TC-12) 1:00 pm - 4:45 pm

Chair: Gang Feng, General Test Systems, Shenzhen, China

1:00 pm **On-Package Decoupling Strategy to Mitigate Radio Frequency Interference from Integrated Voltage Regulators** 121
Ying-Ern Ho[1]; Juan Zeng[2]; Min Keen Tang[1]; Hao-Han Hsu[2]; Pujitha Davuluri[2]
[1]Intel Corporation Penang, Malaysia; [2]Intel Corporation Hillsboro, Oregon, USA

Abstract: This paper presents a new solution for mitigating integrated voltage regulator (IVR) switching noise by using on-package radio frequency (RF) decoupling capacitors. IVR enables product miniaturization but prone to RFI issues without proper design considerations due to high switching frequency. The proposed decoupling strategy allows flexible and low-cost platform designs. The critical design parameters, such as capacitance, capacitor number, and locations, are studied. The effectiveness of the proposed solution is validated with system-level measurements. These recommendations may help to mitigate radio frequency interference (RFI) due to IVR switching noise, relax IVR routing requirements, and eliminate the need of on-board shielding.

2:00 pm **EMI Sensitivity Study and Mitigation Method of Multi-GHz RF Cable and Connector** 127
Tao Wang
Missouri University of Science and Technology, Rolla, MO, USA

Abstract: A mobile system transmitting intermediate frequency/ radio frequency (IF/RF) signals via a cable between Printed Circuit Boards (PCBs) can be vulnerable to electromagnetic interference (EMI), which may result from the connector itself as well as the interface between the connector and the cable. In this paper, the radiation physics of an RF cable and connector is comprehensively analyzed using a commercially available electromagnetic (EM) simulation tool. The sensitivity of EMI to a connector's physical dimension is studied. Based on the sensitivity study, a mitigation solution is proposed to reduce current leakage from the connector and cable interface by adopting the hot bar soldering technique.

2:30 pm **Mechanism Analysis on Radio Frequency Radiation in IC/Package with Bonding Wires** 133
Muqi Ouyang[1]; Yin Sun[1]; Jongjoo Lee[1]; Jingook Kim[2]; Chulsoon Hwang[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Ulsan National Institute of Science and Technology, Ulsan, Korea, Republic of (South)

Abstract: IC/package radiation from a self-designed inverter chip bonded to a PCB was measured, and the radiation mechanism was investigated. Digital signals from ICs can have wide-spread frequency spectrums, and radiated signals in the radio frequency range can be picked up by other radio receivers, which causes radio-frequency interference problems. First, an equivalent radiation source for an inverter chip bonded to a PCB is reconstructed based on near-field patterns measured above the chip. The validity of the reconstructed source is proved by comparing the coupled voltage measured on a victim antenna and the voltage calculated based on the reconstructed radiation source. Then, the radiation mechanism is investigated by analyzing the equivalent radiation source as well as the signal and return current paths in full-wave simulations. Then, the critical current paths responsible for the radiation are identified. Finally, a simplified model is proposed to calculate the equivalent radiation source, with which the errors between the simplified model and full-wave simulation results were found to be within 5%.

Best EMC Student Paper Finalist

3:15 pm **Investigation and Mitigation of Radio Frequency Interference Caused by Weak Grounding of USB Type-C Receptacle Connector** 139
Anfeng Huang[1]; Xin Yan[1]; Jingdong Sun[1]; Qiaolei Huang[1]; Jun Fan[1]; Songping Wu[2]; Dave Zhang[2]; Huan Liao[2]; Shuai Jin[2]; Zhiping Yang[2]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Google LLC, Mountain View, CA, USA

Abstract: In modern mobile electronic systems, USB connector has been identified as one of the dominant noise sources for desense issues. In this paper, the noise coupled to the Wi- Fi antenna from a USB connector is investigated. With the assistance of full-wave simulations, the root cause of desense noise is identified as the non-ideal electrical connection between the metal chassis and the USB receptacle shell where it is installed. The proposed radiation mechanism is validated through measurements of a real tablet device, and 15 dB noise level reduction is observed with a better grounding structure.

THURSDAY TECHNICAL PAPERS – I

Thursday, August 6, 2020

W1_TH_PM_A High-Speed Bus/Link Design (Sponsored by TC-10) 1:00 pm - 4:45 pm

Chair: Sunil Gupta, Qualcomm Technologies, Inc., San Diego, CA, USA

1:00 pm **Differential via Designs for Crosstalk Reduction in High-Speed PCBs** 145
Junda Wang; Chaohui Xu; Shuai Zhong; Siqi Bai; JongJoo Lee; DongHyun Kim
Missouri University of Science and Technology, Rolla, MO, USA

Abstract: With an increased data rate of high-speed PCBs, an increase in crosstalk degrades the signal integrity of the high-speed system. In most PCB designs, via-to-via coupling has the largest impact on crosstalk. Until now, multiple PCB design methods for crosstalk mitigation are proposed under the IC pin field area, such as increasing the distance between signal pairs, adding more ground vias in between the signal vias and placing signal pairs orthogonal to each other. However, such methods sacrifice the signal to ground (S:G) ratio and require a change in the IC package ball map. In this paper, two different via designs are proposed to reduce crosstalk without sacrificing the S:G ratio, while maintaining the package ball maps. In the first proposed design, crosstalk is mitigated through tilted drilling, where the vias are drilled with 45 degrees angle on the PCB. Differential via pairs located in different rows achieves orthogonality for crosstalk cancellation when viewed from the horizontal cross-section. In the second proposed design, additional intermediate vias are designed to achieve orthogonality between differential via pairs without changing the IC package ball map or the drilling direction. Using a 3D full-wave simulation tool, the two prosed designs are simulated. Simulation results demonstrate that both designs decrease in crosstalk with negligible change in insertion loss and return loss compared to the conventional via design up to 30 GHz range. The proposed methods can be directly applied to lower the crosstalk in the existing high-speed PCBs with minor adjustments in the PCB design while maintaining the same IC packages.

Best SIPI Student Paper Finalist

1:30 pm **Impact of Surface Roughness on Return Planes in High Speed Signal Propagation** 150

Han Gao[1]; Soumya De[2]; Steve Payne[1]
[1]Cisco Systems, Inc., San Jose, CA, USA; [2]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Nowadays the impact of conductor surface roughness is extremely important as data rates continue to increase. There are several methods to model surface roughness on copper, e.g. Hemispherical model, Huray model, etc. However, very few studies show the effect of return/reference plane surface roughness on signal propagation. In this paper, the impact of surface roughness on both signal layer and reference plane is investigated.

2:30 pm **Robust Extended Unterminated Line (EUL) Crosstalk Characterization Techniques for High-Speed Interconnect** 155

Yuandong Guo[1]; DongHyun Kim[1]; Jiayi He[1]; Xiaoning Ye[2]; Albert Sutono[3]; Vijay Kunda[2]; Amy Luoh[2]; Zurab Kiguradze[1]; Li Shen[1]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, Missouri, USA; [2]Intel Corporation, Hillsboro OR, USA; [3]Intel Corporation, Chandler, AZ, USA

Abstract: Extend Unterminated Line (EUL) structure allows crosstalk measurements with perfect termination and halves the number of test ports required by the traditional method. Therefore, EUL is a time-efficient and convenient structure for a test vehicle design of high-speed interconnects. In this paper, the potential errors in the EUL measurement are analyzed. In addition, an error detection method to check for causality, passivity and reciprocity is demonstrated. It is the first time to propose the best practices and robustness-enhancement techniques for EUL crosstalk characterization.

3:15 pm **Backplane Channel Design Exploration at 112 Gbps using Channel Operating Margin (COM)** 158

Francesco de Paulis[1]; Tim Wang-Lee[2]; Richard Mellitz[3]; Mike Resso[2]; Rick Rabinovich[4]; O.J. Danzy[2]
[1]University of L'Aquila, Italy; [2]Keysight Technologies, Santa Rosa, CA, USA; [3]Samtec Corporation, New Albany, IN, USA; [4]Keysight Technologies, Calabasas, CA, USA

Abstract: High speed digital design is constantly attracting the attention of the electronic industry due to the constant development of telecommunication standards, with the consequence of ever growing data rate and new modulation schemes. The Channel Operating Margin (COM) comes up as a powerful tool for channel and physical layer designers to explore the design space at an early stage, as well as to optimize the channel physical parameters, thus overcoming the classic channel performance metrics such as eye diagram and BER. The analysis of the test cases proposed herein will guide through the use of COM and the channel analysis by investigating a 112 Gbps PAM4 chip-to-chip communication over a complex channel composed of a host board, a mezzanine connector, and a daughter card. Accurate analysis of these elements is carried out based on the connector characterization by measurements and full wave models; the PCBs, instead, are modeled as multiconductor transmission lines to resemble the typical configuration of coupled differential strip lines. A comprehensive discussion of the COM results set relevant guidelines for a pre-layout analysis of such high speed communication channels.

3:45 pm **Effects of Various via Patterns on Resonance and Crosstalk in High Speed Printed Circuit Boards** 164

IL-Young Park[1]; Iftikhar Ahmed[2]; David Brunker[3]; Pu Xie[3]; Jayanthi Natarajan[1]
[1]Cisco Systems, Inc., San Jose, CA, USA; [2]Sanmina, Inc., Ottawa, ON, Canada; [3]Molex, Inc., Lisle, IL, USA

Abstract: Resonance and crosstalk due to via patterns are critical in design of high-speed multi-layer printed circuit boards (PCBs). Crosstalk causes compliance issues whereas resonance limits bandwidth. These factors can also generate jitter and as a result, degrade signal quality. In this paper, different approaches based on via patterns are proposed to minimize crosstalk and to improve resonance by varying different parameters such as via size and pitch, orthogonal and hexagonal via arrays. Results of the approaches are analyzed and evaluated in terms of crosstalk and resonance on multi-layer, high-speed printed circuit boards. A significant improvement in crosstalk, up-to 12 dB and up-to 8GHz in bandwidth is obtained.

4:15 pm **Die-Package-PCB Signal Integrity Performance Debug of a High-Speed (25Gbps) Retimer: Simulation to Measurement Correlation** 170

Tony Tang; Bridger Wray; Rajen Murugan
Texas Instruments, Inc., Dallas, TX, USA

Abstract: In this paper we detail the signal integrity performance debug of a 130nm BiCMOS high-speed (25Gbps) 4-channel multi-rate retimer device, packaged in a small 7mm×7mm new fine pitch ball grid array (nFBGA), a laminate-based family of chip-scale packaging technology. During the electrolytic plating IC packaging manufacturing process, residual plating tie-bar, i.e. "stubs", can introduce "quarter-wavelength" resonance which can impact signal integrity performance. We discussed here the process of troubleshooting a resonance issue observed during system performance characterization. Key figure of merits for system electrical performance (viz. insertion loss, return loss, crosstalk/isolation, and jitter) are modeled and analyzed. Laboratory measurements are presented that validate the integrity of the system co-design modeling methodology. Good correlation between simulations and laboratory measurements is achieved. Design optimization schemes, to alleviate resonance issues, are implemented and validated with the modeling methodology.

W1_TH_PM_B ESD: Touchscreens, Software and Protection (Sponsored by TC-5) 1:00 pm - 4:15 pm

Chair: Joost Willemen, Infineon Technologies, Neubiberg, Germany
Co-Chair: Michael K. McInerney, US Army Corps of Engineers (USACE), Champaign, IL, USA

1:30 pm **Analysis of CPU Loading Effect on ESD Susceptibility** 176

Omid Hoseini Izadi[1]; Hideki Shumiya[2]; Shota Konno[2]; Kenji Araki[2]; David Pommerenke[3]; DongHyun Kim[1]
[1]Missouri University of Science and Technology Rolla, USA; [2]Sony Global M&O Corporation Tokyo, Japan; [3]Institute of Electronic Graz University of Technology Graz, Austria

Abstract: Two complementary approaches are presented to help to understand how CPU loading affects the sensitivity of an electronic device to ESD (electrostatic discharge) stress. Both approaches rely on synchronized noise injection while the software is running at the desired load. One of the approaches monitors the device's current consumption while the other monitors the device's electromagnetic field to synchronize noise injections. These approaches revealed that as the CPU loading increases, the device becomes more active and hence more susceptible to ESD stress. Moreover, it was observed that, in each loading condition, the device randomly became susceptible. These complementary approaches enable the capturing of high/low active intervals as well as the injection of noise voltage to the desired activity, thus, allowing for the analysis of the effect of CPU loading on ESD susceptibility.

2:00 pm **Experimental Characterization and Methodology for Full-Wave Modeling of ESD to Displays** 182

Hossein Rezaei[1]; Zhekun Peng[1]; Shubhankar Marathe[1]; David Pommerenke[2]; Cheung Wei Lam[3]; Ali Foudazi[3]; Daryl Beetner[1]; DongHyun Kim[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Graz University of Technology, Graz, Austria; [3]Apple Inc., Cupertino, CA, USA

Abstract: An electrostatic discharge (ESD) to the touchscreen display of a cellphone or other handheld device can result in device failures through sparkless discharge. A test model has been designed and a test board built to investigate sparkless discharge to glass displays, based on the discharge path in a typical product. The current waveform at the touchscreen circuit load was captured during an air discharge using an oscilloscope for 40 test cases with different glass thicknesses, load resistances, and patch-to-ground capacitances. Full wave and circuit models of the discharge event have also been developed. Using the circuit model and a genetic algorithm approach, methods were developed for estimating the input current waveform associated with the discharge event. Using this current waveform, it is possible to predict the magnitude, rise time, total charge, and energy of a typical surface discharges to displays during the early stages of product design to prevent device failures.

2:30 pm **Trend Analysis of Dissipated Electrostatic Discharge Energy in Touchscreen Displays** 188

Zhekun Peng[1]; Shubhankar Marathe[1]; Hossein Rezaei[1]; Giorgi Maghlakelidze[1]; David Pommerenke[2]; Ali Foudazi[3]; Cheung-Wei Lam[3]; Daryl Beetner[1]; DongHyun Kim[1]

[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Graz University of Technology, Graz, Austria; [3]Apple Inc., Cupertino, CA, USA

Abstract: Touchscreen displays can be susceptible to spark-less electrostatic discharge events. The energy observed by sensitive touchscreen circuitry can vary significantly with design parameters like the glass thickness, the capacitance between the sensor pad and the ground structure, and the resistance of the traces and sensor terminations connected to the pad. The energy dissipated in resistive structures within the display can lead to damage. Methods are presented to estimate the maximum energy dissipated in the touchscreen circuitry during a spark-less discharge to the display. The trends in the energy with variations in design parameters are analyzed using traditional curve-fitting techniques. The analysis was performed using measured data obtained for 20 touchscreen configurations when the ESD gun was charged to 9 kV and 15 kV. The analysis helps the designer to understand the trends and to predict how future design decisions may impact ESD susceptibility. Results suggest that immunity can be maximized by increasing the glass thickness, reducing the load resistance, and reducing the distance between the sensor pad and the PCB return plane.

