TECHNICAL PAPER ABSTRACTS

Computational EM 1

Modeling Experiences With Full-Wave Time-Domain Modeling Software

H. Zeng, C. Su, H. Ke, T. Hubing, Clemson University, Clemson, United States

When evaluating electromagnetic modeling software, there is usually a significant focus on the "accuracy" of the software. Differences between the results generated by the software and the "correct" solution are the result of several potential sources of error. Of those potential error sources, differences between what the modeler wants to analyze and what the software is actually modeling is usually the greatest source of error even when the analysis is being done by experienced modelers. In this paper, three full-wave time-domain EM modeling codes are evaluated by analyzing three simple canonical problems. These codes employ the three most common time-domain modeling techniques: Transmission Line Matrix method (TLM), the Finite Integration Technique (FIT) and the Finite Difference Time Domain technique (FDTD). The three canonical problems are a center-driven dipole, a circuit board power-bus structure, and a power-bus structure with a cable attached.

Analysis of Distributed Coupling along Nonparallel Traces using PEEC with Phase Term Expansions

M. A. Cracraft[1], J. L. Drewniak[2], [1]IBM Corporation, Poughkeepsie, United States, [2]Missouri Institute of Science and Technology, Rolla, United States

Electrically large problems require full-wave calculations that can be handled using PEEC using either static phase approximations, phase term expansions, or the dynamic Green's function directly. When distributed coupling is significant between traces, parallel or nonparallel, a quasi-static approximation will return incorrect results in the coupling terms. Nonparallel coupled lines pose a problem that is not easily solved by transmission lines, but may in some cases be analyzed by lumped element models or quasi-static models when near-end coupling dominates.

Statistical Response of Nonlinear Equipment in a Reverberation Chamber

I. D. Flintoft, L. Dawson, A. C. Marvin, University of York, York, United Kingdom

The statistics of the fields scattered by nonlinear equipment in a reverberation chamber are investigated using both a Monte-Carlo simulation of a simple statistical model and measurements of real equipment. The probability distributions of the scattered fields of the second and third harmonic are predicted and compared to measurement. The implications of the results for the immunity assessment of digital hardware and harmonic cross-section measurements in reverberation chambers are discussed.

Multiconductor Transmission Line Modeling with VHDL-AMS for EMC Applications

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A multiconductor transmission line (MTL) model for the time domain considering losses, incident fields and skin-effects for the modeling language VHDL-AMS was developed. The model is based on the FDTD method. It can be extended by various VHDL-AMS circuit files and used for linear and non-linear time domain simulations. Modern standardized modeling languages like VHDL-AMS have the important advantage that growing model libraries permit fast creation of large simulation models. Exchange of models and extension of models is easily possible. After a short introduction to VHDL-AMS and presentation of the MTL and FDTD theory used for modeling, examples are shown. The developed model is compared to calculation results gained with other simulation methods. The validity of the implemented VHDL-AMS model is proved.

TECHNICAL PAPER ABSTRACTS

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Aperture modeling using a hybrid method for RFI analysis

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A hybrid method is proposed for radio frequency interference (RFI) prediction of a metal enclosure with an aperture on the top wall. The structure is divided into several segments. While the fields in rectangular segments are described by cavity model, the segments with apertures are modeled by the commercial finite element solver (HFSS). Tangential field continuities along the common boundaries of different segments are enforced by the voltages and currents of boundary ports. Good agreement has been achieved between the hybrid method and full wave simulation.

The Discontinuous Galerkin Finite Element Time Domain Method (DGFETD)

S. D. Gedney[2,1], J. A. Roden[1,2], T. Kramer[1,2], R. Crawford[1,2], C. Luo[1,2], B. Guernsey[1,2], [1]The Aerospace Corporation, Chantilly, United States, [2]The University of Kentucky, Lexington, United States

The Discontinuous Galerkin Finite-Element Time-Domain method is presented. The method is based on a high-order finite element discretization of Maxwell's time-dependent curl equations. The mesh is decomposed into contiguous sub-domains of finite-elements with independent function expansions. The fields are coupled across the sub-domain boundaries by enforcing the tangential field continuity. This leads to a locally implicit, globally explicit difference operator that provides an efficient high-order accurate time-dependent solution. An efficient implementation of the perfectly matched layer media boundary truncation is also presented that allows general tetrahedral meshing through the PML region.

TECHNICAL PAPER ABSTRACTS

PCB Design 1

An Investigation on the Reduction Technique of Radiated Emission from Chassis with PCB

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Correlation between radiated emission from chassis with PCB and the junction current which is the current flowing through screws connecting PCB GND to chassis GND was investigated, and new technique to reduce the junction current was proposed. The measurement results of the junction current frequency spectra showed strong correlation with the emission from chassis with PCB. Also investigation using meshed LCR network SPICE model of PCB and chassis was performed. The calculation results of the junction current showed good correlation with measurement results for frequency spectrum and it suggested that the closer to screw bypass capacitor is placed, the lesser current flows through junction. That new concept was validated by actual measurement and the results of radiated emission showed 19 dB improvements at 320 MHz.

