

APEMC 2017

2017 Asia-Pacific International Symposium on Electromagnetic
Compatibility (APEMC)

20-23 June, 2017 / The Commons, Yonsei University, Seoul, Korea

Final Program : Tutorial and Workshop

Organized by

Yonsei University

Korea Advanced Institute of Science and Technology (KAIST)

Korean Institute of Electromagnetic Engineering and Science (KIEES)

Technical Program at a Glance

Data	Time	Industrial Bank of Korea Hall	Kwak Joung-Hwan Challenge Hall	Helinox Hall	Muak Rotary Club Hall	Exhibition
20 June (Tuesday)	09:00~17:00	Registration (Lobby)				
	10:00~11:50	TU-AM-1: Introduction to “EMC Made Simple” – Printed Circuit Board and System Design	TU-AM-2: SI/PI/EMI Modeling, Simulation and Design			
	11:50~13:00	Lunch Break				
	13:00~14:50	TU-PM-1A: Electromagnetic Compatibility of Switched-Mode Power Supplies (I)	TU-PM-2A: The Role of the IEC Advisory Committee on EMC (ACEC) in Coordinating IEC EMC Activities (I)	TU-PM-3: How to Publish a Paper in the EMC Transactions		
	14:50~15:10	Afternoon Break				
	15:10~17:00	TU-PM-1B: Electromagnetic Compatibility of Switched-Mode Power Supplies (II)	TU-PM-2B: The Role of the IEC Advisory Committee on EMC (ACEC) in Coordinating IEC EMC Activities (II)	TU-PM-4: Metamaterials, Periodic Structures and EBG in EMC/Wave Problems/BioEM		
	18:30~21:00	Welcome Reception				
21 June (Wednesday)	08:00~18:00	Registration (Lobby)				
	09:00~10:20	WE-AM-1: EMC Measurements (I)	WE-AM-2: Wireless Power Transfer	WE-AM-3: EMC of Integrated Circuits (I)	WE-AM-4: EMC Materials	
	10:20~10:40	Morning Break				Open
	10:40~12:20	Opening Ceremony (Venue : Kumho Art Hall) Keynote Speech I : Signal and Power Integrity – Research in EMC (Christian Schuster, Hamburg University of Technology, Germany) Keynote Speech II : Biological Effects of Radio Frequency Electromagnetic Fields on the Brain (Young-Hwan Ahn, Ajou University, Korea)				
	12:20~13:30	Lunch Break				
	13:30~14:50	WE-PM-1: EMC Measurements (II)	WE-PM-2: EMC Standards and Design	WE-PM-3: EMC of Integrated Circuits (II)	WE-PM-4: ESD and Transient EMC	
	14:50~15:10	Afternoon Break				
	15:10~16:50	WE-PM-5: Transport and Aerospace EMC	WE-PM-6: EMC Issues on Wireless Power Transfer	WE-PM-7: Hardware Security for Information/Communication Devices	WE-PM-8: Hot Issues Antenna & Wave Propagation	
	17:00~18:00	WE-PM-9: Poster Session (I) (Venue : Lobby)				

