

## **Workshop I. PEEC Modeling for Signal Integrity and EMC Analysis**

**Organizer:** Prof. Ke-Li Wu

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**Abstract:** The Partial Element Equivalent Circuit (PEEC) model is a general numerical method for electromagnetic problems. It is the only method that converts an EM problem into a physical meaningful circuit domain problem. The method has been widely adopted in signal integrity analysis, electronic packaging design, EM radiation, electromagnetic compatibility (EMC) and power electronics problems. PEEC modeling has been adopted as a physical extraction method underneath many EDA tools. This workshop aims at introducing the basic concepts of PEEC modeling, reviewing the development trajectory of various PEEC modeling schemes for both frequency and time domain simulation, presenting a physics-based model-order-reduction method and showcasing its applications for SI/PI modeling of high-speed electronic system designs, ESD noise modeling, and modeling of lightning current in wireless base-stations. Key Challenges in EMI/ESD control for 5G telecommunication network products at both the IC and the packaging levels will be addressed by an industry leading expert. This workshop will be presented by six renowned experts in PEEC modeling and related industry, and will provide an academic exchange platform for both beginners and matured researchers who are interested in solving practical EM problems using the circuit domain method.

The six presentations in the workshop are

- 1) **Circuit Oriented Electromagnetic Modeling Using the PEEC Techniques**  
Albert E. Ruehli, Giulio Antonini and Lijun Jiang\*, University of Hong Kong
- 2) **PEEC-Based Micro-Modeling Circuit for Signal Integrity – Its Theory, Algorithm, Passivity and Applications**  
Yuhang Dou and Ke-Li Wu, The Chinese University of Hong Kong
- 3) **Key Challenges in EMI/ESD Control for 5G Telecommunication Network Products**  
Yao-Jiang Zhang, Huawei Technologies
- 4) **The concept of radiation resistance in frequency-domain PEEC model**  
Chiu-Chih Chou and Tzong-Lin Wu, National Taiwan University
- 5) **An effective PEEC modeling method to solve system-level ESD noise problems**  
Jingook Kim, Ulsan National Institute of Science and Technology
- 6) **PEEC modeling for lightning protection, magnetic shielding and transient simulation**

Patrick Y. Du, The Hong Kong Polytechnic University

## **Circuit Oriented Electromagnetic Modeling Using the PEEC Techniques**

Albert E. Ruehli<sup>1</sup>, Giulio Antonini<sup>2</sup> and Lijun Jiang<sup>3\*</sup>

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**Abstract:** Electromagnetic (EM) modeling has been of interests to authors of this topic for a large portion of their careers. The PEEC method evolved in a time span of more than 40 years. From the start, the approach has been tailored for electromagnetic modeling of electronic packages or electronic interconnects, which are also called signal integrity (SI), power integrity (PI), noise integrity (NI), as well as EMC problems. In the beginning, only high-performance computer system modeling needed accurate models for the electrical performance of interconnects and power. Quasistatic solutions were adequate even for the highest performance systems. But very soon due to problems of the ever-increasing size, this work was further extended to partial inductance calculations. With the race for higher clock rates in computer chips, the modeling of higher performance chips and packages led to the need for full-wave solutions. As a consequence, stability and passivity issues became important. Today, aspects such as skin-effect loss and dielectric loss models are required for realistic analysis.

Electromagnetic physics-based PEEC equivalent circuit models can be constructed for a multitude of purposes. It has many intrinsic connections with modern computational electromagnetic (CEM) algorithms. PEEC has been conveniently used in practical SI/PI modeling processes to pin point troublemakers in the high-speed electronic system designs. It is also functioning as the physical extraction method underneath many EDA tools. In this tutorial, we will review the development trajectory of PEEC methods, major applications, and several frontier topics rooted in the PEEC idea.