Inductance Calculations For Advanced Packaging in High-Performance Computing

H. Kwak[1], H. Ke[1], B. Lee[2], T. H. Hubing[1], [1]Clemson University, Clemson, United States, [2]Samsung Electro-Mechanics, Suwon, Republic of Korea

Effective decoupling is crucial for the optimum performance of the power distribution network in an electronic system. As component packaging technologies evolve enabling tighter integration and faster operation of electronic systems, it is important to develop better decoupling strategies. This paper describes several new or proposed packaging structures and evaluates the connection inductance associated with possible decoupling capacitor locations. As expected, connections made on the chip tend to have a lower inductance than connections made on the package; and connections made on the package tend to have a lower inductance than connections made to the board. This illustrates the importance of providing decoupling capacitance as close to the chip as possible in order to maximize the effective bandwidth of the power distribution network.

Fast Evaluation of Electromagnetic Interference Between Antenna and PCB Traces for Compact Mobile Devices

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This paper proposes a technique for the fast evaluation of antenna-induced noise at the terminations of PCB traces on compact mobile phones platforms. The main approach is based on the classical theory of transmission lines with external field excitation. We show that a single full-wave electromagnetic simulation is needed to compute the coupling coefficients for an arbitrary location of the trace on the phone PCB. Therefore, the approach is ideally suited for the automated incorporation of EMI constraints within routing and placement algorithms and for parametric and what-if analyses.

TECHNICAL PAPER ABSTRACTS

Determining the Maximum Allowable Heatsink Voltage to Ensure Compliance with a Given Radiated Emissions Specification

X. He, H. Ke, T. H. Hubing, Clemson Vehicular Electronics Laboratory, Clemson, United States

A model to estimate the minimum voltage between a heatsink and a PCB that is required to generate a given radiated electromagnetic field strength from a PCB with attached cables is introduced. The model is based on a previously introduced technique for calculating the maximum possible radiated field due to a known voltage driving a heatsink against a circuit board with attached cables. A closed-form expression is derived that can be used to determine if a measured voltage on a heat sink is capable of generating a field strong enough to exceed an FCC or CISPR radiated emissions limit.

Experimental Validation of Imbalance Difference Model to Estimate Common-Mode Excitation in PCBs

Y. Toyota[1], T. Matsushima[1], K. Iokibe[1], R. Koga[1], T. Watanabe[2], [1]Okayama University, Okayama, Japan, [2]Industrial Technology Center of Okayama Prefecture, Okayama, Japan

A common-mode antenna model designed specifically for estimating the emissions from PCBs very quickly is composed of an excitation source and an antenna. This paper provides the experimental validation of an imbalance difference model of common-mode excitation. In the model, the excitation source is defined by the product of the difference of a current division factor related to the cross-sectional structure of the transmission line, with the voltage between signal line and return plane. Through an evaluation of radiation suppression due to a guard trace placed to narrow return plane, imbalance difference model is found to be generalized to the multi-conductor system and provide helpful information for noise suppression in PCB design.

TECHNICAL PAPER ABSTRACTS

Measurement Techniques 1

Statistical Approach to Alternative Test Method - Measurement Method of Conducted Disturbance Voltage -
K. Osabe[1], A. Maeda[2], J. Kawano[3], [1]VLAC, Tokyo, Japan, [2]A. Maeda Associates Inc., Yokohama, Japan, [3]VCCI, Tokyo, Japan

The WG2 of CISPR/SC-I is discussing a reference test method for measurement of conducted disturbance voltage at mains port. A statistical approach seems to provide reasonable evaluation results to determine that multiple test methods are alternative methods. In the study reported here, we obtained data from measurements of the conducted disturbance voltage at mains port, taken with two different test arrangements, The data recently gathered by VLAC (Voluntary EMC Laboratory Accreditation Center, Inc.) in two proficiency testing (PT) programs; we processed the data statistically and evaluated the results. From the results, we are able to conclude that measurements taken with two test arrangements could be used as alternative test methods.

In situ testing of large machines: alternative methods for conducted emission measurement
J. A. Catrysse, Khbo, Oostende, Belgium

The new European EMC Directive 2004/108 allows for alternative validation methods for large machinery. Following the related harmonized European standard EN50370-1, subassembly testing combined with a final monitoring of the machine may show proof of compliance. A related European Research Project TEMCA2 was developping new, alternative test methods that can easily be used for this final control of large machines, by in-situ testing. This paper is dealing with the description and validation of the methods for conducted emission.

In situ testing of large machines: alternative method for radiated emission measurement
J. A. Catrysse, Khbo, Oostende, Belgium

The new European EMC Directive 2004/108 allows for alternative validation methods for large machinery. Following the related harmonized European standard EN50370-1, subassembly testing combined with a final monitoring of the machine may show proof of compliance. A related European Research Project TEMCA2 was developing new, alternative test methods, that can easily be used for this final control of large machines, by in-situ testing. This paper is dealing with the description and validation of the methods for radiated emission.