Data	Time	Industrial Bank of Korea Hall	Kwak Joung-Hwan Challenge Hall	Helinox Hall	Muak Rotary Club Hall	Exhibition	
22 June (Thursday)	08:00~18:00	Registration (Lobby)					Open
	09:00~10:20	TH-AM-1: System-level EMC	TH-AM-2: Modeling and Simulation Techniques for EMC, SI and PI (I)	TH-AM-3: EMC Issues Related to Common-mode Noise (I)	-		
	10:20~10:40	Morning Break					
	10:40~12:20	TH-AM-4: Signal Integrity and Power Integrity	TH-AM-5: Power Electronics Related EMC	TH-AM-6: Biological Effects of EMC	TH-AM-7: Radio-Frequency Interference		
	12:20~13:30	Lunch Break					
	13:30~14:30	TH-PM-1: Electronic Packaging EMC	TH-PM-2: Modeling and Simulation Techniques for EMC, SI and PI (II)	TH-PM-3: EMC Issues Related to Common-mode Noise (II)	TH-PM-4: Electromagnetic Environment and High Power EMC		
	14:30~14:50	Afternoon Break					
	14:50~16:50	TH-PM-5: Antenna and Wave propagation	TH-PM-6: Computational Electromagnetics and Multiphysics methods for Simulating Complex Electromagnetic Environment Effects	TH-PM-7: Near Field Scanning Technology for EMC	TH-PM-8: EMC & Antenna Design for Wireless Communication Systems		
	17:00~18:00	TH-PM-9: Poster Session (II) (Venue : Lobby)					
	18:30~21:00	Banquet (Venue : Grand Ballroom)					
23 June (Friday)	09:00~17:00	Registration (Lobby)					
	10:00~11:50	FR-AM-1: Testing of Wireless Devices in the Modern World	FR-AM-2: Development of Time-Domain Computational Electromagnetics Methods for Fast Characterizing Complex Electromagnetic Environment Effects	FR-AM-3: Current Activity in the CISPR 16 Series of EMC Standards			
	11:50~13:00	Lunch Break					
	13:00~14:50	FR-PM-1A: Advances in Automotive EMC Test and Measurement (I)	FR-PM-2A: Protection of the Electric Power System from High-altitude Electromagnetic Pulse (HEMP) and Intentional Electromagnetic Interference (IEMI) (I)	FR-PM-3: EMC Standard Measurement in Japanese Industry – Efforts to Improve the Accuracy of Measurement			
	14:50~15:10	Afternoon Break					
15:10~17:00	FR-PM-1B: Advances in Automotive EMC Test and Measurement (II)	FR-PM-2B: Protection of the Electric Power System from High-altitude Electromagnetic Pulse (HEMP) and Intentional Electromagnetic Interference (IEMI) (II)	FR-PM-4: Practical Aspects of a Comprehensive Space Charging Analysis				

Tutorials and Workshops

Tutorials (Tuesday, 20 June)

TU-AM-1: Introduction to “EMC Made Simple” – Printed Circuit Board and System Design

Time 10:00 – 11:50, Tuesday, 20 June
Room Industrial Bank of Korea Hall (B145)
Chair(s) Mark Montrose (Montrose Compliance Services, Inc., Santa Clara, CA, USA)

Abstract

This tutorial presents applied, hands-on content associated with both the design of printed circuit boards and integration into an enclosure to create a functional system that meets any EMC requirement, both emissions and immunity at an introductory level. The target audience is everyone regardless of expertise level who would like to [re]learn electromagnetic theory in a unique non-academic manner “without the math”. Electrical engineering involves understanding transmission line theory thinking in the time domain. An electromagnetic field propagates between a source and load using a transmission line; radiated field or conducted current. Any propagated electromagnetic energy loss that occurs within the transmission line creates undesired common-mode current. To make Maxwell Equations Made Simple, a subset of EMC Made Simple, a visualization approach is taken that allows attendees to understand what Maxwell tells us, converting his four equations conceptually into five simple algebraic equations to solve almost any EMC problem in minutes, using only a calculator. If we understand electromagnetic theory at the circuit or component level, designing anything electrical becomes simple.

- **Introduction to “EMC Made Simple” – Printed Circuit Board and System Design**
Mark Montrose (Montrose Compliance Services, Inc., Santa Clara, CA, USA)

TU-AM-2: SI/PI/EMI Modeling, Simulation and Design

Time 10:00 – 11:50, Tuesday, 20 June
Room Kwak Joung-Hwan Challenge Hall (B146)
Chair(s) Hideki Asai (Shizuoka University, Hamamatsu, Japan)

Abstract

Recently, with the progress of the electrical and electronic equipment, novel methodologies have been demanded for verification of the design. Therefore, a variety of electromagnetic (EM) simulation techniques have attracted attention very much for the efficient SI/PI/EMI (Signal Integrity/ Power integrity/ Electromagnetic Interference) design. In this session, we discuss several kinds of numerical techniques and their applications to efficient electronic design.

- **Signal Integrity (SI) Design and Analysis of Heterogeneous Integration Using Embedded Multi-die Interconnect Bridge (EMIB) Technology for High Bandwidth Memory (HBM)**
Kyungjun Cho (KAIST, Daejeon, Korea)
- **Advanced SI/PI/EMI Simulation Technology for Automotive ECU Design**
Hideki Asai (Shizuoka University, Hamamatsu, Japan)
- **Fast evaluation of transmission characteristics of wiring harnesses using the RLGC parameters**
Fengchao Xiao (The University of Electro-Communications, Tokyo, Japan)
- **Circuit interpretation of mode conversion in differential-line interconnects under the assumption of weak imbalance**
Flavia Grassi (Politecnico di Milano, Milan, Italy)