3:15 pm **Effect of RF Signals on TVS Diode Trigger Voltage for ESD Protection** 194

Giorgi Maghlakelidze[1]; Shubhankar Marathe[1]; Wei Huang[2]; Joost Willemen[3]; David Pommerenke[4]

[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]ESDEMC Technology, Rolla, MO, USA; [3]Infineon Technologies, Neubiberg, Germany; [4]Graz University of Technology, Graz, Austria

Abstract: Discrete transient voltage suppressor devices are used in addition to the on-chip ESD protection to protect the ICs from ESD damage. In applications involving snapback TVS devices, the trigger voltage is selected to be higher than the desired signals on the net. The presence of RF on the net affects the TVS behavior, even if the RF levels are less than the snapback trigger voltage. Known effects are RF intermodulation and harmonic generation, which diminish SNR. This work describes the other effect on the TVS diodes - the observed reduction of the snapback trigger voltage, monotonically dependent on the amplitude of the RF signal. This translates into snapback triggering at lower stress levels than specified in the datasheet or expected by the design engineer. TLP testing was performed using a 100 ns pulse with RF signals from 100 MHz to 2 GHz present at the diode terminals. The results show that the higher frequencies have a weaker impact on the reduction of the snapback trigger voltage. At lower frequencies such as 100 MHz, the overlap of the first few ns of the TLP pulse, the peak voltage, and the phase of the RF signal impact the amount of reduction in the trigger voltage. It is also observed that certain TVS diodes recover from snapback even when the RF amplitude is higher than the holding voltage of the diode.

Best EMC Student Paper Finalist

3:45 pm **Commercial USB IC Soft-Failure Sensitivity Measurement Method and Trend Analysis** 200

Runbing Hua[1]; Omid Hoseini Izadi[1]; Zhekun Peng[1]; Hideki Shumiya[2]; Shota Konno[2]; Kenji Araki[2]; David Pommerenke[3]; DongHyun Kim[1]

[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Sony Global M&O Corporation, Tokyo, Japan; [3]Graz University of Technology, Graz, Austria

Abstract: An electrostatic discharge (ESD) happening on a commercial electronic device such as at the USB interface can induce soft-failure in the IC and disturb the normal operation of the device. This paper investigates the soft-failure behaviors of 14 commercial USB devices in order to obtain an insight into the overall sensitivity trend of such systems and into the severity of different soft-failures. A new analysis method is proposed in this paper. The considered parameters in this study include: injected pulse widths, pulse rise time, current levels, USB standard of the DUTs, etc. Soft-failures started to occur at a current of around 1 A, and nearly all configurations would show errors above 6 A.

W1_TH_PM_C Special Problems Concerning EMC at Low Frequency (Sponsored by TC-7) 1:00 pm - 4:45 pm

Chair: Petre-Marian Nicolae, University of Craiova, Craiova, Romania
Co-Chair: Flavia Grassi, Politecnico di Milano, Milano, Italy
Co-Chair: Sebastian Koj, IAV GmbH Automotive Engineering, Gifhorn/Berlin, Germany

1:00 pm **Multi-Channel Time-Domain EMI Evaluation of Dominant Mode Interference for Optimized Filter Design in Three-Phase Systems** 205
Daria Nemashkalo[1]; Niek Moonen[1]; Frank Leferink[1,2]
[1]University of Twente, Enschede, The Netherlands; [2]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: This paper describes optimal three-phase filter design based on the measured dominant mode of interference. The modes of interference are determined by simultaneously measuring currents and voltages in all phases in time domain, using a multi-channel digitizer. The measured results are evaluated in frequency domain after fast Fourier transform. While usual electromagnetic compatibility measurement equipment is evaluating only one single channel, the described multi-channel technique allows rapid estimation of dominant modes, for stationary loads, but also for cyclo-stationary, transient and nonlinear loads. Using this method, the topology of power line filter for sufficient suppression of a specific mode of interference from commercial of the shelf three-phase power converter is estimated.

1:30 pm **On-Site Efficiency Analysis of a Generator in the Millisecond Range** 209
Bas ten Have[1]; Niek Moonen[1]; Frank Leferink[1,2]
[1]University of Twente, Enschede, The Netherlands; [2]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: Power supply systems, such as a diesel generator, are often designed based on the apparent power and the peak demands of non-linear loads. Because of this the generators run on a lower percentage of the rated load for most of their operation hours and are thus over dimensioned. The efficiency of generators is very poor when these are not running on full power. So, optimizing the power system such that it runs on a higher percentage of the rated load makes the system more efficient. In this paper measurement techniques used to determine the efficiency are researched. A system that uses a diesel generator is measured on-site, and analyzed using conventional power quality measurements and time-domain measurements in the millisecond range. The aim is to get more detailed insight in the behavior of the system and optimize the power supply system accordingly

2:00 pm **Versatile High-Sample Frequency Power Quality Measurement Device** 213
Alexander Matthee[1]; Niek Moonen[1]; Frank Leferink[1,2]
[1]University of Twente, Enschede, The Netherlands; [2]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: Rapidly advancing technology has seen the adoption of non-linear loads which may be considered improving efficiency and decreasing cost. Unfortunately this advance of technology often exceeds the measures to control the unforeseen effects of systems or unwanted interference between multiple manufacturer's devices. In this paper a relatively modern building, with a common experience of conducted electromagnetic interference including power quality problems such as harmonic distortion of the supply, is discussed. A system is developed to monitor the power quality of the mains in various locations and aid in identifying the extent of the electromagnetic interference. With high sampling frequency and synchronising of measurement data between various locations accurate within millisecond scale in the power distributed user network, the extent of conducted emission events especially sub millisecond range, is analysed.

2:30 pm **Multipoint Measurement Technique for Tracking Electromagnetic Interference Propagation and Correlation in a Complex Installation** 216
Muhammad Imam Sudrajat[1,2]; Niek Moonen[1]; Hans Bergsma[3]; Rob Bijman[3]; Frank Leferink[1,3]
[1]University of Twente, Enschede, The Netherlands; [2]Indonesian Institute of Sciences - LIPI, Indonesia; [3]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: Electromagnetic interference (EMI) can degrade the power quality (PQ) in an electrical network. Identification of the interference source and its propagation can only be achieved by distributed measurement methods using synchronous multipoint measurements. This paper proposes a multipoint measurement analysis method using the number of coincidence events and a coincidence ratio to determine the relationship between each EMI event at several measurement locations. The measurement is performed using six distributed power quality analyzers

3:15 pm **Interference of LED Lamps on Narrowband Power Line Communication** 219
Muhammad Ammar Wibisono[1,2]; Niek Moonen[1]; Frank Leferink[1,3]
[1]*University of Twente, Enschede, The Netherlands;* [2]*Institut Teknologi Bandung, Indonesia;*
[3]*THALES Nederland B.V., Hengelo, The Netherlands*

Abstract: This paper presents the impact of LED lamps on the performance of Narrowband Power Line Communication (NB-PLC) in the CENELEC-A band between 9-95 kHz. NB-PLC in is only one of the many victims of interference in the frequency range 2-150 kHz. Only few emission standards for this frequency range are available, while the number of interference cases is growing rapidly. Most equipment will fail at a specific frequency and/or level. PLC is chosen as a victim, as the performance of the PLC is rated through well-established parameters. One of these is the Frame Error Rate (FER), which is calculated as the ratio between the erroneous frames and total received frames. The number of LED lamps has a strong correlation with the peak amplitude of the current pulses from the LED lamps and the FER of the PLC data frames.

3:45 pm **Wideband Tapered Microstrip Transmission Line (MTL) Volume Coil for 1.5T MRI Scanner** 222
Meena Rajendran; Elizaveta Motovilova; Shao Ying Huang
Singapore University of Technology and Design, Singapore

Abstract: Wide bandwidth is a key requirement for Radio Frequency (RF) coils in the emerging body-part-dedicated portable Magnetic Resonance Imaging (MRI) due to the static field inhomogeneity caused by a short magnet. As the size of the magnet, either a superconducting magnet or a permanent magnet array (PMA), is reduced, the B0 field homogeneity is reduced significantly. The lowered B0 field homogeneity leads to an increase in the working bandwidth. A wideband RF coil helps to guarantee the excitation and reception of signals within a targeted field of view (FoV). In this paper, we propose single-tapered and dual-tapered wideband Microstrip Transmission Line (MTL) volume coil for a 1.5T MRI system with a short magnet. The fractional Full Width at Half Maximum (FWHM) bandwidth for the proposed tapered and dual tapered coils are 11.25% and 10.62%, respectively, which are 28.57% and 21.4% higher than that of the traditional non-tapered MTL volume coil, yet having a comparable B1 field intensity.

TUESDAY TECHNICAL PAPERS – II

Tuesday, August 11, 2020

W2_TU_PM_A Signal Integrity Computational Modeling (Sponsored by TC-9 and TC10) 1:00 pm - 4:15 pm

Chair: Songping Wu, Google LLC, Mountain View, CA, USA

1:00 pm **Generic Modeling of Differential Striplines using Machine Learning based Regression Analysis** 226
Srinath Penugonda[1]; Shaohui Yong[1]; Anna Gao[2]; Kevin Cai[2]; Bidyut Sen[2]; Jun Fan[1]
[1]*Missouri University of Science and Technology, Rolla, MO, USA;* [2]*Cisco Systems, Inc., San Jose, CA, USA*

Abstract: In this paper, a generic model for a differential strip line is created using machine learning (ML) based regression analysis. A recursive approach of creating various inputs is adapted instead of traditional design of experiments (DoE) approach. This leads to reduction of number of simulations as well as control the data points required for performing simulations. The generic model is developed using 48 simulations. It is comparable to the linear regression model, which is obtained using 1152 simulations. Additionally, a tabular W-element model of a differential strip line is used to take into consideration the frequency-dependent dielectric loss. In order to demonstrate the expandability of this approach, the methodology was applied to two differential pairs of strip lines in the frequency range of 10 MHz to 20 GHz.

1:30 pm **Dipole Source Reconstruction by Convolutional Neural Networks** 231

Jiayi He; Qiaolei Huang; Jun Fan
Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Equivalent dipole moments are widely used for noise source reconstruction in radio frequency interference (RFI) study. The equivalent dipole sources are usually extracted from measured near-field pattern. This paper introduces a machine learning based method to extract the dipole moments. A convolutional neural network is trained to perform a multi-label classification to determine the type of dipole moments. The locations of the dipole moments are obtained from the global averaging pooling layer. Then the magnitude and phase of the dipoles can be calculated from least square (LSQ) optimization. The proposed method is tested on simulated near-field patterns. The comparison between reconstructed field pattern and original field pattern is given.

2:00 pm **Expedient Prediction of Eye Opening of High-Speed Links with Input Design Space Dimensionality Reduction** 236

Hanzhi Ma[1]; Er-Ping Li[1]; Andreas C. Cangellaris[2]; Xu Chen[2]
[1]Zhejiang University, Hangzhou, China; [2]University of Illinois at Urbana-Champaign, Urbana, IL, USA

Abstract: We propose a new method, named Support Vector Regression-based Active Subspace, for the reduction of the dimensionality of the high-dimensional input space of design parameters pertinent to the predictive assessment of the eye opening prediction of high-speed links with IBIS-AMI transmitter and receiver equalization. We compare the method with Support Vector Regression model and Principal Component Analysis-based dimensionality reduction algorithm. Numerical results show that proposed method exhibits the best accuracy in predicting eye height, eye width, and eye width at 10□12 BER in the presence of correlated design variability.

Best SIPI Student Paper Finalist

2:30 pm **Deep Learning based Poisson Solver in Particle Simulation of PN Junction with Transient ESD Excitation** 241

Ling Zhang[1]; Wenchang Huang[1]; Ze Sun[1]; Nicholas Erickson[1]; Ryan From[2]; Jun Fan[1]
[1]Missouri S&T EMC Laboratory, Rolla, MO, USA; [2]Boeing Company, St. Louis, MO, USA

Abstract: In particle simulations of semiconductor devices for electro-static discharge (ESD) study at the microscopic level, solving Poisson's equation is an inevitable but time-consuming step. In this work, a deep learning technique is utilized to resolve Poisson's equation for a PN junction under an ESD event, namely using a trained deep neural network (DNN) to predict the potential distribution according to the charge distribution and the boundary condition under a transient ESD excitation. To improve the generalization performance of the DNN, multiple typical ESD curves with different parameters are used as the excitation boundary to generate large amounts of training data with a finite-element method (FEM) solver. After being trained, the DNN is used in the particle simulation to calculate the current response of the PN junction to a new ESD voltage curve that has never been trained before, and the result can perfectly match with that obtained from the FEM solver.

3:15 pm **An Enhanced Deep Reinforcement Learning Algorithm for Decoupling Capacitor Selection in Power Distribution Network Design** 245

Ling Zhang[1]; Wenchang Huang[1]; Jack Juang[1]; Hank Lin[2]; Bin-Chyi Tseng; Chulsoon Hwang[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]ASUSTek Computer Inc., Taipei, Taiwan

Abstract: The selection of decoupling capacitors (decap) is a critical but tedious process in power distribution network (PDN) design. In this paper, an improved decap-selection algorithm based on deep reinforcement learning (DRL), which seeks the minimum number of decaps through a self-exploration training to satisfy a given target impedance, is presented. Compared with the previous relevant work: the calculation speed of PDN impedance is significantly increased by adopting an impedance matrix reduction method; also, the enhanced algorithm performs a better convergence by utilizing the techniques of double Q-learning and prioritized experience replay; furthermore, a well-designed reward is proposed to facilitate long-term convergence when more decaps are required. The proposed algorithm demonstrates the feasibility of achieving decent performance using DRL with pre-trained knowledge for more complicated engineering tasks in the future

Best SIPI Student Paper Finalist

3:45 pm **High-Speed Channel Equalization Applying Parallel Bayesian Machine Learning** 251
Zurab Kiguradze[1]; Nana Dikhaminjia[2]; Mikheil Tsiklauri[1]; Jiayi He[1]; Bhyrav Mutnury[3]; Arun Chada[3]; James Drewniak[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Ilia State University, Tbilisi, Georgia; [3]Dell Inc., Round Rock, TX, USA

Abstract: Recovering attenuated signals caused by different issues including connections between connectors and chips of the devices, channel loss, and crosstalk is a challenging problem. Equalization is the most popular way to restore distorted signals. Different optimization algorithms are used to find the best tap coefficients for each equalization that improves eye opening and decreases the bit error rate (BER). Nowadays algorithms of equalization mainly operate to reduce the difference between input and output signals. In turn, this will increase eye height indirectly, but direct maximization of the eye height will restore the signal even better. The paper proposes a new efficient optimization of joint Feed-Forward Equalization (FFE) and Decision Feedback Equalization (DFE) for binary as well as multilevel signals. Unlike to above-mentioned method, which is a linear optimization problem, direct maximization of the eye height applying joint FFE and DFE is a non-linear problem and cannot be solved analytically. Paper proposes the black-box function optimization using the regular as well as parallel Bayesian machine learning to find the best tap coefficients for joint FFE and DFE equalization. The efficiency of the parallel Bayesian algorithm is shown for binary NRZ (nonreturn-to-zero) and PAM4 (Pulse Amplitude Modulation) signals.