Converting Total-Radiated-Power Measurements to Equivalent E-Field Data
H. Garbe, S. Battermann, Leibniz University of Hannover, Hannover, Germany

This paper discusses the procedure to convert total-radiated power measurements data to equivalent electrical field data, which might be get on a standardized test site. The algorithm in use is based on two parameters, which are the geometrical factor gmax and the directivity of equipment-under-test (EuT) Dmax. Both parameters are unknown for unintentional radiators. The aim of this paper is to collect the published information to predict these parameters and to discuss the influencing factors to get a useful approximation for gmax and Dmax. Especially the prediction of Dmax depends on the effective size of the EuT described by the radius of a sphere containing the EuT.

TECHNICAL PAPER ABSTRACTS

Calculation of Antenna Pattern Influence on Radiated Emission Measurement Uncertainty

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In radiated emission measurements an error is introduced by the directive receive antenna. The Monte Carlo Method was used to calculate this error where measured antenna pattern had been taken into account. Although there are large differences between the classical test set-up and the two improvements antenna tilting and antenna bore sighting the impact to the measurement uncertainty is low. For a test distance of 3 m the measurement uncertainty can be reduced from 5.62 dB to 5.43 dB with antenna tilting. With a bore sight antenna tower a reduction to 5.31 dB is feasible. The bias and uncertainty given by CISPR 16-4-2 are not adequate.

New radiated RF immunity/susceptibility test method using RF-pulsed rotating-EM field

K. Murano[1], M. Tayarani[2], F. Xiao[3], Y. Kami[4], [1]Tokai University, Hiratsuka-shi, Japan, [2]Iran University of Science and Technology, Narmak, Iran, [3]University of Electro-Communications, Chofu-shi, Japan, [4]University of Electro-Communications, Chofu-shi, Japan

A new radiated radio-frequency (RF) immunity/susceptibility test method using an RF-pulsed rotating-electromagnetic (EM) field is proposed. The RF-pulsed signal that has an arbitrary bandwidth can be generated by controlling the pulse width. Controlling the pulse width can generate the RF-pulsed signal having an arbitrary bandwidth. By using such RF-pulsed rotating-EM field as an incident-EM field of the immunity/susceptibility test, it is possible to easily investigate the immunity-weak points of electronic equipments. In this paper, the basic characteristics of the RF-pulsed rotating-EM field are clarified. Moreover, some susceptibility characteristics of a cavity with a slit measured by using the RF-pulsed rotating-EM field are shown as an example.

TECHNICAL PAPER ABSTRACTS

Automotive EMC

Outdoor Vehicular Test Range Turntable Impact on Electric-Field Uniformity Study

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This paper describes an electric-field uniformity evaluation of an automotive manufacturer's vehicular antenna range. Dipole measurements, vehicle gain measurements, ultra wideband measurements, and two independent electromagnetic simulations were performed to determine field uniformity characteristics of the antenna range. The simulations and measurements indicated that the turntable significantly influenced the site's field uniformity. It was determined that increasing the size of the metallic turntable degraded the field uniformity performance of the range. Ideally, the size of a metallic turntable should be minimized to maximize field uniformity performance.

Study of a conformal hidden wire antenna used for the detection of stolen cars

A. Ciccomancini Scogna, J. Wang, CST of America, Framingham, United States

Object of this paper is the analysis of a conformal wire antenna used for the detection of stolen cars. The antenna operates in the low frequency range 0-300MHz and it is located on the top part of the metallic chassis, over the back tire. Details on the simulation model are provided and results are validated by comparing two different numerical methods: time domain (Finite Integration Technique) and frequency domain (MoM). In particular the near field (surface current distribution on the vehicle) and the far field results are calculated for the frequency value of 170MHz and a matching network is also designed for the same frequency value in order to minimize the return loss of the antenna at 170 MHz.

Functional Safety and EMC for the Automotive Industry

S. Alexandersson, Lund University, Lund, Sweden

The new era of safety related electronic systems in vehicles puts new demands on the manufacturer to prove reliability and safety of the systems. Standards that earlier have been used by the industry to prove compliance with demands on functional safety are difficult to implement for the automotive industry. Difficulties also arise when trying to prove immunity against electromagnetic disturbances for a vehicle in the real world. The standardization organizations have now started the laborious work to adapt the standards to the reality in the automotive industry. This paper discusses the arising problems when existing standards are employed to comply with the demands on both electromagnetic compatibility and functional safety.