**Dr. Lijun Jiang** received the Bachelor Degree in electrical engineering from the Beijing University of Aeronautics and Astronautics in 1993, the Master Degree from the Tsinghua University in 1996, and the Ph.D from the University of Illinois at Urbana-Champaign (UIUC) in 2004. From 1996 to 1999, he was an Application Engineer with the Hewlett-Packard Company (HP). From 2004 to 2009, he has been the Postdoc, the Research Staff Member, and the Senior Engineer at IBM T.J. Watson Research Center. Since Dec. 2009, he has been the Associate Professor at the Department of Electrical and Electronic Engineering, the University of Hong Kong. He was the Senior Visiting Professor at Tsinghua University from Jun. 2013 to Jun. 2014. And he has been the visiting scholar to Professor T. Itoh's group at UCLA since Sept. 2014 and spent his Sabbatical at UCLA during Sept. 2014 to Mar. 2015.

## **PEEC-Based Micro-Modeling Circuit for Signal Integrity**

### **– Its Theory, Algorithm, Passivity and Applications**

Yuhang Dou and Prof. Ke-Li Wu\*

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**Abstract:** This talk will present the basic concept and the application of a physically derived micro-modeling method for signal integrity analysis of large-scale high-speed and high-density interconnection problems. The micro-modeling circuit is an order-reduced circuit of the partial element equivalent circuit (PEEC) model that is formulated from MPIE and is constructed based on meshing information. The micro-modeling circuit can be obtained by absorbing the insignificant nodes of the PEEC model one by one recursively according to a physics-inspired equivalent circuit transformation and an approximation that retains the essence of the original circuit in a lowpass sense. The process of deriving the micro-modeling circuit doesn't involve any matrix inversion nor physically meaningless circuit components which warrants that the method will not suffer from the scalability problem in time-domain signal integrity analysis.

This talk will also present the mathematic rationale and strategy of using GPU parallel computation techniques for accelerating the micro-modeling. The passivity of the micro-modeling circuit is warranted by a new simple passivity enforcement method. Some practical interconnection examples will be given to demonstrate the versatility, scalability, accuracy, and the simplicity of the new micro-modeling method. It will be shown through numerical examples that the micro-modeling circuit can be three orders of magnitude faster than the traditional PEEC modeling in practical signal integrity analysis.



**Ke-Li Wu** has been with The Chinese University of Hong Kong since 1999, where he is a Professor of Dept of Electronic Engineering and the Director of the Radiofrequency Radiation Research Laboratory. His current research interests include microwave filters, multiple antennas for wireless systems, EM modeling of signal integrity for high-speed packages, and technologies for Internet of Things.

Prof. Wu is a Fellow of IEEE, a member of IEEE MTT-8 subcommittee (Filters and Passive Components).

## **Key Challenges in EMI/ESD Control for 5G Telecommunication Network Products**

Dr. Yao-Jiang Zhang

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**Abstract:** With the data rate increasing to tens Gbps, it becomes more and more difficult to reduce EM radiation from ICs, connectors and optical modules. Shielding by a chassis with ventilation holes is not enough to prevent electromagnetic energy leaking from the high-speed products. Novel measures have to be investigated to reduce EM radiations from integrated circuits, connectors, cables and/or optical modules. On the other hands, the feature size of ICs is continuously reduced to even 10/7nm. It becomes more and more difficult to balance component level electro-static discharge (ESD) protection and manufacture process. Besides hard failures, soft failures caused by ESD or electrical overstress (EOS) are more and more serious. Collaboration among several research areas, including ESD/EMI, signal integrity (SI) and power integrity (PI), is required to overcome these challenges.



**Yao-Jiang Zhang**, IEEE Senior Member, received his B.E. and M. E. from University of Science and Technology of China in 1991 and 1994, respectively. In 1999, he got Ph.D. degree in Physical Electronics from Beijing University. From 1999 to 2001, he worked in Tsinghua University as a research fellow. From 2001 to 2014, he had worked as senior research engineer, research scientist, associate research professor in the Institute of High Performance Computing (IHPC), Agency for Science, Technology and Research (A\*STAR), Singapore, and EMC Laboratory, Missouri University of Science & Technology, USA. From 2014, he is working in Huawei Technologies as a Chief EMC Expert and Director of electromagnetic engineering and protection Lab.

His research interests include computational electromagnetics, signal/power integrity issues in high-speed electronic packages and PCBs, passive inter-modulation in base-station antennas, antenna array design, electromagnetic compatibility and EM protection for telecommunication network products, and optical components, etc.