Best EMC Paper Finalist

W2_TU_PM_B1 MRI Computational Modeling (Sponsored by TC-9) 1:00 pm - 3:00 pm

Chair: Yansheng Wang, Google LLC, Mountain View, CA, USA

1:00 pm **Numerical Study on MRI RF-Induced Heating for the Trauma Screw Implanted in Three Human Models** 257
Meiqi Xia; Jianfeng Zheng; Ji Chen
University of Houston, Houston, TX, USA

Abstract: This study investigates the radio frequency (RF)-induced heating for a common medical implanted device, the trauma screw, in different human models under 1.5 T and 3 T magnetic resonance imaging (MRI) systems. Three different human models, Duke, Ella, and Fats from the virtual family project, are used in the simulations. The human models and the device are loaded in a generic 32 ports RF coil. The screws with suitable sizes are implanted in four regions (hip, knee, shoulder, and wrist) for each human model. From the simulation results, the RF-induced heating near the device shows significantly difference within the models. Consequently, the clinically relevant RF induced heating can be patient specific and needs to be investigated individually.

1:30 pm **Numerical Investigations of MRI RF-Induced Heating for Passive Implants in Birdcage and TEM Body Coils at 3 Tesla** 261
Rui Yang; Jianfeng Zheng; Shuo Song; Ran Guo; Ji Chen
University of Houston, Houston, TX, USA

Abstract: This paper compares the radiofrequency (RF) -induced heating for passive implants between the birdcage (BC) coil and the transverse electromagnetic (TEM) coil at 3 Tesla (T). Two common passive implants, orthopedic plate and spinal fixation device were considered. To assess the RF-induced heating in the two different coils, electromagnetic simulations were performed to calculate the local specific absorption rate (SAR) in the standard phantom. It is determined that the device length leading to the worst-case heating is around 10 cm in both BC coil and TEM coil. This worst-case length corresponds to the half wavelength of the RF field at 3 T. It is also shown that for both orthopedic plates and spinal fixations, the BC coil generates larger RF-induced heatings than those from the TEM coil. This result indicates that in the presence of passive implants, patients undergoing TEM coil can have a larger safety margin. It would be more conservative to use BC coil, rather than TEM coil, to evaluate the RF-induced heating of medical implants.

2:00 pm **Impacts of the Arm and Leg Postures on the RF-Induced Heating for the Human Body under MRI** 266

Xiaolin Yang; Jianfeng Zheng; Ji Chen
University of Houston, Houston, TX, USA

Abstract: This paper investigates the impacts of the arm and leg postures on radio frequency (RF)-induced heating for patients exposed to the electromagnetic field from the RF coil in a 1.5T magnetic resonance imaging (MRI) system. Various arm on body postures and arm touching body postures are studied. Leg bending postures and leg touching postures are considered in the leg posture studies. The peak local specific absorption rate (SAR), which is related to the RF-induced heating, is substantially affected by the arm and leg postures. For the natural arm posture, arm on body posture and the bending leg posture, the peak local SAR increases with the arm or leg moving closer to the coil. For the arm touching body posture and the leg touching posture, the peak local SAR values can be much higher than that from the natural posture. Therefore, guidance that patient posture isn't allowed to get close to the coil or form a closed loop, is proposed to guarantee patient safety.

2:30 pm **Prediction of MRI RF-Induced Heating for Passive Implantable Medical Devices using Convolutional Neural Network** 270

Qianlong Lan[1]; Jianfeng Zheng[1]; Mingchi Zhang[2]; Ji Chen[1]
[1]University of Houston, Houston, TX, USA; [2]Texas Southern University, Houston, TX, USA

Abstract: The purpose of this paper is to present a method to predict the radio frequency (RF) induced heating for passive implantable medical devices under magnetic resonance imaging (MRI) using a convolutional neural network (CNN). A total of 576 generic solid plate devices are constructed as study examples. Numerical simulations were conducted at both 1.5 T and 3 T using a full-wave electromagnetic solver based on the finite-difference time-domain (FDTD) method to simulate the RF-induced heating for the solid devices in the ASTM phantom. Then the solid plate devices are characterized by using three-dimensional (3D) point cloud data (PCD) representations and used as the input of CNN. The extracted RF-induced heating from the numerical simulation, in terms of peak 10 gram (g) averaged specific absorption rate (psSAR10g), is related to the 3D PCD by using a CNN. Seventy percent of the configurations and the corresponding psSAR10g from simulation results were randomly selected and used as the training set of the CNN, while the residuals were used as the test set. The results have shown the test error under 1.5 T system was very small with a mean absolute error which was less than 2.56 W/kg with a mean psSAR10g of 34.52 W/kg. The test error under 3 T system was smaller than that from the 1.5 T system with a mean absolute error which was less than 1.14 W/kg.

W2_TU_PM_B2 IEMI and Power Systems (Sponsored by TC-5) 3:15 pm - 5:15 pm

Chair: Michael K. McInerney, US Army Corps of Engineers (USACE), Champaign, IL, USA
Co-Chair: William A. Radasky, Metatech Corporation, Goleta, CA, USA

3:15 pm **Transfer Function Measurement for Automotive Intentional Electromagnetic Interference** 276

Woncheol Song[1]; Yang Zhong[1]; Cheolhan Kim[2]; Changyul Park[3]; Chulsoon Hwang[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Hyundai Motor Group, Hwaseong-si, Gyeonggi-do, Korea, Republic of (South); [3]Korea Testing Laboratory, Jinju-si, Gyeongsangnam-do, Korea, Republic of (South)

Abstract: The transfer function between the intentional electromagnetic interference (IEMI) attacker and the engine control unit (ECU) circuit in an automobile is extracted to analyze how the IEMI affects the vehicle. A log-periodic antenna is used as the IEMI aggressor based on the frequency domain measurement and the transfer function of the log-periodic antenna is compared with the transfer function of the standard mesoband source generator measured in the time domain. The electric field of the standard source is regenerated with the transfer function of the log-periodic antenna. It is then compared with the original field of the standard source to validate the transfer function of the log-periodic antenna. Since the D-dot sensor is used to measure radiated field in the time domain, a noise in low frequency region is amplified and it is investigated.

W2_TU_PM_C1 EMI/EMC Issues in Aircraft, Spacecraft and Space Launch Vehicles, Robotic and Crewed (Sponsored by TC-8) 1:00 pm - 3:00 pm

Chair: James Lukash, Lockheed-Martin Space Systems, Sunnyvale, CA, USA
Co-Chair: Pablo Narvaez, NASA Jet Propulsion Laboratory, Pasadena, CA, USA
Co-Chair: Manuel Soriano, NASA Jet Propulsion Laboratory, Pasadena, CA, USA

1:30 pm **Electromagnetic Compatibility Test and Analysis Campaign of NASA's Mars 2020 Rover** 298
Edward Gonzales; Nelson Huang
NASA Jet Propulsion Laboratory, Pasadena, CA, USA

Abstract: NASA's Mars 2020 Perseverance Rover—with a launch window opening July 2020, and landing expected February 2021—has mission objectives to look for evidence of habitability, seek biosignatures of past life, collect and cache samples for possible future return to Earth, and prepare for future human missions to Mars. The Rover platform is similar to the previous Mars Science Laboratory (MSL) "Curiosity" rover that landed in 2012 but contains a new suite of scientific instruments and upgrades to existing functionality: seven new and/or upgraded scientific payloads, an upgraded arm and sampling system, and a Helicopter demonstration.

These changes—along with new efficiency goals to operate more Rover subsystems concurrently and thus collect more science—presented new electromagnetic compatibility (EMC) challenges. In this paper, we will describe the campaign to ensure Mars 2020 mission success from an electromagnetic environment perspective: 1) confirming existing MSL heritage subsystems and EMC requirements were compatible with the new Mars 2020 mission objectives, 2) engaging with engineers and scientists early in the project to identify and evaluate risks before hardware assembly and performing ambitious risk reduction tests, 3) undertaking a comprehensive subsystem qualification test program based on tailored MIL-STD-461F requirements, occasionally leading to redesign, 4) synthesizing the data collected to perform detailed analyses toward the goal of making risk-informed decisions at a system level. The spacecraft successfully completed all three planned system level tests, demonstrating self-compatibility with minimal impact to operations from electromagnetic interference in all mission phases.

2:00 pm **Magnetic Shielding Concepts for Reaction Wheel Assembly on NASA Europa Clipper Spacecraft** 305
Katherine Dang; Pablo Narvaez; Joshua Berman; Kevin Pham; Ashley Curiel
NASA Jet Propulsion Laboratory, Pasadena, CA, USA

Abstract: Magnetic shielding concepts were investigated for the Reaction Wheel Assembly on the NASA Europa Clipper spacecraft. This investigation was performed in order to mitigate the magnetic incompatibility between the Reaction Wheel Assembly (RWA) and the two magnetically sensitive science instruments on the Europa Clipper spacecraft. Given the Reaction Wheel Assembly's mass and space design constraints, two magnetic shielding concepts were taken into consideration: (1) magnetic shielding of the internal magnet of the RWA Wheel Unit using Mu-metal material and (2) magnetic shielding of the entire RWA Wheel Unit using Metglas material.

Best EMC Paper Finalist

2:30 pm **Circuit Simulator based Analysis for Cable Induced Lightning Effects** 312
John G. Kraemer
Collins Aerospace, Cedar Rapids, IA, USA

Abstract: DO-160G and MIL-STD-461G contain requirements related to upset and damage immunity to cable induced lightning transients. The ability to quickly predict the risk of damage and/or upset early in the equipment and system development cycles is instrumental in guiding circuit and cable/connector assembly design to ensure economic and first time technical success during equipment qualification and system certification testing. This paper presents methods to predict damage and upset using circuit simulator based methods in situations ranging from simple to complex cable cross-section geometries that are common in defense/aerospace equipment qualification and certification test setups. Test data verifying the simulation process and capability is presented for situations where current waveforms are applicable. Additionally, practical aspects associated with lightning transient generators and how to account for them in simulation and analysis is presented as well.

W2_TU_PM_C2 SS1 – Lessons Learned in Aerospace EMC: Innovations, Findings, Technologies, Business (Sponsored by TC-8) 3:15 pm - 4:45 pm

Chair: Reinaldo Perez, NASA/Jet Propulsion Laboratory, Pasadena, CA, USA
Co-Chair: Jen Dimov, NASA Goddard Space Flight Center, Greenbelt, MD, USA
Co-Chair: Edward Gonzales, NASA Jet Propulsion Laboratory, Pasadena, CA, USA

3:15 pm **Fault Propagation, EMI Propagation, and Fault Containment in Aerospace Systems** 318
Reinaldo Perez
Jet Propulsion Laboratory, Pasadena, CA, USA

Abstract: The occurrence of faults in aerospace system hardware and software have consequences ranging from minor effects to catastrophic effects, and such faults can directly affect the safety of hardware and personnel. There are many origins to fault conditions, and the hardware that is capable of still meeting its performance requirements after experiencing itself a fault is said to be fault tolerant. A fault tolerant hardware is capable of detecting, isolating, and recovering from a fault condition; and this is a subfield of control engineering. An aerospace system that has been shown to have electromagnetic compatibility (EMC) in all its subsystems and systems cannot induced faults caused by electromagnetic interference (EMI). It can be proposed that the presence of EMI (or lack of EMC) is analogous to a potential fault initiator and the effects can likewise range from minor to severe. This paper starts by addressing the consequences of hardware failure in aerospace systems from a fault perspective, because the design of fault tolerant system is a major endeavor in aerospace. To arrive to this goal the paper starts with the concepts of fault, fault propagation, and a new concept called fault containment region. The paper then proceeds to provide two very recent examples in the aircraft industry of fault propagation with catastrophic effects. The paper proceeds to introduce the concept of EMI fault containment and a brief introduction to another new concept called the EMI containment region. The paper proceeds with an example of EMI fault containment region. The paper ends with a lesson learned conclusions.

3:45 pm **Cable Harness Design for Aerospace Platforms** 324
Robert "Bob" Scully
NASA Jet Propulsion Laboratory, Pasadena, CA, USA

Abstract: Cable harness design for aerospace platforms has been, and continues to be, one of the most challenging and difficult areas for platform Electromagnetic Compatibility (EMC) integration. Multiple competing platform needs and requirements, all of which are diverse and are often mutually exclusive, drive cable harness design in often wildly oscillatory directions. Decisions on how cable harnesses are to be constructed must be hammered flat very early in the design process, and this leaves little room for debate or research to demonstrate one design is superior to another. Mass, volume, system complexity, change in process, component availability, manufacturing lead time, manufacturability, parallel hardware certification timelines, published documents and drawings impacted by engineering change orders, and of course cost and schedule, all compete in this fast changing and highly critical area. This presentation will attempt to highlight these competing areas to foment awareness.

4:15 pm **Numerical Analysis Approach to Aid in Launch Vehicle Lightning Effects Protection Design** 328
Jennifer Kitaygorsky
Electro Magnetic Applications, Lakewood, CO, USA

Abstract: Lightning is a critical safety issue for all aerospace vehicles. Commercial aircraft are protected from the effects of lightning strikes per the FAA regulation. Some launch vehicles rely on lightning launch criteria rules to avoid lightning. That launch vehicles can and do get struck by lightning has been recently demonstrated by the Soyuz rocket during a satellite launch on May 27, 2019, through which the rocket persevered and went on to complete its mission successfully (it is unclear what kind of lightning protection design was implemented).

WEDNESDAY TECHNICAL PAPERS – II

Wednesday, August 12, 2020

W2_WE_PM_A1 Passive Component Modeling and Measurement Techniques II (Sponsored by TC-10) 1:00 pm - 3:00 pm

Chair: Shaowu Huang, Marvell Semiconductor Inc., Santa Clara, CA, USA

1:00 pm **A Cross-Sectional Profile based Model for Stripline Conductor Surface Roughness** 334

Shaohui Yong[1]; Victor Khilkevich[1]; Yuanzhuo Liu[1]; Ruijie He[1]; Yuandong Guo[1]; Han Gao[2]; Scott Hinaga[2]; Darja Padilla[2]; Douglas Yanagawa[2]; Jun Fan[2]; James Drewniak
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Cisco Systems, Inc, San Jose, CA, USA

Abstract: As the data rate of high-speed digital systems is getting higher, the conductor loss can no more be modeled assuming perfectly smooth conductor surfaces for even the smoothest foils available. The Huray model, based on the analytical calculation of the additional loss due to the scattering/absorption from conductive spheres on a smooth plane, has been presented to account for this issue. However, in practice it is very difficult to determine the parameters of the model. A modeling approach relating the parameters of the model to the conductor roughness profiles is needed. In this paper an investigation of the scattering by metal hemispheres, including their interaction, is performed. A method is brought up to estimate the multi-level physical model's parameters using the scanning electron microscope (SEM) or optical cross-sectional profile imaging. Accurate modeling of the frequency-dependent conductor loss is achieved.