TECHNICAL PAPER ABSTRACTS

Estimation of the Statistical Variation of Crosstalk in Wiring Harnesses

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Analyzing interference problems in vehicle wiring harnesses requires fast and accurate methods of approximating crosstalk. Worst-case approximations using lumped element models are fast and easy to use, but run the risk of overestimating problems. Statistical methods that account for the random variation of wire position help prevent overdesign, but are often difficult and time-consuming to apply and lack a clear link between problems and their cause. Here we investigate the use of simple lumped-element models to predict the statistical variation of crosstalk in wire harness bundles. Models are based on lumped-element approximations, where inductance and capacitance values are calculated for a single bundle cross-section, and only the circuit position is varied. Accuracy was evaluated by comparing results to numerical simulations. The method does a good job of quickly predicting the reasonable worst-case values of crosstalk due to inductive or capacitive coupling.

Radiated Immunity Tests of Automotive EMC Challenge Vehicle Active Antenna Designs

J. K. Kuvedu-Libla, Delphi Electronics & Safety, Bad Salzdetfurth, Germany

One of the big challenges for the automobile and vehicle antenna manufacturers remains designing the vehicle active antennas for weak signal performance along with meeting the requirements of vehicle radiated immunity tests according to ISO 11451-2 and ISO 11452-2. The past vehicle testing have shown that some vehicle active antenna systems included during those tests had performance issues caused by the vehicle body sizes. Component radiated immunity tests of ISO 11452-2 challenges active antenna system designs. In order to reach effectively the vehicle performance goal, a deep knowledge about the design of the vehicle active antennas is required. There are three major topics this paper addresses: 1) Clarifying the technical parameters of the vehicle antenna designs; 2) Characterizing parameters useful for the “Electromagnetic Compatibility” (EMC) in order to pass the radiated immunity tests; and finally 3) Identifying the causes of the antenna amplifier distortion

Frequency Modulated (FM) Radio Band Audio Interference Pre-Compliance Test Method

S. Mee, Johson Controls Automotive Electronics, Cergy, France

The FM band radio is one of the most common receivers found in today’s automobile and is considered to be an important factor in consumer’s ratings of vehicle quality and craftsmanship. As automotive electronics continue to evolve with new technology and mounting locations, suppliers and automakers must take care not to create interference conditions between these sensitive on-board receivers and potential sources of noise. Therefore a significant amount of resources are applied in electrical component, systems, and vehicle development to ensure good radio performance. The authors propose a precompliance test method that can be used during electronic component and electronic system development to detect and quantify such cases of interference. The test method can be performed prior to vehicle integration to allow for efficient and low cost solutions to potential issues.

Open Forum 1

Comparing Full Lateral Metallization and Reference Plane Stitching in LTCC Boards for Satellite Applications

A. Trave, A. Di Pasquale, G. Antonini, A. Orlandi, University of L'Aquila, L'Aquila, Italy

In this paper a methodology for taking into account the frequency dependence of a possible referencing (grounding) techniques in LTCC boards for satellite applications is presented. The aim of this work is to analyze and compare the input impedance and S-parameters values for different strategies of inter connection of the reference planes among them. The numerical analysis presented has proven the importance of the lateral metallization set up in the LTCC board working into a metal housing. For board used stand alone the lateral metallization can be replaced by an adequate density of vias stitching among the planes. The modeling agrees well with real grounding solution.

Shielding Effectiveness of Planar Negative-Permeability Screens

G. Lovat, S. Celozzi, "La Sapienza" University of Rome, Roma, Italy

A planar screen made of a periodic array of small resonant particles showing a strong magnetic resonance is studied in detail. Two types of inclusions are considered: the double split-ring resonator (SRR) and the spiral resonator (SR). The homogenized screen is shown to behave as a homogeneous slab with an effective magnetic permeability having large positive or negative values around the magnetic resonance of the particle, giving rise to selective shielding properties. The shielding performance of the screen are investigated, and the effects of several geometric parameters are carefully evaluated through an equivalent-circuit representation of the single particle and full-wave simulations.

Techniques for Measuring the Common Mode Current and Voltage of ASIC Devices

R. Flinders, J. McHenry, E. Nakauchi, Emulex Corporation, Costa Mesa, United States

Abstract With the increasing numbers of transistors in today’s die as well as incorporating mixed technology (i.e. analog, RF, digital, and power), large scale devices with their large switching currents create internal voltage drops due to the package design (i.e. wire bond or flip-chip) that can be a source of common mode noise. The normal lumped components, the printed circuit boards, the harnessing, and the packaging are well known contributors and there are various measurement techniques to identify these noise sources. However, what is lacking are some measurement techniques applicable specifically for determining if a large scale integrated circuit type devices could be a noise source. This paper will look at a couple of proposed techniques specifically for the chip level.