### **The Concept of Radiation Resistance in Frequency-domain PEEC Model**

Chiu-Chih Chou and Prof. Tzong-Lin Wu

**Affiliation:** National Taiwan University

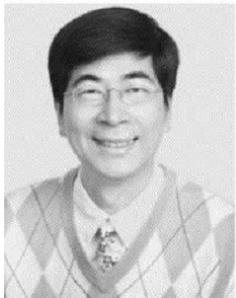
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**Abstract** The traditional time-domain PEEC deals with real circuit elements (RLC) while some quantities are evaluated at the retarded time. The frequency-domain PEEC formulation eliminates the difficulty for the retarded time, but introduces complex inductance and potential coefficients whose physical meaning were studied in detail only recently. Several works together revealed that the imaginary parts of the mutually-

coupled complex inductance and complex capacitance represent the radiation resistance network of the whole structure. In this talk, we will go through the development of the understanding regarding the meaning of complex LC. The relation between the imaginary LC and radiation resistance will be rigorously derived based on Poynting's theorem, and some physical implications of the result will be discussed.



**Chiu-Chih Chou** received the B.S.E.E. from National Taiwan University (NTU) in 2011. He is currently pursuing Ph.D. degree at the Graduate Institute of Communication Engineering, National Taiwan University. His research interests include EMC/SI/PI and applied electromagnetic.



**Tzong-Lin Wu** is a Fellow of IEEE. He received the B.S.E.E. and Ph.D. degrees from National Taiwan University (NTU), Taipei, Taiwan, in 1991 and 1995, respectively. From 1995 to 1996, he was a Senior Engineer with Microelectronics Technology Inc., Hsinchu, Taiwan. In 1996, he joined the Central Research Institute of the Tatung Company, Taipei, where he was involved in the analysis and measurement of EMC/EMI problems of high-speed digital systems. In 1998, he joined at the Electrical Engineering Department, National Sun Yat-sen University. Since 2006, he has been a Professor with the Department of Electrical Engineering, NTU. His current research interests include EMC/EMI and the signal/power integrity design for high-speed digital/optical systems. Dr. Wu is the recipient of many prestigious awards including the IEEE Transactions on Advanced Packaging Best Paper Award in 2011. He served as the Distinguished Lecturer with the IEEE EMC Society from 2008 to 2009. He is currently an Associate Editor of the IEEE Trans on EMC and the IEEE Trans. CPMT.

### **An Effective PEEC Modeling Method to Solve System-level ESD Noise Problems**

Prof. Jingoek Kim

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**Abstract:** The coupling from electrostatic discharge (ESD) events can be effectively calculated using the partial element equivalent circuit (PEEC) method both in time and frequency domains. The PEEC method has several advantages in predicting dominant coupling sources and waveforms of ESD. First, the ESD generator can be easily incorporated as an equivalent circuit model in the PEEC method. Second, the PEEC method allows a fast and accurate calculation method of system-level ESD noise coupling based on the model decomposition process. The proposed method can

significantly reduce the calculation time without loss of accuracy by separating small victim structures from the large aggressor structures such as ground planes and ESD gun strap. Also, when the overall aggressor geometry is fixed and the coupling to various victim geometries needs to be found, the separation of aggressor and victim structures reduces the computational time significantly. Using the method, the ESD noise coupling at the terminations of a victim signal trace is rigorously calculated and validated with measurements and full-wave simulations both in frequency and time domains.



**Jinguook Kim** received his B.S., M.S., and Ph.D. degrees in electrical engineering from Korea Advanced Institute of Science and Technology, Daejeon, Korea, in 2000, 2002, and 2006, respectively. From 2006 to 2008, he was with DRAM design team in Memory Division of Samsung Electronics, Hwasung, Korea, as a senior engineer. From January 2009 to July 2011, he worked for the EMC Laboratory at the Missouri University of Science and Technology, Missouri, USA, as a postdoc fellow. In July 2011, he joined the Ulsan National Institute of Science and Technology (UNIST), Ulsan, Korea, where he is currently an associate professor. He has authored or co-authored over 100 journal and conference papers. His current research interests include high-speed I/O circuits design, 3D-IC, EMC, ESD, RF interference.