1:30 pm **Resistance Modeling for Striplines with Different Surface Roughness on the Planes** 340

Shaohui Yong[1]; Victor Khilkevich[1]; Yuanzhuo Liu[1]; Jiayi He[1]; Han Gao[2]; Scott Hinaga[2]; Darja Padilla[2]; Douglas Yanagawa[2]; Jun Fan[1]; James Drewniak[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Cisco Systems, Inc., San Jose, CA, USA

Abstract: To model additional conductor loss due to foil surface roughness various empirical or physical models have been brought up to provide surface roughness correction factors for the per-unit-length (PUL) resistance assuming certain roughness of foil conductors. However for strip lines on typical printed circuit board, different sides of the traces and references planes may have different surface roughness levels due to the fabrication process. Traditionally engineers may calculate surface roughness correction factors using averaged roughness level of the upper and lower sides of the trace. However this empirical estimation may lead to inaccurate modeling results especially when the strip line is not vertically symmetrical or the differences among the roughness levels of planes are significant. In this project, a methodology is presented to calculate the resistance of a strip line with different surface roughness levels on upper and lower sides of the trace and reference planes. After separating the resistances contributed by different smooth planes, each plane's resistance is corrected independently using corresponding surface roughness correction factor. The strip line's resistance is obtained by combining the corrected resistances of different planes.

Best EMC Paper Finalist

2:00 pm **Dielectric Material and Foil Surface Roughness Properties Extraction based on Single-Ended Measurements and Phase Constant (β) Fitting** 346

Shaohui Yong[1]; Victor Khilkevich[1]; Srinath Penugonda[1]; Xiao-Ding Cai[2]; Qian Gao[2]; Bidyut Sen[2]; Han Gao[2]; Douglas Yanagawa[2]; Darja Padilla[2]; Scott Hinaga[2]; James Drewniak[1]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Cisco Systems, Inc., San Jose, CA, USA

Abstract: Dielectric substrate and foil surface roughness properties of fabricated printed circuit boards (PCB) are important for high-speed channel design. Several strip line-based extraction methods have been developed to characterize dielectric relative permittivity ($\boldsymbol{\varepsilon r}$), dielectric dissipation factor ($\mathbf{tan}\boldsymbol{\delta}$), and foil surface roughness correction factor ($\boldsymbol{KR}$) using measured S-parameters. However, the $\mathbf{tan}\boldsymbol{\delta}$ extraction still needs further improvement due to the difficulty in separation of dielectric and conductor loss. The authors found that the frequency-dependence of the strip line phase constant ($\boldsymbol{\beta}$) is helpful to determine the $\mathbf{tan}\boldsymbol{\delta}$ without introducing high sensitivity to foil surface roughness. By introducing a causal dielectric frequency-dependent model, $\boldsymbol{\varepsilon r}$ and $\mathbf{tan}\boldsymbol{\delta}$ are extracted by fitting measured $\boldsymbol{\beta}$. The foil surface roughness property (correction factor $\boldsymbol{KR}$) is obtained using the conductor loss calculated by subtracting extracted dielectric loss from the total loss. To demonstrate the feasibility of the proposed method examples are provided using simulation data and fabricated PCB.

Best EMC Paper Finalist

2:30 pm **The Effect of the Parallel-Plate Mode on Striplines in Inhomogeneous Dielectric Media** 352
Jiayi He; Shaohui Yong; Zurab Kiguradze; Arun Chada; Bhyrav Mutnury; James Drewniak
Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Strip lines are widely used in high speed printed circuit boards (PCB). When the strip line is in inhomogeneous dielectric media, its principle operation mode is quasi-TEM. In this case, the parallel-plate mode between two ground planes can be excited as a parasitic mode. This paper investigates the effect of this parasitic mode on strip lines through simulations. The simulated S-parameters of strip lines when this parallel-plate mode is excited and suppressed are compared. The measured S-parameters of strip lines with and without the ground stitching vias are also compared. The impact of the parasitic mode on time domain crosstalk and eye diagram is also shown.

W2_WE_PM_A2 Multi-Physics (Sponsored by TC-9 and TC10) 3:15 pm - 4:45 pm

Chair: Hanfeng Wang, Google LLC, Mountain View, CA, USA

3:15 pm **Decoupling Capacitor Layout Design Guidelines for Acoustic Noise Consideration in Power Distribution Network** 357
Yin Sun[1]; Songping Wu[2]; Jianmin Zhang[2]; Chulsoon Hwang[1]; Zhiping Yang[2]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Google LLC, Mountain View, CA, USA

Abstract: Acoustic noise induced by multilayer ceramic capacitors (MLCCs) in power distribution network (PDN) is a critical issue regarding product user experience. In this work, design guidelines for decoupling capacitor selection, layout geometries are proposed targeting the acoustic noise, through analysis of the acoustic noise generation mechanism in printed circuit board (PCB). A test board is designed to validate the proposed design guidelines. With sound pressure level measurement of the test vehicle, the effectiveness of the proposed design guidelines is confirmed. In general, the decoupling capacitor layout design guidelines for acoustic noise consideration are consistent with the requirements for PDN to achieve high electrical performance.

3:45 pm **Measurement Investigation of MLCC Mounting Variation Impact on Acoustic Noise in Power Distribution Network** 363
Yin Sun[1]; Songping Wu[2]; Jianmin Zhang[2]; Chulsoon Hwang[1]; Zhiping Yang[2]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Google LLC, Mountain View, CA, USA

Abstract: The multilayer ceramic capacitors (MLCCs) mounting method impact on the MLCC induced acoustic noise in printed circuit board (PCB) is investigated through measurement. The influence of MLCC soldering stencil height, MLCC orientation and MLCC pair offset distance are evaluated on a series of test boards. The sound pressure level (SPL) is measured to evaluate the PCB acoustic noise performance. In the investigated mounting variation range, the acoustic noise performance does not exhibit noticeable changes.

4:15 pm **Multi-Physics Analysis of Polystyrene based RF Absorbers** 369
Anoop Adhyapak; Zhong Chen
ETS-Lindgren Inc., Cedar Park, TX, USA

Abstract: RF absorbers dissipate the incident electromagnetic fields into heat to the environment. Depending on the substrate of the absorber, different processes govern the heat transfer methodology like conduction, convection or radiation. In EMC applications, the absorbers can be subject to multiple applications with high incident fields. Hence, it is vital to investigate the thermal aspect of the absorbers experimentally or with multi-physics numerical tools. In this paper, polystyrene-based absorbers are inspected experimentally initially. The same test setup is modeled in Ansys HFSS and Ansys Icepak to simulate the EM and thermal behavior of the absorber. The simulation model is validated by comparing the simulation results to the experimental results. Based on the validation, further simulations are conducted to explore the temperature variations due to change in the measurement distances from the source to the absorber and the temperature variations over different frequencies. These simulations provide better insights into the temperature distribution inside the absorbers.

W2_WE_PM_B Circuit and System EMC Analysis (Sponsored by TC-4) 1:00 pm - 4:15 pm

Chair: Ken Hillen, Retired, Aloha, OR, USA

1:00 pm **Analysis of the Sampling Rate of Image Reconstruction using Electromagnetic Waves Leaked From a Monitor** 375

Dong-Hoon Choi; Ho Seong Lee; Jong-Gwan Yook
Yonsei University, Seoul, Korea, Republic of (South)

Abstract: Leakage electromagnetic waves usually leak from liquid crystal display(LCD) monitors, which are representative output devices of modern computers. In this paper, the image information of electromagnetic waves leaked from a FHD resolution monitor was analyzed using low sampling rate and frame averaging techniques.

1:30 pm **Analysis of the Distributed Bifilar Isolation Transformer and Current Balun** 376

James McLean
TDK R&D Corp., Cedar Park, TX, USA

Abstract: Bifilar windings have been employed in isolation transformers in order to minimize the leakage inductance and hence improve frequency and time response. A numerical analysis of the bifilar isolation transformer viewed as a 3-port balun based on odd/even mode transmission line analysis is given. The numerical predictions for the 3-port admittance parameters show that the device functions as a true current balun in the low frequency limit, but that the performance degrades as the electrical length of the bifilar winding approaches one quarter wavelength for the odd mode. The model also shows that for an isolated, 2-terminal, load a complete null in the response occurs when the electrical length of the bifilar windings is one-half wavelength for the odd mode. A prototype bifilar isolation transformer was fabricated and characterized. The measured data is in agreement with the numerical predictions thus supporting the statements concerning performance. It is further shown that a previously proposed, 2-stage current balun consisting of a bifilar isolation transformer followed by a bifilar, common-mode choke provides superior current balance over a broad bandwidth, but is still limited to operation below the oddmode half-wave frequency of the bifilar winding of the isolation stage.

2:00 pm **Wireless Communication Desense Due to Electromagnetic Shields** 382

Essam Elkhouly; Mehrbod Mohajer
Amazon Lab126, Sunnyvale, CA, USA

Abstract: EM shields are commonly used to prevent unwanted radiations and isolate the electronic devices from outside environment. In this paper, we show EM shields may cause the degradation of wireless communication performance if not carefully deigned. In the presented wireless system, the resonance frequency of EM shield is within the range of Wi-Fi communication band. The thermal pad inside the EM shield has high dielectric constant that reduces the resonance frequency from above the operating frequency band to inside the band. Also, the certain harmonic of digital clock happens to be at the resonance frequency of the EM shield. Therefore, the harmonic spur couples to Wi-Fi chains of communications through resonance of EM shield and degrades the sensitivity of Wi-Fi receivers. We will discuss the mechanism of EM coupling and how to alleviate the system performance degradation through a few mitigation techniques. The dielectric constant of the thermal pads inside the EM shield should be chosen carefully to prevent the coupling through EM shield or external radiation.

3:15 pm **Influence of Scd21 Characteristics of Common-Mode Filter on Radiated Emission from UTP Cable** 386

Koichi Kikuchi[1]; Tohlu Matsushima[2]; Kenta Ishibashi[2]; Nobuo Kuwabara[2]; Yuki Fukumoto[2]
[1]TDK Corporation, Chiba, Japan; [2]Kyushu Institute of Technology, Kitakyushu, Japan

Abstract: The common-mode filter (CMF) is a key device for suppressing emissions radiated from telecommunication cables. Recent serial interfaces deliver the necessity of considering that common-mode (CM) disturbances are converted from the differential mode (DM) telecommunication signals by a CMF. To examine this phenomenon, this study investigated the Scd21 characteristic, which is one of the mixed-mode S-parameters. Two types of CMFs whose Scd21 were different were examined. A signal was supplied to an unshielded twisted pair (UTP) cable through the CMF. The emission from the cable was measured using a setup complying with CISPR 25. Then, the relationship between the ratio of CM to DM signals and the emission level was investigated. The results showed that the emission level decreased as a result of employing the lower Scd21 CMF and that the emission level was linearly proportional to the ratio of the CM to DM signals. The results indicate that Scd21 is an essential parameter with which to evaluate CMFs used in telecommunication ports of serial interfaces.

3:45 pm **Increasing the EMI-Resilience of Triplication-Based Error Correction Codes for PAM-4 Line Coding in Harsh Electromagnetic Environments** 392

Jonas Van Waes; Jens Vankeirsbilck; Jonas Lannoo; Dries Vanoost; Davy Pissoort; Jeroen Boydens
Katholieke Universiteit Leuven, Bruges, Belgium

Abstract: When transmitting data within a harsh electromagnetic environment, Error Correction Codes have been used for many years. However, not all systems are able to overcome the incurred overhead by those Error Correction Codes. As a solution to the overhead, engineers opted for a Pulse Amplitude Modulation (PAM) technique to encode two bits into a single symbol. This line-coding technique, called PAM-4, reduces the overhead that is imposed by the Error Correction Codes. A trade-off for the reduced overhead is a reduced noise margin between each individual symbol. It is the goal of this paper to assess if different techniques and measures can be applied towards both the Error Correction Codes and the line coding to provide resilience against harsh electromagnetic conditions. This paper focuses on the occurrence of False Negatives: corrupted data deemed valid. By using a combination of techniques, it is possible to significantly reduce the amount of False Negatives within the Error Correction Codes.

Best EMC Paper Finalist

W2_WE_PM_C Near Field and Radiated EMI in Power Electronics Systems (Sponsored by SC-5) 1:00 pm - 4:15 pm

Chair: Shuo Wang, University of Florida, Gainesville, FL, USA
Co-Chair: Hong Li, Beijing Jiaotong University, Beijing, China

2:00 pm **Investigation of Power Converter's Near Field EMI Containment using Passive Filters** 398

Asif Imran Emon; Balaji Narayanasamy; Hongwu Peng; Mustafeez ul-Hassan; Zhao Yuan; Fang Luo
University of Arkansas, Fayetteville, AR, USA

Abstract: With the advent of the wide-bandgap devices, it has become possible to switch at a faster rate (on and off) along with higher switching frequencies. This results in attaining higher power density, smaller filter size, and lighter weight for the power converter. But the bottleneck of taking advantage of these ultra-fast devices is spurious behavior during operation due to cross talk and electromagnetic interference inheriting from higher dv/dt and di/dt. To meet the standard and to ensure robust operation, EMI filter is in place for a time being; mostly to meet conducted emission requirements. To deal with radiation, shielding is a common practice. This work aims to understand how much the EMI filter helps with radiated EMI reduction. A converter with a traditional passive EMI filter is considered to evaluate the effect of the filter on the near magnetic field adjacent to the converter. The observed phenomenon has been analyzed and explained to understand to what extent the conducted EMI filter helps with mitigating radiated emission.

Best EMC Student Paper Finalist

2:30 pm **Near Field Coupling Measurement and Modeling between High Voltage and Low Voltage Cables in Electric Vehicles** 404

Le Yang[1]; Shuo Wang[1]; Yongjian Zhi[2]
[1]University of Florida , Gainesville, FL, USA; [2]CRRC Zhuzhou Institute Co., Ltd., Zhuzhou, China

Abstract: The near field electromagnetic interference coupling between the high voltage cables and low voltage cables in electric vehicles and hybrid electric vehicles will degrade the reliability of the vehicle's electronic system and may cause serious safety issues on the vehicles if a large disturbance appears on the transmission lines. In this paper, an alternative scattering parameter measurement technique is proposed for the complicated immunity measurement approach used in CISPR 25 standard. Both inductive and capacitive coupling models are developed based on the immunity test. The effect of electromagnetic interference filters on immunity test results is analyzed.