The Influence of Test Parameters on TEM Cell Measurements of ICs

V. Kasturi, D. G. Beetner, Missouri University of Science and Technology, Rolla, United States

The IEC 61967-2 TEM cell standard allows for variations in test parameters which may cause variations in the measured emissions from integrated circuits (ICs). To test the impact of these parameters, two printed circuit boards were designed within the IEC standard using “poor” PCB design strategies and using “good” design strategies. Emissions from three pin-for-pin compatible 8051 microcontrollers were tested. Emissions were measured using both PCBs, changing the PCB configuration, and changing test parameters like the program running on the IC, the rise time of the input clock, and I/O switching. Emissions from the “poor” PCB were about 3-8 dB higher than emissions from the “good” PCB. A change in the program run by the IC, the clock rise-time, and I/O caused a 4-15 dB change in emissions. Emissions differed considerably among the ICs. Possible causes for variations in emissions with the test parameters are discussed.

TECHNICAL PAPER ABSTRACTS

Radio Frequency Compatibility of an RFID Tag on Glideslope Navigation Receivers

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A process is demonstrated to show compatibility between a radio frequency identification (RFID) tag and an aircraft glideslope (GS) radio receiver. The particular tag chosen was previously shown to have significant peak spurious emission levels that far exceeded the emission limits in the GS aeronautical band. The spurious emissions are emulated in the study by capturing the RFID fundamental transmission and playing back the signal in the GS band. The signal capturing and playback are achieved with a vector signal generator and a spectrum analyzer that can output the in-phase and quadrature components (IQ). The simulated interference signal is combined with a desired GS signal before being injected into a GS receiver's antenna port for interference threshold determination. Minimum desired propagation loss values to avoid interference are then computed and compared against actual propagation losses for several aircraft.

On Contact Conditions in Connectors to Cause Common Mode Radiation

Y. Hayashi[1], Y. Kayano[3], T. Mizuki[2], H. Sone[2], H. Inoue[4], [1]Tohoku University, Sendai, Japan, [2]Tohoku University, Sendai, Japan, [3]Akita University, Akita, Japan, [4]Akita University, Akita, Japan

When contact failure occurs in a connector in a coaxial HF signal transmission line, Common Mode (CM) radiation occurs on the line. We focus on contact conditions in a connector causing CM radiation. The experiments and the simulations verified that the CM radiation increases as contact resistance increases. While the CM current greatly depends on the pattern of distribution of contact resistance at a low resistance, the CM current does not depend on it at a high resistance. It is necessary to keep a distribution of four or more contact spots symmetrical.

Analysis and Improvement the Isolation between antennas on airborne platform with traveling wave antennas method

H. Y. Chun, S. D. Lin, C. W. Qing, D. K. Jia, Bei Jing University of Aeronautics and Astronautics, Beijing, China

Isolation between antennas is an important index for electromagnetic compatibility (EMC) on airborne platform. A solution which is adding traveling wave antennas to ameliorate the isolation between interfered antennas mounted on airborne platform is proposed in this paper. According to the radiation pattern and the absorbed characteristic of terminal impedance of traveling wave antenna, the harmful electromagnetic wave of a certain region could be absorbed and the isolation is improved. The method is validated by calculation and analysis.

Effect of slider conductive adhesive on EMI radiation of hard disk drives

E. Jang[1], H. Choi[2], Y. Ku[2], [1]Samsung Information Systems America , San Jose, United States, [2]Samsung Electronics Co. , Suwon , Republic of Korea

EMI radiations from hard disk drives are measured outside a computer in a 3 m anechoic chamber. Hard disk drives with two different adhesive materials between the suspension and head slider are compared in EMI radiation level. The average EMI radiation of one type is 52.87 dBuV/m while that of the other is 46.34 dBuV/m. The main causes for EMI radiation difference of the two types of drives are investigated in this study. They have different DC resistance, breakdown voltage, and capacitance between the suspension and head slider when used in head gumbal assembly. It was found that the capacitance between slider and suspension is a critical factor for EMI radiation of hard disk drives.

TECHNICAL PAPER ABSTRACTS

Signal Integrity 1

Signal Integrity Analysis of single-ended and differential signaling in PCBs with EBg structure

A. Ciccomancini Scogna[1], A. Orlandi[2], V. Ricchiuti[3], [1]CST of America, Framingham, United States, [2]University of L'Aquila, L'Aquila, Italy, [3]Technolabs, L'Aquila, Italy

Object of this paper is the signal integrity analysis of Printed Circuit Boards with Electromagnetic Bandgap structures. In particular the signal quality of single-ended and differential lines is discussed both in time and frequency domain (S-parameters, TDR and eye-diagrams). Two different configuration types (two dimensional and three dimensional) of Electromagnetic Bandgap structures are analyzed by means of a three dimensional full wave field simulator based on the Finite Integration Technique. Results show a consistent improvement of the signal integrity when differential signaling is used, while keeping the typical advantage of noise mitigation due to Electromagnetic Bandgap layers.