TU-PM-1A & 1B: Electromagnetic Compatibility of Switched-Mode Power Supplies

Time 13:00 – 17:00, Tuesday, 20 June (14:50 – 15:10 Coffee Break)
Room Industrial Bank of Korea Hall (B145)
Chair(s) Gunter Keller (Deggendorf Institute of Technology, Deggendorf, Germany)

Abstract

The tutorial is subdivided into six parts: Terminology and legal requirements, EMC tests (emissions and immunity), coupling mechanisms and countermeasures, types of interferences and their characteristics, origin of electromagnetic interferences in switched-mode power supplies and practical aspects of EMC design of switched-mode power supplies (SMPS).

After an overview of international standards and test procedures the coupling mechanisms are explained in theory and in SMPS applications with a number of worked examples. Signals are classified into differential and common mode and discussed in terms of Fourier analysis.

The origin of interferences are discussed in terms of normal operating mode of SMPS in low, medium and high frequency range, common-mode and differential-mode and due to parasitics of active and passive components.

Main part (half of the time) is the EMC design, including power factor correction, EMC filter, shielding, hard and soft-switching converters, suitable active and passive components, general and specific layout recommendations, examples: buck converter, flyback converter, immunity. Many recommendations are confirmed by measurements or simulations. Other characteristics as efficiency and life time are also taken into account.

- **Electromagnetic Compatibility of Switched-Mode Power Supplies**
Gunter Keller (Deggendorf Institute of Technology, Deggendorf, Germany)

TU-PM-2A & 2B: The Role of the IEC Advisory Committee on EMC (ACEC) in Coordinating IEC EMC Activities

Time 13:00 – 17:00, Tuesday, 20 June (14:50 – 15:10 Coffee Break)
Room Kwak Joung-Hwan Challenge Hall (B146)
Chair(s) Donald Heirman (Don HEIRMAN Consultants, Lincroft, NJ, USA)
William A. Radasky (Metatech Corporation, Goleta, CA, USA)

Abstract

This Tutorial continues to update researchers in the field of EMC of the coordination of EMC standards and activities in the International Electrotechnical Commission (IEC) by the IEC Advisory Committee on EMC known as ACEC. The members of this committee include representatives of IEC technical committees that produce EMC basic standards for measurement instrumentation/measurements and also product committees that apply the basic standards along with specific test levels, performance criteria, and emission limits.

- **What is ACEC?**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **Recent Trends in CISPR and its Subcommittees**
Donald Heirman (Don HEIRMAN Consultants, Lincroft, NJ, USA)
- **Recent Trends in TC77 and its Subcommittees**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **Emission Standardization in the 2 kHz to 150 kHz Frequency Band**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **EMC for E-mobility**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **Recent Topics in IEC TC62 (Electrical Equipment in Medical Practice) and its Subcommittees**
Donald Heirman (Don HEIRMAN Consultants, Lincroft, NJ, USA)

- **TC106 Overview: Assessment of Human Exposure to EMF**
Donald Heirman (Don HEIRMAN Consultants, Lincroft, NJ, USA)

TU-PM-3: How to Publish a Paper in the EMC Transactions

Time 13:00 – 14:50, Tuesday, 20 June
 Room Helinox Hall (B147)
 Chair(s) John Norgard (NASA/JSC EMI/EMC E3 Lab, Houston, USA)

Abstract

This tutorial is on the IEEE Transactions on Electromagnetic Compatibility (EMCT).
 Presentations on EMCT include:

- i) How to publish a paper in the EMCT.
- ii) How to prepare and write a good technical paper for the EMCT.

The presentation for part i), by Prof. Norgard, entitled “Publishing a Paper in the EMCT”, will cover the initial paper preparation process (topic & text), the submission process, the review cycle (Reviewers, Associate Editors, and the Editor-in-Chief), and final paper publication procedures for the IEEE Transactions on EMC. In addition, acceptance criteria are covered, along with style guides, on-line web support and help-aids, and proper paper organization.

The presentation for part ii), by Dr. Wilson, entitled “Writing a Good EMCT Paper: My Perspective” will cover aspects of writing a good paper for submission to the IEEE Transactions on EMC. Covered will be goals, hints, and dos and don'ts for the abstract, index terms, main text, and conclusions of a paper. The material is very much from the personal perspective of the presenter based on his experience as both a reviewer and a former Editor-in-Chief of the Transactions.