Abstract: In this paper, we proposed a deep neural network (DNN)-based estimation of EMI reduction by an intermediate (Int) coil in automotive wireless power transfer (WPT) system. The Int coil can reduce electromagnetic interference (EMI) level in the WPT system with the proper resonant frequency of the Int coil. The previous study has explained the resonant frequency of the Int coil should be higher than the operating frequency. According to the resonant frequency of the Int coil, we can achieve the amount of EMI reduction. Therefore, the design of the Int coil is essential for optimization of the EMI reduction of the automotive WPT system. However, it is impossible to get the optimized results of EMI reduction by simulations. The proposed DNN-based estimation method can predict the amount of reduced EMI level in real cases consisted of ferrites and shielding structures.

Abstract: Power modules with high-speed power devices such as IGBTs and SiC MOSFETs have become crucial components of medium to high power applications. However, their faster switching speed and compact design raise near magnetic field emission issues. The near magnetic field from the high-speed power modules could contaminate the peripheral circuits and filters. In this paper, the near magnetic field emission is analyzed for three power modules. The root cause and sources of the near magnetic emission are identified. Based on the analysis, the near magnetic field is predicted and verified with finite element analysis (FEA) simulation and measurement.

THURSDAY TECHNICAL PAPERS – II

Thursday, August 13, 2020

W2_TH_PM_A Numerical Modeling and Simulation Techniques (Sponsored by TC-10) 1:00 pm - 4:15 pm

Chair: Songping Wu, Google LLC, Mountain View, CA, USA
Co-Chair: Zhifei Xu, Missouri University of Science and Technology, Rolla, MO, USA

Abstract: A hardware-based artificial intelligence (AI) operation using memristor crossbar array is a promising AI computing architecture due to its energy-efficiency. It mimics the computational form of matrix-vector multiplication, which is the main AI operation and is implemented in an analog way. However, the reliability problem is serious because of the hardware-based operation. In this paper, we propose a hybrid circuit model of a hardware-based deep neural network (DNN) for a large-scale memristor crossbar array in terms of signal integrity (SI) problems. After DNN classification training for the optimized weight matrix in memristors, we demonstrated and analyzed the effect of SI on DNN accuracy using the proposed model. It is possible to analyze the effect of the SI problems due to interconnection at the crossbar on the reliability of computational accuracy through this hybrid circuit model. Simulated accuracy of DNN inference is degraded up to 36.4% in the worst case due to IR drop and ringing depending on the physical dimension of array interconnection and operating frequency in a memristor crossbar array.

Best SIPI Student Paper Finalist

1:30 pm **Limitations of First-Order Surface Impedance Boundary Condition and Its Effect on 2D Simulations for PCB Transmission Lines** 422

Yuandong Guo[1]; DongHyun Kim[1]; Jiayi He[1]; Shaohui Yong[1]; Yuanzhuo Liu[1]; Xiaoning Ye[2]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Intel Corporation, Portland, OR, USA

Abstract: Signal integrity (SI) issue is a critical concern as the data rate continues to increase and SI analysis is heavily dependent on simulations. Inaccurate simulation data may result in inadequate design decisions influencing high-speed digital design and optimization. The surface impedance boundary condition (SIBC) concept is generally utilized in commercial electromagnetic (EM) solvers, which is considered to be an efficient technique as the interior region of the conductor of interest does not need to be included in the numerical procedure. The first-order SIBC has been incorporated into many EM simulation tools widely used in industries. In this paper, the limitations of the first-order SIBC in 2D simulations for PCB transmission lines are analyzed and demonstrated for the first time. Different PCB transmission lines with various cross-sectional geometries are simulated in a commercial 2D EM solver with and without the implementation of the first-order SIBC to reveal the effect on the simulated transmission line behaviors. It is found that the accuracy of the simulations with the first-order SIBC decreases as the edge of the signal conductor in the cross-section becomes narrower. The possible solutions are proposed to overcome the issue.

2:00 pm **Genetic Algorithm PDN Optimization based on Minimum Number of Decoupling Capacitors Applied to Arbitrary Target Impedance** 428

Francesco de Paulis[1]; Riccardo Cecchetti[1]; Carlo Olivieri[1]; Markus Buecker[2]
[1]University of L'Aquila, Italy; [2]Zuken GmbH, Paderborn, Germany

Abstract: The current demand in Power Distribution Network (PDN) design is characterized by the accurate placement of decoupling capacitors and the minimization of their number aimed at cost saving. The paper proposes an optimization algorithm for accordingly placing decoupling capacitors one-by-one and iteratively evaluating the cost function of each PDN design solution. This allows the designer to identify the minimum number of decaps whenever the input impedance satisfies the target impedance requirements. The algorithm is based on the Genetic Algorithm accordingly adapted for the specific application of PDN design. It may involve the evaluation of the input impedance at multiple locations, representing either multiple ICs, as well as multiple power input areas/pins of the same IC. The validation of the developed optimization algorithm is carried out by applying it to a manufactured PCB and by employing typical (low inductance) decaps for PDN design. The optimization process led to a decap configuration that effectively takes into account the decap value, the parasitics inductance, and the decap location. An accurate experimental test further validates the optimized PDN.

Best EMC Paper Finalist

3:45 pm **A Collaborative Optimization for Floorplanning and Pin Assignment of 3D ICs based on GA-SA Algorithm** 434

Qin Hu; Mu-Shui Zhang
Sun Yat-Sen University, Guangzhou, China

Abstract: In this paper, a collaborative optimization for floorplaning and pin assignment of 3D ICs using genetic and simulated annealing(GA-SA) algorithm is presented. Layout problem is usually solved by using multi-objective function optimization developed from stochastic optimization algorithm. The weight value of multi-objective function has great impact on the final layout results. A hybrid algorithm combined Genetic and Simulated Annealing(GA-SA) algorithm is developed to find the weight values in the co-optimization. By this method, area, interconnection length, maximum temperature of 3D floor planning, and partial return-path inductance of signal pins and mutual inductance of power/ground pins of pin assignment are well considered in the optimization procedure.

W2_TH_PM_B EMP: Protection and Coupling (Sponsored by TC-5) 1:00 pm - 4:15 pm

Chair: William A. Radasky, Metatech Corporation, Goleta, CA, USA
Co-Chair: Michael K. McInerney, US Army Corps of Engineers (USACE), Champaign, IL, USA

1:00 pm **Design Approach for HPEM Mitigation for Electrical Substations** 439
Eric Easton[1]; Kevin Bryant[1]; William Radasky[1,2]
[1]CenterPoint Energy, Houston, TX, USA; [2]Metatech Corporation, Goleta, CA, USA

Abstract: A design effort to identify an effective, cost efficient solution for High-Power Electromagnetic (EM) mitigation for new and retrofit installations was recently completed. Following the review of potential electromagnetic environments, both natural and man-made, a design was completed to address EM event effects associated with Geomagnetic Disturbances (GMD), High-Altitude Electromagnetic Pulse (HEMP) and Intentional Electromagnetic Interference (IEMI). The preliminary design was shared during AMEREM 2018 and has now resulted in the fabrication of an initial unit. The mitigation design avoids compromising the reliability of existing power substation functions, results in minimal increases to maintenance costs, and avoids significant changes in normal operating procedures. Components of the system were evaluated both individually and collectively to avoid sub-optimization of the system.

1:30 pm **Testing of a Module for Electrical Substations to Demonstrate HEMP and IEMI Protection and GIC Detection** 442
Eric Easton[1]; Kevin Bryant[1]; William Radasky[2]
[1]CenterPoint Energy, Houston, TX, USA; [2]Metatech Corporation, Goleta, CA, USA

Abstract: A design of a module to be installed in an electric substation that is protected from the high power electromagnetic disturbances such as the early-time high altitude electromagnetic pulse (E1 HEMP) and intentional electromagnetic interference (IEMI) for EM weapons has been completed. In order to ensure that the design is acceptable, a series of tests were performed and are described in this paper along with the results of the testing.

Best EMC Paper Finalist

2:00 pm **Assessment of EMP Hardended Substation Protection and Control Module** 448
Eric Easton[1]; Randy Horton[2]; Kevin Bryant[1]; Josh Butterfield[3]
[1]CenterPoint Energy, Houston, TX, USA; [2]EPRI Washington, DC, USA; [3]EPRI, Knoxville, TN, USA

Abstract: The following paper describes modeling and testing that was performed to assess the performance of an EMP hardened substation protection and control system that can be used as a mitigation solution for new and retrofit applications. The system was assessed against both radiated and conducted E1 HEMP threats. Results from laboratory testing and 3D electromagnetic (EM) simulations show that the system provides adequate protection from E1 HEMP fields up to 50 kV/m

Best EMC Paper Finalist

2:30 pm **Proposal of Electromagnetic Pulse (EMP) Coupling Estimation Method to Power System including Load Condition and Surge Protection Device (SPD)** 454
Hyunwoong Kim[1]; Kibeom Kim[1]; Kyunghwan Song[1]; Yoon-Mi Park[2]; Seung-Kab Ryu[2]; Seungyoung Ahn
[1]KAIST, Daejeon, Korea, Republic of (South); [2]The Affiliated Institute of Electronics and Telecommunications Research Institute, Daejeon, Korea, Republic of (South)

Abstract: In recent years, the interest of the electromagnetic pulse (EMP) threat is increasing with the rapid development of the electronics industry. Especially, the power cable is one of the targets that can be exposed to EMP and affect to the appliance. However, the EMP-coupling method is previously insufficient and is partially analyzed between EMP sources and cable. Because the simulation method such as the finite-difference time-domain (FDTD) and an experiment often take a very long time to present the EMP-cable coupling. Therefore, in this paper, we propose the EMP-estimation coupling method to analyze from the overall perspective based on the hybrid electro-magnetic (EM) numerical method. In addition, the protection guideline for the appliance is evaluated as the cable length is changed.

3:15 pm **Effect of Line-Tower Coupling on E1 Pulse Excitation on an Electrical Transmission Line** 460
Luis San Martin; Larry Warne; Salvatore Campione; Matthew Halligan; Ross Guttromson
Sandia National Laboratories, Albuquerque, NM, USA

Abstract: In a transmission line, we evaluate the coupling between a line and a tower above ground when the excitation is an E1 high-altitude electromagnetic pulse (HEMP). Our model focuses on capturing correctly the effect of the coupling on the peak of the HEMP induced current that propagates along the line. This assessment is necessary to accurately estimate the effect of the excitation on the systems and components of the power grid. This analysis is a step towards a quantitative evaluation of HEMP excitation on the power grid.

3:45 pm **High-Frequency Metal-Oxide Varistor Modeling Response to Early-Time Electromagnetic Pulses** 466
Tyler Bowman; Matt Halligan; Rodrigo Llanes
Sandia National Laboratories, Albuquerque, NM, USA

Abstract: The electric power grid is one of the most critical infra-structures in the modern world, and the continued protection and resilience of this system from threats is of significant concern. One such set of threats is nanosecond-scale transient effects generated by high-altitude electromagnetic pulses, for which the effect on the power grid is still being studied. Lightning surge arresters serve as the current grid protection against fast transients but are designed and modeled for protection against lightning and switching transients. Surge arrester response to faster transients is not well known. This work defines a scalable metal-oxide surge arrester model with specific consideration to frequencies at-tributed to fast transient over voltages from electromagnetic pulses. Measurements using vector network analyzer sweeps at low and high bias as well as high-voltage I-V curve traces are pre-sented to define arrester behavior and to parameterize it from measurement data. The proposed model is compared to the stand-ard IEEE model for lightning arresters in this paper. Further-more, model parameters are defined by scalable terms to be easily implemented for transmission-level devices. The scalable model enables enhanced assessment of protection levels and grid susceptibility against fast transients.

W2_TH_PM_C Low Frequency EMC (Sponsored by TC-7) 1:00 pm - 4:15 pm

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

1:00 pm **An AC Controlled-Current Load for Controllable Waveform Parameters to Quantify Static Energy Meter Errors** 472
Johan Dijkstra[1]; Tom Hartman[1]; Niek Moonen[1]; Frank Leferink[1,2]
[1]University of Twente, Enschede, The Netherlands; [2]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: This paper proposes a method for quantifying static energy meter errors using current waveform parameters. This will be realized via a controlled-current load, for which the design is given. Several parameters like the rise time, current slope, crest factor and phase firing angle are considered to identify relations which cause static energy meter measurement errors. Some of these parameters are also used as a way to verify the functionality of the controlled-current load in a quantitative manner. This is realized by comparing these parameters for the original and reproduced current waveform, where a feedback capacitor is used to optimize the system tailored to which parameter is deemed most crucial.

Best EMC Student Paper Finalist

1:30 pm **An Induction Heating System Analysis Method based on Operating Conditions** 478
Hyungmin Kang[1]; Daehwan Lho[1]; Hyunwook Park[1]; Taewoong Kong[2]; Hyojin Choi[2]; Joungho Kim[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea, Republic of (South); [2]LG Electronics, Seoul, Korea, Republic of (South)

Abstract: In this paper, we propose an induction heating system analysis method under operating conditions. In the induction heating system, the current of the coil generates an eddy current on the load surface, and heat is generated by the eddy current. At this time, a high level of current is applied depending on the operating conditions of the induction heating system. When the equivalent resistance and inductance of the coil and load are measured and applied to the time domain simulation in the stop condition, the output voltage and current show different results from the measured results. Therefore, we propose a simulation method that calculates the equivalent resistance and inductance in the operating conditions of the induction heating system, and verify the proposed method by measurements. When the proposed method is applied to the simulation, the errors of the output voltage and output current are reduced up to 90% compared to the conventional method when the time domain simulation results are compared with the measurements.

Best EMC Student Paper Finalist

2:00 pm **Using Computational Techniques to Improve the Accuracy of Stationary Wavelet Transform Analysis** 482

Ileana-Diana Nicolae; Petre-Marian Nicolae
University of Craiova, Craiova, Romania

Abstract: The Stationary Wavelet Transform (SWT) represents a reliable tool to evaluate the instantaneous components of fundamental frequency. The tree topology, wavelet mother and deviations from stationarity influence the decomposition accuracy. Three wavelet mothers were firstly analyzed considering two types of synthetic waveforms: stationary and quasi-stationary (characterized by constant slopes). Firstly an analysis of errors with respect to harmonic parameters was made for stationary regimes. Afterward, per period time-dependent mean and extreme errors waveforms were built, considering fixed harmonic orders. It was proved that for wide ranges of harmonic orders, the time-dependent errors waveforms (TEW) are characterized by patterns which can be used as skeletons to build well approximated TEW yielded by the SWT decomposition of quasi-stationary waveforms with increasing/decreasing constant slopes. Tests on real signals allowed for comparisons of results yielded by different wavelet mothers.