Signal integrity analysis of a 26 layer board with emphasis on the effect of non-functional pads

A. Ciccomancini Scogna, CST of America, Framingham, United States

Aim of this paper is the signal integrity analysis of a complex multilayer board with emphasis on the effect of non-functional pads. In particular it is demonstrated how in some cases it is mandatory removing the non-functional pads due to coupling mechanisms of the pads with the planes above and/or below. The unwanted capacitance adds capacitive loading to the via and if it is long enough a stub effect can be observed therefore reducing the signal quality. Accurate and reliable numerical simulations are in this case really important in order to correctly determine the impact of those nonfunctional pads on the signal integrity. A 26 layer Printed Circuit Board is analyzed by simulating with a 3D EM field solver a portion of the original brd Allegro file.

A Novel HU-shaped Common-mode Filter for GHz Differential Signals

S. Wu, H. Chuang, T. Wang, T. Wu, National Taiwan University, Taipei, Taiwan

A novel low-cost filter design for common-mode noise suppression in high-speed differential signals is proposed. It is realized by etching a HU-shaped defected-ground structure (DGS) to perturb the return current of the common-mode noise. A simple LC resonator model for the proposed structure is also developed with good agreement to the full-wave simulation and measurement result. It is found that over 15dB of common-mode noise suppression can be achieved over a wide frequency ranges from 3.6 to 9.1 GHz, while the differential signals still keep good signal integrity in eye-pattern observation.

Power/Ground Noise Immunity Test in Wireless and High-Speed UWB Communication System

C. Yoon, H. Park, W. Lee, M. Shin, J. Pak, J. Kim, KAIST, Daejeon, Republic of Korea

This paper presents a wireless and high-speed transceiver system for Ultra-Wideband (UWB) communication with a high noise immunity. A proposed transceiver system has a high-speed data transmission up to 130 Mbps. Then, the measurement setup for the noise immunity test is introduced. Also, in order to demonstrate a noise immunity of the system, timing jitter, accumulated waveform, and bit error rate (BER) are measured in the presence of a power/ground noise with various frequencies or amplitudes. The numerous measurement results help to understand the relationship between the power/ground noise and the noise immunity of the proposed transceiver system.

TECHNICAL PAPER ABSTRACTS

A 6.4Gbps On-chip Eye Opening Monitor Circuit for Signal Integrity Analysis of High Speed Channel

M. Shin[1], J. Kim[1], J. Pak[1], J. Shim[1], H. Kim[2], C. Hwang[1], J. Kim[1], Y. Kim[2], K. Park[2], C. Yoon[1], [1]KAIST, Daejeon, Republic of Korea, [2]Hynix, Kyunggi do, Republic of Korea

In this paper, we have proposed an on-chip eye opening monitor circuit with 4ps time and 4mv voltage resolutions for analyzing signal integrity of on-chip high speed channel. The proposed eye opening monitor circuit can detect the maximum 6.4Gbps data rate and give eye diagrams depending on on-chip high speed channel conditions. The performance of the proposed eye opening monitor circuit was verified by using a general spice simulations and showed the variations of eye diagram of 6.4 Gbps random data when on-die terminations of on-chip high speed channel was changed from 50 ohm to 80 ohm.

Method and Applications of Oscilloscope Waveform De-embedding to Remove Measurement Parasitics

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At multi-Gbps data rates, the electrical impact of test and measurement structures can distort the intended signals to be measured. Many specifications, such as PCI-Express, define a compliance point at which the electrical perform-ance of a component must be validated. To practically per-form the measurement, test fixtures on the PCB and cables to measurement equipment are often a necessary part of the measurement setup. This paper discusses a methodology for de-embedding the effects of the text fixtures and cables to recover the time domain waveform at the compliance point. De-embedding formulations are given and validated by time-domain waveform simulations. The methodology is then applied to a practical design to solve a real-world problem.

EM Environment

Understanding Pantograph Arcing in Electrified Railways -- Influence of Various Parameters
S. Midya[1], D. Bormann[3], A. Larsson [2,1], T. Schutte[4], R. Thottappillil[1], [1]Uppsala University, Uppsala, Sweden, [2]FOI -- Swedish Defence Research Agency, Tumba, Sweden, [3]ABB AB - Corporate Research, Västerås, Sweden, [4]Rejlers Ingenjörer AB, Västerås, Sweden

The most common and yet unavoidable EMC problems with electrified railways are due to pantograph arcing, which distorts the waveform of the supply voltage and current and in some cases even generates sharp voltage overshoots at the current zero crossings. In this paper we will discuss different modes of arc behavior and correlate them with parameters that describe test conditions, (like speed of the train, current, power factor, pantograph material etc.). A number of different voltage and current waveforms are analyzed and the influence of each of the parameters, both individually and in combination with others, is discussed.

The Use of High Performance HF Antenna Arrays to Optimize Reception in Urban Noise Environment
V. P. Arafiles[1,2], D. P. Anderson[1,2], M. T. Bail[2,1], [1]Department of Defense , Washington, United States, [2]Integrated Engineering Concept, Warsaw, United States

This paper presents a straightforward method to determine the sensitivity of an HF receiving system based upon measured noise as specified in antenna noise factor Fa or the measured noise field strength En. In using noise data to perform RF propagation analysis predictions for assessing the coverage capability of monitoring stations, noise has traditionally been described in rather generic terms as urban, suburban, rural and quiet rural. Also described is the development and deployment by the authors of HF antenna arrays that effectively eliminates the effect of man-made noise in receiving systems. The development of such high performance antennas has also led to changes in HF RF propagation analysis software to account for antenna noise figure measurements.