### **PEEC Modeling for Lightning Protection, Magnetic Shielding and Transient Simulation**

Prof. Patrick Y. Du

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**Abstract:** With the proliferation of electrical and electronic systems, the electromagnetic (EM) environment in or around modern buildings, telecommunication facilities and other grounded structures has been increasingly concerned as the EM fields can cause interference to sensitive equipment and potential adverse health effects. The EM fields of concern in this presentation are mainly contributed by power equipment running at power frequency or a lightning protection system (LPS) during a lightning strike. The lightning protection system is intended to intercept lightning and to carry substantial lightning current. This current will generate intense transient electromagnetic fields in and around the grounded structure.

Many numerical methods have been developed to analyze electromagnetic compatibility problems which include MoM, FEM, FDTD and others. Recently, PEEC has been increasingly used in lightning transient analysis because its advantages in wire modelling. This method has been further extended to model planar structures as well for shielding analysis at low frequency. This presentation reports recent advances in PEEC applications for evaluating the electromagnetic environment in buildings caused

by power-frequency equipment and lightning current, and lightning transients in radio bases stations. Modelling techniques for metallic structures found in buildings and steel towers are presented, which include steel bars, metal decking, metal trunking and other large metal plates or sheets. These metallic parts may not be part of electrical equipment or systems, but they do affect the electromagnetic environment in the buildings or at the towers. Examples are given to illustrate how these modelling techniques are applied to the electromagnetic environment evaluation, shielding effectiveness evaluation and lightning transient evaluation. A simulation tool TAES is introduced finally to analyze lightning transient currents in a cabling system for the radio base station.



**Patrick Du** graduated with the Bachelor of Science in Electrical Engineering from Shanghai Jiao Tong University, and received the Doctor of Philosophy degree from the University of Southern California in the US. He joined the Hong Kong Polytechnic University in 1995 as an Assistant Professor, and is now a Professor in the Department of Building Services Engineering. His research interests include building electromagnetic environments, electromagnetic compatibility, and lightning protection for electrical distribution systems, railway systems, and communication systems. He serves as a consultant for local industry in the areas of electromagnetic compatibility and lightning protection. Currently he is a member of the Steering Committee of the Asia-Pacific International Conference on Lightning. He is a member of IET and a chartered engineer of the UK.

### **Workshop II: Multiphysics Modeling and Simulation for Advanced Integration and Packaging**

**Organizers:** Prof. L. J. Jiang, Prof. G. B. Xiao, and Prof. J. M. Jin

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**Title: Multiphysics modeling and simulation for large-scale integrated circuits**

**Speakers:** Dr. Tianjian Lu and Prof. Jian-Ming Jin

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**Abstract:** This workshop presentation summarizes our efforts and findings in seeking solutions to two important and challenging problems related to the design of modern integrated circuits (ICs): the ever-increasing couplings among the multiphysics and the large problem size arising from the escalating complexity of the designs. A multiphysics-based computer-aided design methodology is proposed and implemented to address multiple aspects of a design simultaneously, which include electromagnetics,

heat transfer, fluid dynamics, and structure mechanics. The multiphysics simulation is based on the finite element method for its unmatched capabilities in handling complicated geometries and material properties. The capability of the multiphysics simulation is demonstrated through its applications in a variety of important problems, including the static and dynamic IR-drop analyses of power distribution networks, the thermal-aware high-frequency characterization of through-silicon-via structures, the full-wave electromagnetic analysis of high-power RF/microwave circuits, the modeling and analysis of three-dimensional ICs with integrated microchannel cooling, the characterization of micro- and nanoscale electrical-mechanical systems, and the modeling of decoupling capacitor derating in the power integrity simulations. To perform the large-scale analysis in a highly efficient manner, a domain decomposition scheme, parallel computing, and an adaptive time-stepping scheme are incorporated into the proposed multiphysics simulation. Significant reduction in computation time is achieved through the two numerical schemes and the parallel computing with multiple processors.