This EMCT tutorial is intended for anyone and everyone interested in publishing a paper in the EMCT, especially for the first time.

- **How to Publish a Paper in the EMC Transactions**
John Norgard (NASA/JSC EMI/EMC E3 Lab, Houston, USA)
- **How to Prepare and Write a Good Technical Paper for the EMC Transactions**
Perry Wilson (NIST, Boulder, USA)

TU-PM-4: Metamaterials, Periodic Structures and EBG in EMC/Wave Problems/BioEM

Time 15:10 – 17:00, Tuesday, 20 June
 Room Helinox Hall (B147)
 Chair(s) Sungtek Kahng (Incheon National University, Incheon, Korea)

Abstract

As the operating frequency goes higher and the demands on complex architectures of electronics and new materials increase, the classic guide lines and design rules on EMC and RF device designs are facing the challenges and limitations in meeting the requirements

In response to the need to find the alternatives, periodic structures such as FSS are adopted or hybridized with the conventional practices to stop the radiated/conducted noise and unwanted resonance more effectively. Especially, the photonic bandgap design as the periodic structures with perfect or imperfect periodicity is revisited and becomes the EBG by being adapted to RF frequency from optics.

With a different motivation, metamaterial is researched that when permittivity and permeability the constitutive parameters of a material are given unusual or usual values, they possibly result in phenomena interpreted meaningful to overcome the limitations above in EMC, microwave engineering and Bio EM problems. Particularly, the left-handedness and the infinite wavelength are introduced by negative permittivity and negative permeability and zero refractive index, respectively, and they are used to change the direction or phase of wave propagation. The dispersion engineering stemming from the metamaterials has drawn attention in that it is helpful to reduce the volume of a structure and form a bandgap free from the resonance condition of the conventional periodic structure approach. So, in this session, the analysis and design methods of FSS, DNG/SNG/AMC and EBG are dealt with as well as advanced applications to EMC/antenna/RF designs/Bio

EM & Human-EM Interaction. Also, we discuss the slow-wave effects of a periodic geometry and the resonant slots(non-metamaterial) of DGS and SRR/CSRR. Last but not least, a number of electromagnetic computational methods are shown to efficiently and accurately predict the scattering and radiation of the aforementioned structures.

- **Introduction to Metamaterials and the Advanced Technologies in EMC and RF Passive Components/Antennas**
Sungtek Kahng (Incheon National University, Incheon, Korea)
- **Advanced Technologies in RF Active Components**
Hongjoon Kim (Kyungpook National University, Daegu, Korea)
- **Advanced Technologies in BioEM problems**
Sungtek Kahng (Incheon National University, Incheon, Korea)

Workshops (Friday, 23 June)

FR-AM-1: Testing of Wireless Devices in the Modern World

Time 10:00 – 11:50, Friday, 23 June
Room Industrial Bank of Korea Hall (B145)
Chair(s) Alex Yeo (ETS-Lindgren, Singapore)

Abstract

With the continuous development of wireless technologies and their tight integration with various electronic/computer/communication devices, EMC issues, at both the system and the intra-system levels, become increasingly important. This tutorial will begin with a general overview on IoT and the new IEEE IoT Initiative, of which the IEEE EMC Society is a member. The workshop provides an overview and primer on testing wireless devices, the biggest challenges the test labs face with testing wireless devices and their techniques for addressing those challenges. We will look at the increasing concern of IEMI effects on wireless communication. The tutorial will conclude with a review of the growing wireless activity at the National Institute of Standards and Technology, the US Government metrology lab of the USA.

- **Internet of Things: IoT, M2M, 5G & EMC**
Mike Violette (Washington Labs, Gaithersburg, MD, USA)
- **Complex Challenges in Measuring 5G/Millimeter Wave Device Performance**
Andy Chung (ETS-Lindgren, Tokyo, Japan)
- **Assessing the Vulnerability of Wireless Systems to (Intentional) EMI**
Frank Leferink (University of Twente Enschede, The Netherlands; Thales Netherlands Hengelo, The Netherlands)
- **Millimeter-wave Channel Sounder Development at the National Institute of Standards and Technology**
Perry Wilson (National Institute of Standards and Technology, Boulder, CO, USA)

FR-AM-2: Development of Time-Domain Computational Electromagnetics Methods for Fast Characterizing Complex Electromagnetic Environment Effects