Electromagnetic Environment Characterization of Below-Deck Spaces in Ships
G. B. Tait, M. B. Slocum, Naval Surface Warfare Center Dahlgren, Dahlgren, United States

With wireless systems currently being introduced into confined, reflective spaces that were not originally intended for radio frequency emissions, it becomes necessary to assess the resultant electromagnetic environment of these spaces, especially where potential hazards may exist. In this work, we present experimental data to demonstrate that the below-deck compartments aboard Navy ships can be characterized as complex reverberant cavities. For general reverberant spaces, a cavity calibration factor can be used to predict maximum diffuse electric fields as a function of frequency and total radiated power.

TECHNICAL PAPER ABSTRACTS

Description and classification of electromagnetic environments - revision of IEC 61000-2-5

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Knowledge of electromagnetic environment where equipment is operated is an essential precondition for the achievement of EMC. Its necessity results from the fact that immunity requirements can be concluded from corresponding data of the environment. The description of a general environment should consider a multitude of phenomena having a broad spectrum of parameters. Such a description, however, is not helpful in most cases because it implies that immunity against all such phenomena has to be considered. A more practical approach consists in introducing a classification scheme which gives a correlation between locations and the phenomena existing there. This approach forms the basis of the publication IEC 61000-2-5. Because of changes of technologies or of the introduction of new ones, the electromagnetic environments change fundamentally. Hence the consequence results to adapt its description which is currently done by a working group of IEC TC 77.

EMC Feasibility Study of the use of 2.4-GHz-WLAN Applications on Bridges of Cruise and Container Vessels

T. Pilsak, J. L. ter Haseborg, Hamburg University of Technology, Hamburg, Germany

This paper is an preliminary investigation of an add-on to the 2.4-GHz-ISM-band of the IEC 60945. Focus is taken to the question which field strength is to be expected at the electrical equipment inside control consoles on bridges of cruise and container vessels caused by wireless LAN. Moreover the question is discussed how adequate wireless LAN is to transmit data on the bridge of vessels.

Characterization of the EM environment of railway spot communication systems

J. del Portillo[1], M. Osinalde[1], E. Sukia[2], I. Sancho[1], J. Mendizabal[1], J. Melendez[1], [1]CEIT and Tecnun (University of Navarra), San Sebastian, Spain, [2]CAF, Beasain, Spain

Trains require spot communication systems to be supervised and controlled. EM interferences in their vicinity could cause their malfunction. Nowadays, the electromagnetic environment of these systems is being researched, but it is not well characterized yet. One of the most relevant origin of these interferences are the electromagnetic fields generated by the train itself. This work presents the measured signals of the EM fields generated by the common mode currents in the traction system and by the contact discontinuities between the pantograph and the catenary. The EM environment analysis is focused on the frequency range of the ASFA and ERTMS BTM systems.

TECHNICAL PAPER ABSTRACTS

System EMC Analysis

A Study on the Correlation between the Stray Capacitance of a Signal Transformer and the Magnetic Field Emitted from Communication Lines

Y. Akeboshi[1], S. Nitta[1,2], S. Saito[1], [1]Mitsubishi Electric Corp., Kamakura, Japan, [2]Salesian Polytechnic, Machida, Japan

In order to reduce the radiated emissions from communication cables, we investigated a relation between the stray capacitance of a signal transformer and the common mode currents. From analysis and experimental results, it is confirmed that the stray capacitances of the signal transformer have strong correlation to the common mode currents and magnetic field strength. This indicates that the implementation design of transformer is important factor to reduce the radiated emissions.

Modelling Interference Phenomena between Cosite Radiocommunication Equipments to Evaluate Systems Performance Degradation

E. Yalçin[1,2], C. Girard[1], M. Cabellic[1], M. Hélier[2], G. Alquié[2], J. Montmagnon[2], [1]Thales Communications, Colombes, France, [2]UPMC Univ Paris 06, Paris, France

Electromagnetic Interference (EMI) is part of Electromagnetic Compatibility (EMC) handling all issues of non-intentional interference between transmitters and receivers. In this document, various models and methods are described in order to carry out EMI simulations and evaluate the performance degradation of cosite equipments of a system. A next step will consist in validating the developed EMI simulation tool. The chosen study case is the 2.4 GHz ISM band Bluetooth/WiFi interaction. We have carried out BER measurements which results, summarized at the end of the paper, will be used for the planned validation work.