**Jian-Ming Jin** is Y. T. Lo Chair Professor in Electrical and Computer Engineering and Director of the Electromagnetics Laboratory and Center for Computational Electromagnetics at the University of Illinois at Urbana-Champaign. He has authored and co-authored over 275 papers in refereed journals and over 20 book chapters. He has also authored *The Finite Element Method in Electromagnetics*, *Electromagnetic Analysis and Design in Magnetic Resonance Imaging*, and *Theory and Computation of Electromagnetic Fields*, co-authored *Computation of Special Functions*, *Finite Element Analysis of Antennas and Arrays*, and *Fast and Efficient Algorithms in Computational Electromagnetics*. His name often appeared in the University of Illinois's *List of Excellent Instructors*. He was elected by ISI among world's most cited authors in 2002. He is a Fellow of IEEE, Applied Computational Electromagnetics Society (ACES), and Electromagnetics Academy. Recently, he received the 2014 ACES Technical Achievement Award, 2015 IEEE APS Chen-To Tai Distinguished Educator Award, 2016 ACES Computational Electromagnetics Award, and 2017 IEEE APS Harrington-Mitra Computational Electromagnetics Award.

### **Coupled Thermo-electromagnetic Analysis Based on Integral Equations**

Gaobiao Xiao and Yibei Hou

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**Abstract:** The power density handled in an electronic system has increased significantly in the past years, so does the leakage power. Leakage power may generate heat and cause high internal temperature in the device. The electronic device can be

functionally deteriorated or even be damaged due to the high internal temperatures. Thermal management is an important issue for a compact electronic system, and thermo-electro- magnetic analysis may play a significant role.

There are many numerical techniques for analyzing this kind of heat transfer problems. The heat in an electronic system may be generated by ohmic loss in conductors and lossy media, switching loss in capacitances, etc.. All these heat sources are dependent on current densities or electromagnetic fields that also have to be numerically calculated. In this workshop, we try to solve the coupled thermo-electromagnetic problem based on integral equations associated with the corresponding electromagnetic problem and the heat transfer problem. The equivalence source principle is used in the analysis of the electromagnetic scattering problem and the heat conduction problem. Based on the equivalence principle, integral equation formulations for electromagnetic scattering problems and steady-state heat analysis are introduced. Basically, the numerical implementation of solving the heat conduction equation can be embedded in the process of analyzing the corresponding electromagnetic problem. Therefore, it is possible to solve heat conduction problem and electromagnetic scattering problem with the same computer-code on a single mesh structure.



**Dr. Gaobiao Xiao** received the M.S. degree from Huazhong University of Science and Technology, Wuhan, China, in 1988, the B.S. degree from the National University of Defense Technology, Changsha, China, in 1991, and the Ph.D. degree from Chiba University, Chiba, Japan, in 2002. He worked in Hunan University, Changsha, China, from 1991 to 1997. Since April 2004, he has been a faculty member in the Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai, China. His research interests are numerical methods in electro-magnetic fields, coupled thermo-electromagnetic analysis, microwave filter designs, fiber-optic filter designs, phased arrays, and inverse scattering problems.

**Title: Computational Electromagnetic Methods for Atomic Thin Graphene  
Characterization**

**Speaker:** Lijun Jiang

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**Abstract:** Graphene, an atomically thin 2-D sheet of carbon atoms in which the atoms are arranged in a honeycomb lattice, has already gained intense attentions from many groups over the world because of its unique electrical, mechanical, and thermal properties. These remarkable properties make it as a promising candidate for semiconductor, tunable nanoantenna, and surface plasmon waveguide, etc. The surface conductivity of graphene is particular of interest to study the electromagnetic properties

of graphene such as surface plasmon polarization (SPP). In the absence of external magnetostatic bias, the surface conductivity is a scalar. Otherwise it becomes a tensor.

To quantify the EM properties of graphene, various numerical algorithms have been developed such as MoM, FDTD method, etc. In this talk, we will first discuss the experimental study of Graphene conductivity properties in the microwave region. Then we will discuss the computational electromagnetic methods in solving structures with general graphene sheets. There are two approaches to treat graphene: i) The graphene is considered as a thin layer with finite thickness, thus volumetric meshing is required. With this approach, the surface conductivity is transformed to an equivalent permittivity. ii) The volumetric graphene is modeled as an infinitesimal thin sheet over which a surface-impedance boundary condition (SIBC) is satisfied. Compared with frequency domain methods, time-domain methods have advantages such as broadband characterization with only single simulation, transient response capture, etc. Two specific methods, discontinuous Galerkin's time domain (DGTD) method and PEEC method will be introduced to model and analyze both static and biased graphene structures. The numerical verifications will demonstrate the feasibility and flexibility of the introduced methods. These approaches provide solutions not only graphene characterizations, but also for anisotropic medium analysis in electromagnetic fields.