Time 10:00 – 11:50, Friday, 23 June
Room Kwak Joung-Hwan Challenge Hall (B146)
Chair(s) Wen-Yan Yin (Zhejiang University, Hangzhou, China)

Abstract

In this workshop, new research progresses in the development of computational time-domain electromagnetics methods will be addressed for fast solving and characterizing various complex electromagnetic environment effects in the presence of high-power electromagnetic pulse (HP-EMP) or intentional electromagnetic interferences (IEMI). These methods mainly include hybrid finite difference time domain (FDTD), time-domain integral equation (TDIE), adaptive integration method (AIM) together with time-domain physics optics approximation, etc. Some typical numerical examples will be shown to demonstrate their capability for accurately predicting 3-D current and field distributions over missile, aircraft and warship platforms for different incident EMP strengths, directions, and polarization states.

- **Development of Time-Domain Computational Electromagnetics Methods for Fast Characterizing Complex Electromagnetic Environment Effects**
Wen-Yan Yin (Zhejiang University, Hangzhou, China)

FR-AM-3: Current Activity in the CISPR 16 Series of EMC Standards

Time 10:00 – 11:50, Friday, 23 June
Room Helinox Hall (B147)
Chair(s) Zhong Chen (ETS-Lindgren, Cedar Park, TX, USA)

Abstract

The CISPR 16 series is an important basic standard in EMC and continues to be updated by CISPR Sub Committee A. Important changes to this standard continue below 30 MHz, above 1 GHz and in the areas of equipment calibration. Our speakers include experts active in the CISPR Subcommittee A and in the ANSI ASC C63® committee on EMC. Mark Terrien will describe changes associated with CISPR 16-1-1 on EMI receivers; Zhong Chen will discuss measurement uncertainty associated with CISPR 16-4-2; and Wolfgang Muellner will discuss the methods being developed for radiated measurements below 30 MHz.

- **Understanding the Importance of EMI Compliance Receiver Calibration Measurements**
Mark Terrien, (Keysight Technologies, Santa Rosa, CA, USA)
- **CISPR 16 Measurement Instrumentation Uncertainties from Site Contribution for Radiated Emissions Measurements above 1 GHz**
Zhong Chen (ETS-Lindgren, Cedar Park, TX, USA)
- **Recent Developments in CISPR 16 Series on Measurements below 30 MHz**
Wolfgang Muellner (Seibersdorf Laboratories, Siebersdorf, Austria)

FR-PM-1A & 1B: Advances in Automotive EMC Test and Measurement

Time 13:00 – 17:00, Friday, 23 June (14:50 – 15:10 Coffee Break)
Room Industrial Bank of Korea Hall (B145)
Chair(s) Alex Yeo (ETS-Lindgren, Singapore)

Abstract

Vehicle platforms continue to become increasingly more complex with propulsion, entertainment and safety related systems all having to function reliably without impacting safety or the legacy communications infrastructure. In this workshop, industry experts will share their latest research in automotive EMC test and measurement. They will address current and future requirements brought on by the increasing use of electronic components as well as the increased demand for electric and hybrid vehicles. This has driven the need for ever increasing permutations of system operation, operating frequency ranges and immunity levels. This will be discussed in light of current EMC test chamber design and test challenges.

- **An Update on Global Automotive EMC Standards and Testing**
Hyunwoo Park (Hyundai Calibration & Certification Technology, Icheon, Korea)
- **EMC Chamber Design and Test Challenges for E-Vehicles and Electronic Sub-Assemblies (ESA)**

K.D. Kim (ETS-Lindgren, Cedar Park, TX, USA)

- **Novel and Simplified Immunity Testing Methods for Automotive Applications**
Flavia Grassi (Politecnico di Milano, Milan, Italy)
- **Common RF Absorbers Evaluations in the W Band (75-110 GHz)**
Zhong Chen (ETS-Lindgren, Cedar Park, Texas, TX, USA)
- **Suppression of Power/Ground Noise on Power Window Control System in Automotive**
Karam Hwang (KAIST, Daejeon, Korea)

FR-PM-2A & 2B: Protection of the Electric Power System from High-altitude Electromagnetic Pulse (HEMP) and Intentional Electromagnetic Interference (IEMI)

Time 13:00 – 17:00, Friday, 23 June (14:50 – 15:10 Coffee Break)

Room Kwak Joung-Hwan Challenge Hall (B146)

Chair(s) William A. Radasky (Metatech Corporation, Goleta, CA, USA)

Abstract

Over the past 28 years the International Electrotechnical Commission (IEC) has written 22 standards and reports dealing with the environments and protection of civil electronic systems from HEMP and IEMI. Because it has become clear that the electric power system is the most important critical infrastructure in advanced economies throughout the world, it is important that these standards be applied to protect the basic building blocks of the high voltage power system: substations and control centers. This tutorial will present how the IEC standards can be used to provide the necessary levels of protection against these two security threats.