2:30 pm **Theoretical and Practical Aspects of Harmonics from a Railway Traction System Supplying Line** 488

Petre-Marian Nicolae[1]; Marian-Ştefan Nicolae[1]; Radu-Florin Marinescu[1]; Nicolae Raluca-Cristina[1]; Ileana-Diana Nicolae[1]; Valentin Kese[2]; Alexandru Netoiu[2]
[1]University of Craiova, Craiova, Romania; [2]SC SOFTRONIC SA, Craiova, Romania

Abstract: The paper deals with the influence of railway systems over the supplying line. Firstly, the configuration of an electric railway traction system using power electronics in Electric Multiple Units is presented. Details are provided for the electric driving system components which can influence the harmonic distorting regime (single phase traction transformer, asynchronous traction motors, power inverters and converters, static power converters and contact line). Theoretic and practical considerations related to them are included. Dynamic effects of the voltage harmonics from the power supplying network are presented. Overvoltages caused both by the power supplying network instability and respectively by current harmonics are discussed. Experimental results concerned with the instability aspects due to electric resonance at a frequency of 800 Hz were analyzed and the condition to prevent them was deduced, along with the technical solution. Experiments made before and after the designed filter introduction proved its design and implementation correctness. Overall and perharmonic influence of the filter was revealed.

Best EMC Paper Finalist

3:45 pm **Predicting the Conducted Emission of a CRM PFC Below 1MHz by Transient Modeling** 494

Hongseok Kim[1]; Jiayi He[1]; Chunyu Wu[1]; Nicholas Erickson[1]; Sangho Cho[2]; Dohyung Kim[2]; Yeong Hur[2]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]LG Electronics Inc., Pyeongtaek, Korea, Republic of (South)

Abstract: Power Factor Corrections (PFC) are widely used in ac to dc power supplies. Modeling the PFC circuits and predicting the conducted emission (CE) are important in power supply designs. This paper introduces a transient model of a critical conduction mode (CRM) power factor correction. The control circuit of the PFC is built to achieve a CRM working condition with a constant on-time switching. The simulated time domain noise waveform is converted to the conducted EMI in frequency domain via short-time fast Fourier transform (STFFT). The simulated conducted EMI is compared to measured results below 1MHz.

TUESDAY TECHNICAL PAPERS – III

Tuesday, August 18, 2020

W3_TU_PM_A1 Power Integrity Analysis and Design II (Sponsored by TC-10) 1:00 pm - 3:00 pm

Chair: Bo Pu, Missouri University of Science and Technology, Rolla, MO, USA

2:30 pm **Prevention of Voltage Instabilities due to Peak Current Consumption by Active Compensator** 498

YongSeung Yi[1]; SoYoung Kim[2]
[1]Samsung Electronics Co., Ltd., Suwon, Korea, Republic of (South); [2]Sungkyunkwan University, Suwon, Korea, Republic of (South)

Abstract: Due to the increase in current consumption caused by higher integration of high performance and diverse functioning chips in mobile phones, it has become more important to design a stable global power distribution network. When the operation of high-power functions overlap and there is excess peak current consumption, a sudden voltage dip occurs from the battery to the power management unit. In this paper, we propose an active compensator method to prevent voltage dip below the under-voltage lockout (UVLO) threshold voltage in the mobile phone power distribution network. To design the active compensator circuit, a simulation model for the power delivery network is developed based on the load current profile, power delivery network PCB layout, and Lithium-Ion battery model.

W3_TU_PM_A2 SIPI/EMC Co-Simulation and Co-Design (Sponsored by TC-10) 3:15 pm - 5:15 pm

Chair: Hanfeng Wang, Google LLC, Mountain View, CA, USA

3:15 pm **Noise Coupling Mechanism Analysis and Mitigation Method for Receiver Sensitivity Improvement in an Optical QSFP Transceiver Module** 502

Yuandong Guo[1]; Shuai Jin[1]; Xinglin Sun[2]; Jun Fan[1]
[1]Missouri University of Science and Technology, Rolla, MO, USA; [2]Zhejiang University, Hangzhou, China

Abstract: The increasingly growth of the traffic in data centers demands for high-speed data transition and high bandwidth density. Optical communication is a promising way for the propagation of high-speed signals with less distortions. The quad small form-factor pluggable (QSFP) transceiver module is an essential component converting an electrical signal into an optical signal for point-to-point data transition. Considerable attentions have been paid to the signal integrity (SI) optimization for the optical QSFP transceiver modules with different data rates, where the receiver sensitivity is generally considered to be critical. In this paper, the receiver sensitivity problem of a typical QSFP transceiver module with 10 Gbit/s data rate is studied. It is the first time to demonstrate that the receiver sensitivity improvement is not only related with the SI design, but also connected with the electromagnetic interference (EMI) mitigation inside the DUT. The convential simulation model used for SI analysis with important metal configurations excluded is limited in the ability to identify the coupling between the radiating structures. It is found that the EMI noise induced by the unbalanced PCB routing and the interconnect between the PCB and flexible printed circuit (FPC) has significant contribution to the total noise at the receiver end. The generation of the antenna-mode current is verified and further studied using the full wave simulations. The mitigation method is proposed and confirmed through the measurements to improve the receiver sensitivity.

Best SIPI Student Paper Finalist

4:15 pm **SMPS Electromagnetic Noise in System-on-Chip: Noise Propagation** 507

Eric Feltrin[1]; David Chesneau[1]; Arnaud Brèard[2]; Bruno Allard[2]; Christian Vollaire[2]
[1]STMicroelectronics, Grenoble, France; [2]University of Lyon, Lyon, France

Abstract: There is a trend for embedding of a power management unit along with digital system-on-chip. Few off-chip passive components are necessary. The embedded power management unit is meant to deliver dynamical adequate voltage levels to improve the performances of the mix-mode system. The conversion architecture is optimized in efficiency against high and low power mode but preventing impacts on the analog performance of sensitive blocks in the mix-mode system. The active part of an inductive buck converter is integrated but some switching noise is observed that severely impact analog blocks. The objective of this work is the analysis of the noise propagation of the SMPS noise in the SoC part. The whole system, i.e. the electronic board holding the package and the SoC-chip, is modeled to extract the system-level propagation paths between the buck converter and sensitive blocks. The analysis of the model permits to discriminate the different propagation paths inside the chip through the silicon substrate or outside by PCB interconnection and ground plane. The model is verified by measurement on a test vehicle.

4:45 pm **Intra-Pair Length Matching by Asymmetric Dual Bend to Reduce Mode Conversion** 511

Jianquan Lou[1]; Juhi Garg[2]; Alpesh Bhobe[3]; Joel Goergen[3]; Yang Tang[1]
[1]Cisco System (China) R&D Co. Ltd., Shanghai, China; [2]Cisco Systems India Pvt Ltd, Bangalore, India; [3]Cisco Systems, Inc., San Jose, CA, USA

Abstract: Asymmetric dual bend (ADB) technique for intrapair length matching of differential routing is proposed in this paper, to reduce the differential mode to common mode conversion in system. This layout technique helps in achieving lower EMI without impacting SI performance and with insignificant effect on PCB cost. Three types of asymmetric dual bend designs are evaluated in this paper, by simulating the EMI and SI performance in two layout scenarios i.e. fixed length and fixed location routing. The results illustrate that the asymmetric dual bend scheme can provide 10+ dB improvement for Scd21 in strip line layout and nearly 5dB improvement for microstrip layout. Several PCB coupons were also made, and the results match quite well between simulation and measurement.

W3_TU_PM_B SS2 – Measurement Methods for Electromagnetic Information Security (Sponsored by TC-5) 1:00 pm - 4:15 pm

Chair: Yuichi Hayashi, Nara Institute of Science and Technology Ikoma, Japan
Co-Chair: William A. Radasky, Metatech Corporation, Goleta, CA, USA

1:30 pm **Eavesdropping a (Ultra-) High-Definition Video Display from an 80 Meter Distance Under Realistic Circumstances** 517

Pieterjan De Meulemeester[1,2]; Bart Scheers[1]; Guy A.E. Vandenbosch[2]
[1]Royal Military Academy, Brussels, Belgium; [2]Katholieke Universiteit Leuven, Bruges, Belgium

Abstract: In this paper a method is presented which successfully reconstructs the video image of a video display unit (VDU) by exploiting its leakage emissions at a distance of 80 meters. The video image reconstruction is realized without any prior knowledge of the leaking VDU and by using commercial off-the shelf material. The tested VDUs comprise of an UHD (ultra-high definition) video display and a full HD (high-definition) video display, both employing an HDMI (high-definition multimedia interface) cable as a video data signaling interface linked to a notebook. The tested setups are located in an urban environment with sporadic radio emissions and occupied frequency bands. Subsequently, the methods and results are thoroughly discussed which give new insights into this video eavesdropping risk for improving video data security.

2:00 pm **Design and Evaluation of a Spark Gap based EM-Fault Injection Setup** 523

Arthur Beckers[2]; Masahiro Kinugawa[1]; Yuichi Hayashi[1]; Josep Balasch[2]; Ingrid Verbauwhede[2]
[1]Nara Institute of Science and Technology, Ikoma, Japan; [2]imec-COSIC, Katholieke Universiteit Leuven, Leuven-Heverlee, Belgium

Abstract: The rapid and widespread deployment of electronic devices operating in the field is bringing security issues into the spotlight. Fault injection, for instance, is a class of attacks that allows adversaries to bypass security-related capabilities by tampering with the normal functioning of a device. In this paper we describe a setup capable of faulting integrated circuits by exposing them to a pulsed magnetic field. The magnetic field is generated by discharging a pulse forming network made from a transmission line over an injection probe. The discharge is triggered by a spark gap based switch. We describe the mechanisms behind the different circuit components and evaluate the performance of the setup in practice. To the best of our knowledge, this is the first time a spark gap switch is used to build an electromagnetic (EM) pulse fault injection setup.

2:30 pm **Possibility of Injecting Malicious Instructions from Legitimate Communication Channels by IEMI** 527

Masahiro Kinugawa[1]; Yuichi Hayashi[2]
[1]The University of Fukuchiyama, Fukuchiyama, Kyoto, Japan; [2]Nara Institute of Science and Technology, NAIST, Ikoma, Nara, Japan

Abstract: This study investigates the vulnerability of malicious instruction injection caused by low-power IEMI on internet of- things (IoT) devices. The communication antennas of the devices with wireless functions have possibilities to generate the potential vulnerability that the IEMI effectively propagates into the devices. Based on experiments, we verified the possibility of injecting malicious instructions from the communication channels by the IEMI.

3:15 pm **A Study on Evaluation Board Requirements for Assessing Vulnerability of Cryptographic Modules to Side-Channel Attacks** 528

Kengo Iokibe; Tomonobu Kan; Yoshitaka Toyota
Okayama University, Okayama, Japan

Abstract: We studied for specifying requirements for side channel attack (SCA) vulnerability evaluation boards. SCAs are a potential threat to cryptographic modules mounted in electronics products. Cryptographic modules are required to be evaluated in terms of vulnerability by using a test board. However, no reasonable requirements for such test boards have been specified. In this paper, we investigated the signal-to-noise ratio (SNR) of side-channel leakage and the transfer impedance from the side-channel leakage source to an observation port where side-channel leakage is probed in an evaluation board. We examined two models of existing SCA vulnerability evaluation boards that implemented the Advanced Encryption Standard (AES). Results suggest that cryptographic modules need to provide SNRs of side-channel leakage greater than 2 dB for implementations of the cryptographic algorithm involving no SCA countermeasures. It is also inferred that the transfer impedance needs to satisfy two conflicting requirements. The transfer impedance should be as large as possible, considering the ease of evaluation. At the same time, the transfer impedance needs to be low enough to suppress fluctuations in the power supply voltage and guarantee evaluation in a state equivalent to the actual operating state of the IC. Coaxial connectors would be recommended to be implemented for increasing the SNR and for reproducibility of measurements.

3:45 pm **Efficient Electromagnetic Analysis based on Side-Channel Measurement Focusing on Physical Structures** 532

Shinpei Wada[1]; Youngwoo Kim[1]; Daisuke Fujimoto[1]; Naofumi Homma[2]; Yuichi Hayashi[1]
[1]Nara Institute of Science and Technology, Ikoma, Japan; [2]Tohoku University, Sendai, Japan

Abstract: In this paper, we study on improving efficiency of the electromagnetic analysis (EMA) based on side-channel measurement for revealing a secret key inside the cryptographic module. In this study, we focus on the specific physical structures of the printed circuit board (PCB) near the cryptographic module and conducted the EMA where the distribution of electric or magnetic field containing the secret key information is dominant. Based on the experimental results, we validated that the whole secret key information can be efficiently extracted by conducting the EMA using a single electric or magnetic probe on the location where a specific field is dominant due to the physical structure. By analyzing the physical structure of the PCB including the cryptographic module and considering the dominant field, the secret key information from the cryptographic module can be efficiently extracted.

W3_TU_PM_C EMC Standards Topics (Sponsored by TC-2) 1:00 pm - 4:45 pm

Chair: Monrad Monsen, Oracle, Broomfield, CO, USA

1:00 pm **Technique for Locating RF Leaks in the Flooring of Electromagnetic Shielding Enclosures** 537

Marc Gaidosh
Hitachi Healthcare Americas, Twinsburg, OH, USA

Abstract: A challenge encountered in the troubleshooting of RF leaks in electromagnetic shielded enclosures comes when the RF breach is located in the floor. A particular application where this is troublesome has been shielded enclosures used in the medical industry for Magnetic Resonance Imaging (MRI) scanners. The gantry, or high field strength magnet, typically weighs over 4,000kg, with some gantry types weighing over 14,000kg. The rigging in and placing of this gantry over the RF shielded floor during installation can create RF leaks if caution is not used, or if construction techniques for the flooring are marginal. In addition, environmental factors such as moisture in the flooring after installation can create shielding problems leading to RF leaks.

Abstract: Different test sites are used for radiated emissions testing from 9 kHz to 40 GHz. The CISPR 16 and ANSI C63 standards mention the different site validation techniques for the test sites from 30 MHz to 18 GHz. They are based on the Normalized Site Attenuation test from 30 MHz to 1 GHz and Site VSWR test from 1 to 18 GHz. Due to the limitations of the conventional sVSWR test mentioned in the standards, an alternate method using Time Domain gating is proposed from 1 to 18 GHz. The Time Domain sVSWR method is a more robust and statistically consistent method and equivalent to the conventional sVSWR test. Although the different site validation techniques are laid out, there are no site validation methods mentioned from 18 to 40 GHz. This paper explores the site validation from 18 to 40 GHz using the Time domain sVSWR test and summarizes the test results in a 3m EMC chamber. It analyzes the various contribution factors for the measurement uncertainty budget and recommendations to reduce the sVSWR uncertainty factor. It also investigates the effect of gap in the absorber layout to the chamber validation results and the rationale for chamber validation from 18 to 40 GHz. In addition, an improved version of the CISPR 16 sVSWR test is presented and the results are compared to the time domain sVSWR method.