**Title: Silicon Integration and Packaging - the Hardware Pillars of mmWave 5G Communication**

**Speaker:** Dr. Xiaoxiong (Kevin) Gu

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**Abstract:** mmWave technology is rising as a crucial component for 5G radio access and other emerging ancillary wireless networks including Gb/s device-to-device communication and mobile backhaul. This talk covers recent advances in state-of-the-art mm-wave silicon technology, packaging and integrated antenna design in the context of 5G communications. The main challenges in 5G hardware development and the corresponding mitigation strategies are discussed with a focus on RFIC, antenna and packaging integration technologies. The talk emphasizes the following key enablers for the commercial scale deployment of mm-wave technology in the 5G era: 1) highly integrated and complex circuits in silicon technologies, and 2) strategies for IC, package, antenna and board co-design and integration. Through various examples of mmWave transceivers with antennas-in-package demonstrated in hardware, this talk illustrates how these challenges can be addressed for a variety of potential 5G usage scenarios, from PAN to backhaul.



**Dr. Xiaoxiong (Kevin) Gu** received his Ph.D. in electrical engineering from the University of Washington in 2006. He joined IBM Research as a Research Staff Member in January 2007. His research activities are focused on 5G radio access technologies, optoelectronic and mm-wave packaging, electrical designs, modeling and characterization of communication and computation systems. He has recently worked on antenna-in-package design and integration for mm-wave imaging and communication systems including K-band, V-band and W-band phased-array modules. Dr. Gu has authored and co-authored over 70 technical papers and has 8 issued patents. He received an IBM Outstanding Technical Achievement Award in 2016, four IBM Plateau Invention Awards in 2012 ~ 2016, the IEEE EMC Symposium Best Paper Award in 2013, two SRC Mahboob Khan Outstanding Industry Liaison Awards in 2012 and 2014, the Best Conference Paper Award at IEEE EPEPS in 2011, IEC DesignCon Paper Awards in 2008 and 2010, the Best Interactive Session Paper Award at IEEE DATE in 2008, and the Best Session Paper Award at IEEE ECTC in 2007. Dr. Gu is the co-chair of Professional Interest Community (PIC) on Computer System Designs at IBM. He is a Senior Member of IEEE and has been serving on the technical program committees for numerous IEEE Conferences (IMS, EPEPS, ECTC, EDAPS) and DesignCon.

### **Workshop III. Analyzing Power Supply Induced Jitter in I/O Buffers: from Simple to Complex**

**Organizer:** Prof. Jun Fan

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**Abstract:** High-speed interconnects are the enable technologies for emerging applications such as Internet of Things and cloud computing. With continuous increase of data rate, for example, an increase from 28 Gb/s to 56 Gb/s over a single lane for the next-generation 400 Gb/s Ethernet, power supply induced jitter (PSIJ) becomes an important player in determining the link quality, and thus needs to be addressed carefully. Noise and voltage fluctuations in the power distribution network due to device switching, if propagated to the I/O buffers, could result in jitter in the output waveforms. This power- and signal-net interaction is one of the aspects of Signal and Power Integrity co-design. In this workshop, analysis of PSIJ for I/O buffers are introduced from analytical formulations for simple single buffer structures, to extended approaches for buffer chains and complex I/O circuits.

**Speaker:** Professor Jingook Kim

**Affiliation:** Ulsan National Institute of Science and Technology,  
Korea

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## **Analytic Calculation of Jitter Induced by Power and Ground Noise Based on IBIS I/V Curve**

**Speaker:** Prof. Xiuqin Chu

**Affiliation:** Xidian University

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**Abstract** Supply fluctuation is one of the most significant factor that causes jitter in high-speed I/O links. Traditional SPICE simulation or measuring method for power supply induced jitter (PSIJ) is quite time consuming and draining on resource. IBIS model is a popular standard for electronic behavioral specifications of digital integrated circuit I/O characteristics. This presentation reports a method of analytic jitter transfer functions for supply fluctuations by solving two order differential equations based on IBIS I/V characteristics and pin package parameters. In this method the spectrum of output jitters induced by power supply fluctuations is obtained in frequency domain. Then the time jitter is obtained after transforming the jitter frequency spectrum into time domain. The method is validated by comparing the analytic calculation results with HSPICE simulated results for a DDR4 output buffer.