- **Description of the Radiated and Conducted Environments Associated with HEMP and IEMI**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **Description of the Vulnerability of Electronic Equipment to HEMP and IEMI**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)
- **Approach to the Hardening of Power Substations and Control Centers to HEMP and IEMI**
William A. Radasky (Metatech Corporation, Goleta, CA, USA)

FR-PM-3: EMC Standard Measurement in Japanese Industry – Efforts to Improve the Accuracy of Measurement

Time 13:00 – 14:50, Friday, 23 June

Room Helinox Hall (B147)

Chair(s) Osami Wada (Kyoto University, Kyoto, Japan)

Abstract

In the Technical Working Groups in Expert Committee on EMC in KEC (KEC Electronic Industry Development Center) in Japan, practical research activities on EMC measurement technology related to EMC standard measurement have been conducted. The experts will explain important notes on ensuring measurement accuracy and measurement reliability in conducting measurement conforming to the EMC standard.

The topics in this workshop include; influence of measurement environment in radiated and conducted emission tests and influence of measurement system difference which have been clarified in a series of round robin tests; possibility of antenna calibration in an anechoic chamber and verification of its accuracy; important points on magnetic field measurement in radiated emission test below 30 MHz; and EMC measurement of automotive electronic devices. In addition, we will introduce the current status and future prospects of EMC test standards in Japan, particularly in comparison with US / European / Asian standards.

- **Workshop Overview**
Osami Wada (Kyoto University, Kyoto, Japan)
- **Radiated Emission Test - Influence of Measurement Environment**
Hirotugu Hashimoto, (Riken Environmental System Co. Ltd., Kumagaya, Japan)
- **Conducted Emission Test - Influence of Measurement System Difference**
Masahiro Inoue (KEC Electronic Industry Development Center, Kyoto, Japan)
- **Verification of Accuracy and Validity of Antenna Calibration in Anechoic Chamber**
Yujiro Seki (IPS Corporation, Nagano, Japan)
- **Important Points on Magnetic Field Measurement in Radiation Emission Test Below 30 MHz**
Fumiaki Yaguchi (TOYO Corporation, Tokyo, Japan)
- **Japanese EMC Test Standards - Comparison with US / European / Asian Standards and Future Perspective**
Aki Hattori (Tokin EMC Engineering Co., Ltd., Kawasaki, Japan)
- **Issues in EMC measurement of automotive electronic devices**
Takanori Uno (DENSO EMC Engineering Service Corporation, Kariya, Japan)

FR-PM-4: Practical Aspects of a Comprehensive Space Charging Analysis

Time 15:10 – 17:00, Friday, 23 June
Room Helinox Hall (B147)
Chair(s) Bryon Neufeld (Electro Magnetic Applications, Lakewood, CO, USA)

Abstract

Space charging presents a significant safety and reliability risk for many space platforms. Proper design strategy can mitigate or greatly reduce the risks associated with space charging. It is often not feasible or is even impossible to perform full vehicle testing for space charging, and testing does not offer the possibility to quickly and inexpensively check the effectiveness of design permutations. This makes numerical analysis an important part of developing an effective design strategy against space charging risks. In this presentation, we focus on some of the practical steps and issues involved with performing a comprehensive space charging analysis. We will discuss the model geometry development, materials characterization, simulation and processing that go into numerically assessing charging risks. We will also discuss how aspects of the space environment, including different plasma environments, sunlight illumination, and plume and wake effects, impact the charging analysis.

- **Surface Charging, Geometry Development and Meshing**
Bryon Neufeld (Electro Magnetic Applications, Lakewood, CO, USA)
- **Plume Modeling, Internal Charging**
Nicole Pothier McGillivray (Electro Magnetic Applications, Lakewood, CO, USA)
- **Programmatic Considerations**
Bob Scully (NASA, Houston, TX, USA)