Abstract: Since 2010 CISPR product committees have become increasingly concerned about advances in technology, for example plasma televisions using some ISM (Industrial Scientific and Medical) frequency bands, that might impact the radio frequency spectrum control below 30 MHz. As a result, CISPR Subcommittee A (CISPR/A) has since been working on developing methods of radiated measurements to address this concern. This work is culminating in amendments to the basic standard CISPR 16 that are still in preparation and are currently forecast for publication through 2020 to 2021. CISPR product committees are currently tracking this work with the intention of referencing it as they adapt their own standards to this frequency range. This paper is designed to draw the attention of all users of EMC Anechoic Chambers to these important changes.

Abstract: Wind turbines have a strong impact on the radio environment and need to be tested for electromagnetic emissions. With their size, in-situ measurements at the location of operation apply. The test engineer has to deal with a challenging environment including ambient electromagnetic emissions. The draft of IEC 61400-40 [2] standard is currently under development and deals with in-situ wind turbine measurements. The standard assumes knowledge on the present ambient emissions. This paper presents methods on how to examine those using advanced analysis methods of a real-time spectrum analyzer.

Abstract: In this article, we investigated the influence on radiated emission characteristics in the condition that an mains cable of equipment under test (EUT) leaving from test area was terminated by balanced and unbalanced type common mode impedance stabilization devices. To investigate the influence by the same termination condition of mains cable, we performed the simulation analysis on radiated emission characteristics of the product with 3 wires (3W) mains cable which has a protective earth (PE) line and a product with 2 wires (2W) mains cable which has no PE line. With regard to this analysis, we conducted also the actual measurements with two types of mains cable by using a comb generator. From these results, we were able to estimate that the radiated emission from the products having 3W mains cable were became from 3 to 5 dB lower at a VHF band than the product having 2W mains cable. Furthermore, we investigated the influence on radiated emission characteristics by two terminating conditions when EUT setups including cable arrangement were changed. As a result, there was no difference compared with the maximum standard deviation of without device. This means it is insufficient only by establishing the termination condition of mains cable.

3:45 pm **Will 4% Steps Find Radiated Susceptibilities?** 563
David Arnett[1]; Ed Blankenship[2]
[1]Garmin International Olathe, Kansas, USA; [2]IEEE EMC Member, Vancouver, Washington, USA

Abstract: CISPR Publications 24 and 35 allow radiated and conducted immunity tests to be performed using 1% or 4% steps. This paper looks at measured radiated immunity test data to determine the typical shapes of radiated susceptibilities for multimedia equipment. The authors consider what those shapes tell us about the validity of the 4% step method.

Best EMC Paper Finalist

4:15 pm **The Magnetic Field Conversion Factor for the Van Veen Loop** 569
James McLean
TDK R&D Corp., Cedar Park, TX, USA

Abstract: The Loop Antenna System (LAS) provides accurate measurements of the magnetic dipole moment of a compact source of magnetic field interference. Using the appropriate conversion factor, the output of LAS can be used to predict the magnetic field at a specified distance and height in a particular environment, e.g. over conducting ground. The conversion factor given in the CISPR 16-1-4 standard allows the LAS to replace conventional 60-cm shielded loop measurements on an open area test site (OATS). Here, a detailed, transparent derivation of the conversion factor is presented with the intent being to facilitate rapid, accurate, analytical computation of numerical values for the conversion factor. It is shown that, despite retardation of the electromagnetic field, a rational function accurately represents the conversion factor for standard test distances and thus the well-known Bode techniques for plotting and interpreting such functions can be applied effectively. Finally, the ability of the loop to respond to sources within the loop preferentially over external plane wave excitation is discussed and this gain in signal-to-noise ratio (SNR) is derived in terms of the conversion factor.

WEDNESDAY TECHNICAL PAPERS – III

Wednesday, August 19, 2020

W3_WE_PM_A1 Printed Circuit Board Technology and SI Design (Sponsored by TC-10) 1:00 pm - 3:00 pm

Chair: Shuai Jin, Google LLC, Mountain View, CA, USA

1:00 pm **Study of Thickening Soldermask Coated Microstrip Lines on High-Speed PCBs for Crosstalk Reduction in DDR5** 575
Xiao-Bo Yu[1]; Qiang-Ming Cai[1]; Yinglei Ren[2]; Xiaoning Ye[3]; Jun Fan[4]
[1]Southwest University of Science and Technology, Mianyang, China; [2]Intel Corporation, Shanghai, China; [3]Intel Corporation, Hillsboro, OR, USA; [4]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Far-end crosstalk (FEXT) is one major factor impacting performance of DDR signals on printed circuit board (PCB) external layers (microstrip routing). Bigger spacing can help reduce FEXT. However, as there are lots of DDR signals, in most cases, there is little room to increase spacing. In this paper, we develop a simple and efficient DDR5 crosstalk reduction approach by using thickening soldermask coated microstrip lines (TSCMLs). The type of soldermask is regular low-loss material, which is mainly used for resistance welding transform. The simulated results show the achieved FEXT can maintain under -36.0 dB from dc to 16 GHz, and 23 dB reduction in FEXT is achieved at 3.2GHz in comparison with the initial microstrip lines. The measured results show that the peak FEXT voltage can be de-creased by 83% of that without thickening soldermask. The ex-perimental results are in agreement with the simulation and both validate the proposed design.

1:30 pm **Multiple Bus Design Methodology for Low Loss and Low Crosstalk with Mesh Ground in FPCB** 578

Hung Khac Le; Hoang Van Nguyen; YoungBong Han; SoYoung Kim
Sungkyunkwan University, Suwon, Korea, Republic of (South)

Abstract: In this paper, we propose a design methodology for multiple bus structures implemented on flexible printed circuit board (FPCB) with mesh ground structure. The proposed methodology suggested an optimum distance of the signal lines and relative location with respect to the grid to guarantee the 50 characteristic impedance without resonance in insertion loss and with minimum crosstalk. Also, the proposed design shows identical impedance of signal lines in time-domain-reflectometer (TDR) measurements and improves Far-End Crosstalk (FEXT) by 4.3 dB in and Near-End Crosstalk (NEXT) 6.1 dB with respect to conventional design (signal lines with 50 characteristic impedance at grid center) at 1.25 GHz for the design targeted to be used at C-PHY with 20-mm multiple bus structures in 2-layer FPCB using polyimide.

2:00 pm **A Study of Coverlay Coated Microstrip Lines for Crosstalk Reduction in DDR5** 581

Qiang-Ming Cai[1]; Yuyu Zhu[1]; Runren Zhang[2]; Yinglei Ren[3]; Xiaoning Ye[4]; Jun Fan[5]
[1]Southwest University of Science and Technology, Mianyang, China; [2]Duke University, Durham, NC, USA; [3]Intel Corporation, Shanghai, China; [4]Intel Corporation, Hillsboro, OR, USA; [5]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Crosstalk becomes a serious problem in microstrip design of printed circuit boards (PCBs) in DDR5. In high-density and high-speed PCBs, widening space or putting shielding between traces to mitigate crosstalk noise may become less effective, because of the limited space. This paper presents a simple and efficient crosstalk reduction approach by using coverlay coated microstrip lines. This coverlay is available in a variety of film and adhesive thicknesses, which is commonly used materials for the resistance welding transform in PCB production. Based on the simulated S-parameters, the FEXT keeps under -40 dB from dc to 16.0 GHz, and more than 24 dB reduction for FEXT at 3.2 GHz can be achieved by using the coverlay technology, in comparison with that of the initial microstrip lines. The measured results show that the peak FEXT voltage with coverlay can be decreased by 83% of that without coverlay. Moreover, when the experimental results are compared with the simulated results, good agreement can be observed, demonstrating the validity of the proposed design.

2:30 pm **Sensitivity Analysis of Local Soldermask and Coverlay in High Speed Transimission Lines for DDR5 Applications to Reduce FEXT** 586

Zhu Lin[1]; Xin Cao[1]; Qiang-Ming Cai[1]; Yinglei Ren[2]; Xiaoning Ye[3]; Jun Fan[4]
[1]Southwest University of Science and Technology, Mianyang, China; [2]Intel Corporation, Shanghai, China; [3]Intel Corporation, Hillsboro, OR, USA; [4]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: This article investigated the effects of local solder-mask and overlay structure changes on crosstalk. This structure is based on a four-layer high-speed PCB on a computer DDR5 board. Our goal is to use the obtained simulation results to locate the optimal response that not only meets the performance re-quirements but is also robust to geometric changes caused by manufacturing tolerances. These two methods have a good correlation with the simulation results and show strong capabilities in the practical applications.

W3_TH_PM_A2 Nanotechnology and Advanced Materials (Sponsored by TC-11) 3:15 pm - 4:15 pm

Chair: Alessandro Giuseppe D'aloia, Sapienza Universita di Roma, Roma, Italy

3:15 pm **Novel Carbon Additive for High Performance EMI Shielding Materials** 591

Limeng Chen
Cabot Corporation, Billerica, MA, USA

Abstract: A novel carbon additive, carbon nanostructure (CNS), is introduced as an effective additive for EMI shielding plastic and silicone compounds. Compounds containing CNS have higher EMI shielding efficiency than compounds containing other carbon-based additives. CNS can also enable better performance/processing balance of compounds compared to traditional metal-based EMI shielding additives.

W3_WE_PM_B1 Shielding, Gasketing and Filtering (Sponsored by TC-4) 1:00 pm - 2:30 pm

Chair: William Wantz, Spira EMI, San Fernando, CA, USA

1:00 pm **A Study of Small Aperture Diffraction** 592
Huadong Li
Molex, LLC, Lisle, IL, USA

Abstract: Bethe's interpretation of a small metallic aperture as an electric dipole and a magnetic dipole provides a method which makes electromagnetic leakage through a small metallic aperture be easily understood and predicted. This paper reviewed Bethe's theory for small aperture leakage. Unreasonable assumptions in the theory derivation were pointed out. Limitations and recommendations on its application were listed and suggested.

1:30 pm **Localization of Electromagnetic Interference Source using a Time Reversal Cavity: Application of the Maximum Power Criterion** 598
Hamidreza Karami[1]; Mohammad Azadifar[2]; Amirhossein Mostajabi[1]; Marcos Rubinstein[2]; Farhad Rachidi[1]
[1]Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland; [2]University of Applied Sciences of Western Switzerland (HES-SO), Yverdon-les-Bains, Switzerland

Abstract: The localization of Electromagnetic Interference (EMI) sources is very important in Electromagnetic Compatibility applications. Recently, a novel localization technique based on the Time Reversal Cavity (TRC) concept was proposed using only one sensor. In this paper, we discuss the concept of TRC and its application to the localization of EMI sources. We investigate the maximum peak field criterion to localize an EMI source in the cavity using one sensor. We show that the maximum peak field criterion in the presence of the cavity can be used to localize an EMI source with high accuracy. The performance of the proposed criterion is evaluated using the finite difference time domain method. Finally, we provide a proof of concept to show the ability of the time reversal concept in the localization of an EMI source in a cavity. Experimental results confirm that the proposed method can be used in practical EMC problems.

2:00 pm **Design of Metamaterial Impedance Matching Surfaces at Near Field for EMC Solutions** 603
Ali Khoshniat; Ramesh Abhari
Santa Clara University, Santa Clara, CA, USA

Abstract: The wave impedance concept is employed in this paper to design an absorber of radiated emissions at a compliance failure frequency. Dimensions of the system box considered in this paper are electrically small at the failure frequency. This result in a complex wave impedance for the radiated emissions at the system box boundary which is in the near field region of the unintentional radiators on the system board. A metamaterial frequency selective absorber is developed to exhibit the target surface impedance for the wave impedance by finding an equivalent bulk material. It is shown that the most effective absorber in near field should conjugate match to the wave impedance at that location. To demonstrate the validity of this approach, the radiated electric fields leaked outside the system box with various material lining its top wall, from copper to the proposed metamaterial design are calculated using full wave simulations. Obtained results prove that the proposed conjugate matching absorber provides 13.6 dB mitigation of radiated emissions which is 4.7 dB higher than that of a commercial absorber.

Best EMC Student Paper Finalist

W3_WE_PM_B2 Spectrum Engineering (Sponsored by TC-6) 3:15 pm - 4:15 pm

Chair: Sarah A. Seguin, Resonant Frequency, Maple Grove, MN, USA

3:15 pm **EMI Reduction Control based on 8b/10b** 609
Pei-Yang Weng; Chiu-Chih Chou; Tzong-Lin Wu
National Taiwan University, Taipei, Taiwan

Abstract: Wireline devices are in close proximity to wireless devices, which causes electromagnetic interference (EMI) to degrade the signal quality of wireless communications. Most of literatures dealing with this problem take actions on suppressing the coupling paths, such as low-radiation structures. In this paper, a novel source-control method is proposed which reduces the power spectrum of the source signal and thus the unintentional radiation by careful insertion of control symbols in 8b/10b, at the cost of throughput reduction. According to the reduction level, one parameter can be tuned properly to achieve the desired performance. In addition, the proposed control strategy is easy to integrate and scale with silicon process nodes due to its digital nature.

Best EMC Student Paper Finalist

3:45 pm **Adaptive Interference Mitigation using Frequency-Selective Limiters over GPS Band for Automotive Applications** 614

Mahima Shukla; Marina Y. Koledintseva; Michael Geiler; Scott Gillette;
Michael Hunnewell; Anton L. Geiler
Metamagnetics, Inc., Westborough, MA, USA

Abstract: In this work, we address the challenges associated with the necessity to protect Global Positioning system (GPS) receivers from various types of electromagnetic interference (EMI) generated by internal or external sources. We have developed a compact, lightweight, and passive frequency selective limiter (FSL) technology that automatically and adaptively protects vulnerable input circuits of a GPS receiver from unwanted emissions and prevents a GPS receiver from going into saturation. This technology is based on using magnetostatic surface waves in a magnetically biased ferrite film. The nonlinear processes in ferrite films enable discrimination of signals based on their power levels. In these devices, the frequency-selective transmission response adjusts rapidly and automatically, in real time, such that no portion of the output spectrum exceeds a designated power threshold. FSLs are capable of mitigating multiple interfering signals without prior knowledge of the timing or the frequency content of the interferers. A few examples of FSL design and measured characteristics are provided for GPS L1 band.

W3_WE_PM_C SS3 – Advances of EMI Research for Power Conversions (Sponsored by SC-5) 1:00 pm - 4:15 pm

Chair: Seungyoung Ahn, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea, Republic of (South)
Co-Chair: Mingchang Wang, Christie Digital Systems Inc., Kitchener, Ontario, Canada

1:30 pm **Electric Parameter Tuning of Wireless Power Transfer Coil for Charging Interoperability of Electric Vehicles** 619

Dongwook Kim[1]; Seungyoung Ahn[1]; Qiusen He[2]; Anfeng Huang[3]; Jun Fan[3]; Hongseok Kim[3]
[1]Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea, Republic of (South); [2]Southwest University of Science and Technology, Mianyang, China; [3]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: The SAE J2954 recommended practice (RP) contains the power transfer frequency, electric values, and test procedure for the electric vehicle (EV) wireless power transfer (WPT). In particular, this document expresses the inductance range of the powering coil, the power receiving coil and the coupling coefficient (k) and the impedance values. It is very important that adhering the electrical parameters in the standard considering that the wireless charging system's compatibility. However, once the coil is processed, it is not easy to adjust the inductance of each powering coil, power receiving coil as well as the coupling coefficient of between transmitting coil and receiving coil. In this article, we introduce the method of tuning the coil's inductances and coupling coefficient by adjusting the effective permeability of the ferrite blocks. By controlling the permeability of ferrite blocks, self-inductance of coils and coupling coefficient are successfully adjusted. Through this idea, we obtained reasonable electrical parameters; inductance of ground-assembly coil, inductance of vehicle assembly coil, and coupling coefficient.