This method provides the completely analytic solution for noise-to-jitter sensitivity based on IBIS I/V curve and package parameters without any measuring or simulation. It is efficient for all I/O buffers in high-speed links.



**Xiuqin Chu** received the B.S. degree in electronic engineering at Xi'an Shiyou University, Xi'an, China, in 1994. She received her M.S. and Ph.D. degrees at Xidian University, Xi'an, China, in 1997 and 2003, respectively.

In April 1997, she joined the Xidian University and is currently an Associate Professor with Electronic and Engineering institute. From March 2016 to April 2017, she was a Visiting Scholar with the EMC Laboratory, Missouri University of Science and Technology (formerly University of Missouri-Rolla), Missouri, USA. Her current research interests include signal/power integrity and jitter analysis in high-speed digital systems.

### **Workshop IV. Title: Machine Learning for Hardware Design**

**Organizer:** Madhavan Swaminathan

**Affiliation:** Georgia Institute of Technology

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**Abstract:** Moore scaling and More than Moore scaling have led to the miniaturization of electronic systems over the last several decades. This trend is expected to continue into the future with applications related to high performance computing, automotive, internet of things and health care being major drivers. EDA tools have allowed the electronics industry to successfully manage more than five decades of exponential increase in design complexity. These tools have always relied on simulation for the development of low-cost, safe, energy-efficient electronic systems ranging from smart phones to airplanes. Though these tools have reduced the number of design re-spins, the observed failures during qualification testing continue to be a direct result of insufficient modeling capability. Therefore, a new and better approach to generating models are necessary that can advance the capabilities of EDA. This special session explores the use of Machine Learning based modeling as a way to design and optimize electronic systems. The speakers in this workshop cover diverse areas related to IC, Package and System integration.



**Madhavan Swaminathan** is the John Pippin Chair in Microsystems Packaging & Electromagnetics in the School of Electrical and Computer Engineering (ECE) and Director of the Center for Co-Design of Chip, Package, System (C3PS), Georgia Tech. He formerly held the position of Joseph M. Pettit Professor in Electronics in ECE and Deputy Director of the NSF Microsystems Packaging Research Center, Georgia Tech. Prior to joining Georgia Tech, he was with IBM working on packaging for supercomputers. He is the author of 450+ refereed technical publications, holds 29 patents, primary author and co-editor of 3 books, founder and co-founder of two start-up companies (E-System Design and Jacket Micro Devices) and founder of the IEEE Conference Electrical Design of Advanced Packaging and Systems (EDAPS), a premier conference sponsored by the packaging society on Signal Integrity in the Asian Region. He is an IEEE Fellow and has served as the Distinguished Lecturer for the IEEE EMC society. He received his MS and PhD degrees in Electrical Engineering from Syracuse University in 1989 and 1991, respectively.

**Speaker:** Prof. Paul Franzon

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**Paul D. Franzon** is currently the Cirrus Logic Distinguished Professor of Electrical and Computer Engineering and Director of Graduate programs in ECE at North Carolina State University. He earned his Ph.D. from the University of Adelaide, Adelaide, Australia. He has also worked at AT&T Bell Laboratories, DSTO Australia, Australia Telecom and three companies he cofounded, Communica, LightSpin Technologies and Polymer Braille Inc. His current interests center on the application of, technology and design of complex microsystems incorporating VLSI, advanced packaging and nano-electronics.

He has lead several major efforts and published over 300 papers in these areas. In 1993 he received an NSF Young Investigators Award, in 2001 was selected to join the NCSU Academy of Outstanding Teachers, in 2003, selected as a Distinguished Alumni Professor, received the Alcoa Research Award in 2005, and the Board of Governors Teaching Award in 2014. He served with the Australian Army Reserve for 13 years as an Infantry Soldier and Officer. He is a Fellow of the IEEE.