2:00 pm **Low EMF Design of Cochlear Implant Wireless Power Transfer System using a Shielding Coil** 623

Seokwoo Hong[1]; Seungtaek Jeong[1]; Seongsoo Lee[1]; Boogyo Sim[1]; Hongseok Kim[2]; Joungho Kim[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea, Republic of (South); [2]Missouri University of Science and Technology, Rolla, MO, USA

Abstract: Wireless power transfer (WPT) technology is widely used for various applications because of convenience and safety. Especially, medical implant devices such as a cochlear implant are one of the typical application of the WPT technology. However, WPT systems have problems with electromagnetic field (EMF) leakage, which can cause electro-magnetic interference (EMI) issues in the human body.

In this paper, we propose an additional shielding coil for the effective suppression of EMF radiation of a WPT system. The proposed method reduces the EMF leakage in operating frequency range. We verified that the proposed shielding coil reduced the EMF leakage by 5.1 dB using 3D EM simulation. Also, the power transfer efficiency (PTE) and link gain stability of the proposed cochlear implant WPT system are designed to work well with proposed shielding coil.

2:30 pm **Common-Mode Voltage Reduction of Modular Multilevel Converter based on Chaotic Carrier Phase Shifted Sinusoidal Pulse Width Modulation** 626

Jiaxin Wang[1]; Hong Li[1]; Zhichang Yang[1]; Bo Zhang[2]
[1]Beijing Jiaotong University, Beijing, China; [2]South China University of Technology, Guangzhou, China

Abstract: High frequency fluctuation in common-mode (CM) voltage of the modular multilevel converter (MMC) causes serious CM conducted electromagnetic interference (EMI), which could damage the load motor and shorten its service life. To suppress the CM EMI in the MMC, the chaotic carrier phase shifted sinusoidal pulse width modulation (CPS-SPWM) is proposed for the MMC by introducing the idea of chaotic PWM into CPS-SPWM. The chaotic CPS-SPWM is used to suppress CM EMI by spreading the carrier frequency with a chaotic sequence in a given range, thereby reducing the peaks of CM EMI spectrum. This paper builds a 5-level MMC simulation platform based on MATLAB/Simulink. The correctness and effectiveness of the chaotic CPS-SPWM to suppress CM EMI of the MMC is verified by the simulation results. This paper provides a new way for improving the CM EMI in the MMC.

3:15 pm **Selective Digital Active EMI filtering using Resonant Controller** 632

Hongwu Peng[1]; Balaji Narayanasamy[1]; Asif Imran Emon[1]; Zhao Yuan[1]; Rongxuan Zhang[2]; Fang Luo[1]
[1]University of Arkansas, Fayetteville, AR, USA; [2]Nanjing University of Aeronautics and Astronautics, Jiangsu, China

Abstract: Conventional passive EMI filters are bulky and occupy up to 30% of converter volume and weight. Active EMI filters are a key technology that enables the reduction in the size of passive components. The performance of active EMI filters (AEF) with feedback control for volume reduction is limited by relatively low-gain on the feedback loop to ensure stability. A novel digital active EMI filter (DAEF) with resonant controller which provides ultra high-gain at frequencies of interest is demonstrated for DM noise attenuation. The filter consists of noise sensing circuit, resonant controller built in the Field Programmable Gate Array (FPGA), and noise injection circuit. The experimental test results show that the proposed EMI filter has 45 dB more attenuation at 150 kHz than the conventional passive EMI filter, which is also the highest attenuation reported in the DAEF literature.

3:45 pm **Inductor Winding Capacitance Cancellation for Flyback Converters without Grounding Paths** 640

Yiming Li[1]; Shuo Wang[1]; Honggang Sheng[2]; Srikanth Lakshmikanthan[2]
[1]University of Florida, Gainesville, FL, USA; [2]Google LLC, Mountain View, CA, USA

Abstract: As the switching frequency of power converters is increased to achieve high power density, the high frequency common mode (CM) EMI noise becomes a severe challenge. The inductor equivalent parasitic capacitance (EPC) cancellation technique was proposed to improve the high frequency performance of CM inductors. Although it was verified in separate inductors, few papers are addressing its application within power converters. This paper first reviews the EPC cancellation technique and the common mode noise model of an isolated Flyback power adapter. The CM inductor EPC cancellation technique without using grounding paths is proposed. Two filter topologies are discussed. A technique to conveniently evaluate the performance of EPC cancellation in a power adapter with a network analyzer is proposed. Experiments were conducted to verify the techniques.

THURSDAY TECHNICAL PAPERS – II

Thursday, August 20, 2020

W3_TH_PM_A1 RFI Issues and 5G Measurements II (Sponsored by TC-12) 1:00 pm - 3:00 pm

Chair: Jiyu Wu, Hunan University, Hunan, China

2:30 pm **Radiated Spurious Emission Prediction based on Dipole Moment and Full Wave Simulation** 646
Qiaolei Huang; Jagan Rajagopalan; Duck Ho Bae; Akshay Mohan; Deepak Pai
Amazon Lab126, Sunnyvale, CA, USA

Abstract: In this paper, an equivalent dipole moment method and full wave simulation are proposed to predict radiated spurious emissions (RSE). The proposed method is utilized in design of a practical electronic device. Based on near field patterns, the radiation physics of 2.4GHz Wi-Fi transmitter harmonics in the device is identified to be a magnetic dipole moment. Reduction of loop size is proved to be an effective method to reduce RSE of 2.4 GHz. In addition, RSE of 5 GHz Wi-Fi transmitter is simulated using a full wave solver and methods to reduce RSE are discussed. Measured RSE results are also shown to validate proposed prediction and mitigation methods.

W3_TH_PM_A2 EM Environment (Sponsored by TC-3) 3:15 pm - 4:45 pm

Chair: Fred Heather, IEEE Senior Member, Lexington Park, MD, USA

3:15 pm **Electromagnetic Radiation Measurement and Analysis of High Voltage Wires** 650
Nan Lu; Feng Zhu; Yingchun Xiao; Yingying Chen; Xiao Yang; Qianqian Jiang
Southwest Jiaotong University, Chengdu, China

Abstract: In order to study the space electromagnetic emission characteristics of 500kV AC high voltage transmission line (HVTL) during corona generation. In this paper, the whole HVTL with corona is regarded as a kind of electromagnetic radiation source by using lossy transmission line theory. Using this model, it can predict the longitudinal propagation characteristics of electromagnetic field emitted by AC HVTL. It provides guidance for the perfection of the standard and the prediction of electromagnetic emission of HVTL.

3:45 pm **Analysis of Electromagnetic Emission of Pantograph-Catenary Arc to VOR** 654
Yingchun Xiao; Feng Zhu; Nan Lu; Yingying Chen; Qianqian Jiang; Xiao Yang
Southwest Jiaotong University, Chengdu, China

Abstract: In order to analyze the influence of pantograph-catenary arc electromagnetic emission on airport Very high omnidirectional range (VOR) with High-Speed train(HST) passing the articulated neutral section(ANS), based on a large amount of electromagnetic emission test data, this paper analyzes the difference in error of test data and improve the regression analysis method, the amplitude-frequency characteristic curve of the arc in the omnidirectional beacon frequency band is fitted, and the influence of arc electromagnetic emission on the omnidirectional beacon of the airport is analyzed. The results show that: 1) The electromagnetic emission of the arc has a certain random characteristic. The maximum field strength is in articulated neutral section point, larger than the ordinary site.2) In modern electrified railway, the difference in error of the test data of neutral section is more obvious, and the ordinary least squares estimation method is not applicable for fit the amplitude-frequency characteristic curve. 3) When the distance of the electrified railway articulated neutral section point and the aircraft are less than 6.982km, it may affect the airport omnidirectional beacon signal.

4:15 pm **Electromagnetic Field Safety Compliance Assessments for 5G Wireless Networks** 659
Tan Rumeng[1]; Shi Ying[1]; Wu Tong[2]; Zhu Wentao[3]
[1]China Telecom Co., Ltd., Guangzhou, China; [2]National Institute of Metrology, Beijing, China; [3]China Mobile Group Design Institute Co., Ltd., Beijing, China

Abstract: This paper provides guidance on the radio frequency electromagnetic field (RF-EMF) safety compliance assessment considerations for 5G wireless networks, including 5G base stations located at existing wireless network facilities. Given that the commercial 5G networks are just launched and there are insufficient users to conduct on-site assessments of real user scenarios, this paper is to mainly address the computational assessment options.

W3_TH_PM_B1 EMC Assessment and Verification (Sponsored by TC-1) 1:00 pm - 3:00 pm

Chair: Thomas E. Braxton, Shure Inc., Niles, IL, USA

1:00 pm **Proficiency Testing Scheme of Conducted Disturbance at Mains Terminals in 150kHz~30MHz using Multi-Items** 663

Mi Jincai; Chen Hui; Liu Qunxing; Liu Xin; Chu Rui; Song Jun

China CEPREI Laboratory, Guangzhou, China

Abstract: The paper introduces a Proficiency Testing scheme of conducted disturbance at mains terminals in 150kHz~30MHz using Multi-items method, compared with a single item Proficiency Testing scheme, test time and costs is greatly reduced, reliability is largely increased. 150 items which could generate comb signal with stable frequency and stable voltage in the frequency range of 150 kHz to 30MHz were developed. And the item could simulate the power supply, grounding and setup of the actual test sample. Mailed it to 101 participants in parallel to evaluates performance and identifies problems of participants.

1:30 pm **Determining the Electromagnetic Environment on Board Ships for Risk-Based Approach EMC Analysis** 666

Nancy Omollo[1,2]; Jan-Kees van der Ven[2]; Robert Vogt-Ardatjew[1]; Frank Leferink[1,3]

[1]University of Twente, Enschede, The Netherlands; [2]RH Marine, Rotterdam, The Netherlands; [3]Thales Nederland, Hengelo, The Netherlands

Abstract: The increased implementation of new electronic systems in a small physical space has resulted in complex electromagnetic environments. A ship is an example of such a system with a complex electromagnetic environment. In order to prevent electromagnetic interference in such complex systems, one needs to understand the composition of the environment and the interaction between the different elements. This paper determines the electromagnetic environment onboard ships, with the intention of achieving electromagnetic compatibility using a risk-based approach.

2:00 pm **Automatic Sparse ESM Scan using Gaussian Process Regression** 671

Jiangshuai Li; Jiahao Zhou; Shaohui Yong; Yuanzhuo Liu; Victor Khilkevich

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

Abstract: Emission source microscopy (ESM) technique can be utilized for localization of electromagnetic interference sources in complex and large systems. In this work a Gaussian process regression (GPR) method is applied in real-time to select sampling points for the sparse ESM imaging using a motorized scanner. The Gaussian process regression is used to estimate the complex amplitude of the scanned field and its uncertainty allowing to select the most relevant areas for scanning. Compared with the randomly selected samples the proposed method allows to reduce the number of samples needed to achieve a certain dynamic range of the image, reducing the overall scanning time. Results for simulated and measured 1D scans are presented.

Best EMC Student Paper Finalist

2:30 pm **Risk-Based EMC Approach in Hospital Environment** 676

Mumpy Das[1]; Robert Vogt-Ardatjew[1]; Bärbel van den Berg[2]; Frank Leferink[1,3]

[1]University of Twente, Enschede, The Netherlands; [2]MST Hospital, Enschede, The Netherlands; [3]THALES Nederland B.V., Hengelo, The Netherlands

Abstract: A modern hospital has a wide range of medical devices that can be technologically very advanced and complex in terms of electromagnetic emissions and susceptibility. It is a public environment where people carry communication equipment and/or medical active implants. Therefore, electromagnetic interference among the devices in the hospital environment is not an unfamiliar topic. There is a misconception among engineers that if all medical devices comply with harmonized standards, then the installation of a large number of medical devices altogether would work absolutely fine. However, this is not always true, and so for complex systems, a smarter approach is necessary to assess and control the risks of electromagnetic interference. This paper emphasizes the importance of using the risk-based approach to deal with the often unpredictable factors causing electromagnetic interference in a complex hospital environment.

Best EMC Student Paper Finalist

W3_TH_PM_C Antenna, Cable, Filter and Sensor Design Evaluation (Sponsored by TC-2) 1:00 pm - 4:15 pm

Chair: Monrad Monsen, Oracle, Broomfield, CO, USA

2:00 pm **Probability Distribution Approach of EMI Filter Performance for Photovoltaic Applications** 681

Duc-Thanh Do; Holger Hirsch
[1]*University of Duisburg-Essen, Duisburg, Germany*

Abstract: This paper proposes a probability distribution approach to investigate the uncertainty of Electromagnetic Interference (EMI) filter performance based on filters used for PV applications. In general, a Line Impedance Stabilization Network (LISN)is utilized to measure conducted EMI. Typically, the filter performance is measured in a 50 / 50 -System or a 0.1 / 100 or 100 / 0.1 system (see CISPR 17). In real power installations, the impedances vary significantly from this value. Empirical data had been derived and published in several papers. Based on that, Monte-Carlo simulations have been performed in order to determine the stray of a margin below the disturbance voltage limits Ucispr of test laboratory voltage Ulab to take into account the parameter tolerance and measurement uncertainties. Based on statistical results for a representative PV application, the tolerance intervals used to recommend the performance of an EMI filter design to satisfy EMC standards.

2:30 pm **Experimental Evaluation of Spatial Resolution for Optical Electric Field Sensor with Dipole Element** 685

Kimihiro Tajima[1]; Yoshiharu Akiyama[1]; Yoshiki Kayano[2]; Fengchao Xiao[2]
[1]*NTT Advanced Technology Corporation, Musashino, Tokyo, Japan;* [2]*The University of Electro-Communications, Chofu, Tokyo, Japan*

Abstract: This paper presents a method for evaluating the spatial resolution of an optical electric field sensor with a dipole element by measurement. The electromagnetic wave radiated from a standard horn antenna was applied perpendicularly to a flat metal surface, and the electric field distribution of the generated standing wave was measured while moving the optical electric field sensor with a step width smaller than the element length. It evaluated by calculating the theoretical value of ideal dipole element length dependence by 0.1mm step. As a result, it was found that a spatial resolution equivalent to the element length can be expected with a deviation within 2.15 dB when the element length is 1 cm and the frequency is 2.5 GHz.