Digital to RF Coupling Analysis Methodology for Mixed-Signal Systems

D. Lim, Y. Kim, A. S. Kim, Samsung Electronics Co., ltd., Suwon, Republic of Korea

Digital harmonics could be coupled to a RF system in a digital & RF mixed signal board or a package. The coupled digital harmonic could reduce the RF sensitivity of the system, or cause a system failure. Digital to RF coupling is the most important factor of degrading mixed-signal systems. The analysis methodology of evaluating the RF performance reflected by the digital harmonics is addressed. In this paper, proposed methodology has been applied to RF receiver hardware and verified by 3D electromagnetic simulation.

The Behavioral Simulation of EMI System by DNA Method at the System Level

C. W. Qing[1,2], S. D. Lin[1], S. Wei[1], H. Y. Chun[1], [1]Beijing University of Aeronautics and Astronautics, Beijing, China, [2]the Navy Academy of Equipment Research, Beijing, China

A behavioral-level simulation technique that can be used together with the nonlinear discrete technique for a system-level electromagnetic compatibility and electromagnetic interference (EMC/EMI) analysis. According to nonlinear interference sources and the transmission matrix, a complicated system was separated into many DNA models, thus carried out the complicated system to imitate true and analytical. The technique presented allows one to simulate a system in the time domain mode as well as in the frequency domain mode by taking into account the nonlinearity transfer characteristics. The technique was validated by making comparisons with measurements and simulation data.

Characterization and Modeling of Faceplates by a Frequency-Dependent Impecance Matrix

H. M. Kudyan, Alcatel-Lucent, Whippany, United States

The use of non-metallic faceplates on circuit-packs populating an equipment shelf can impact both the conducted emissions and surge immunity characteristics of the system when it is exposed to electromagnetic stimuli. The characterization of these faceplates in terms of their respective frequency-dependent impedance matrices can be useful in predicting the impact of the faceplates on the EMC performance of the system. Lumped circuit elements of the impedance matrix for faceplates are calculated from the frequency-dependent scattering matrix data generated experimentally for each type of faceplate. The derived elements of the impedance matrix are used to develop approximate circuit models for metallic and non-metallic faceplates. These circuit models can be used to predict and compare the behaviors of non-metallic faceplates with respect to each other or to that of standard metallic faceplates when subjected to transient and/or steady-state stimuli.

EMI Analysis Methods for Synchronous Buck Converter EMI Root Cause Analysis

K. W. Kam[1,2], D. Pommerenke[1,2], R. Steinfeld[2,1], C. Lam[2,1], [1]Missouri University of Science and Technology, Rolla, United States, [2]Apple Inc., Cupertino, United States

DC/DC synchronous buck converters cause broadband emissions. A variety of methods are applied to analyze the root cause of the EMI. Time-domain voltage measurement and joint-time-frequency analysis allows to determine the location of the noise source. The near field scan reveals the current paths, and impedance measurement and 3D modeling can be used for further analysis of the noise source. A dual port TEM cell allows to distinguish E from H field coupling, This paper shows the application of those methods to a synchronous buck converter and reveals the sources of EMI leading to advice on the optimal PCB design. Finally, an innovative method of using a TEM cell measurement to predict the maximum possible radiated emissions is introduced.

Open Forum 2

Multimodal Circuit Model for The Analysis of Asymmetric Shunt Impedance Transitions
P. Rodríguez-Cepeda, M. Ribó, F. Pajares, J. Regué, A. Sànchez, A. Pérez, Enginyeria i Arquitectura La Salle, Barcelona, Spain

In PCB circuits, signal traces are often routed close to other signal traces. This situation originates the appearance of coupled strip sections. Due to the fact that coupled strip sections behave as multimodal transmission lines, several electromagnetic modes propagate simultaneously. Any asymmetry in the circuit will generate an energy exchange among the propagating modes which will lead to signal integrity problems. In this paper, a new multimodal circuit model for a Three-Line-Microstrip Asymmetric Shunt Impedance Transition is presented. The model allows a rigorous and a quantitative analysis of the transition. The model is successfully applied to the analysis of a PCB configuration where a clock signal trace is routed close to two other signal traces. The good agreement between measurements and circuit simulations validates the proposed multimodal circuit model.

Determination of Gain for Pyramidal-Horn Antenna on Basis of Phase Center Location
K. Harima, M. Sakasai, K. Fujii, National Institute of Information and Communications Technology, Koganei, Japan

The phase center location is used to determine the gain for horn antennas using the three-antenna method. The phase center of a pyramidal-horn antenna in the 18 to 26.5 GHz frequency range was calculated using the finite integration method, and then the gain was measured by using the distance between phase center locations obtained from this calculation. The measured results of the gain on the basis of the phase center location were in good agreement with the theoretical values. The uncertainty (k = 2) of the measurement was 0.13 to 0.16 dB in the given frequency range.

Investigation of Conducted Immunity and Spatial Distribution of RF Currents for a 2-Sided PCB
C. Rostamzadeh, Robert Bosch LLC, Plymouth, United States

Influence of the RF noise in automotive 12-volts power distribution network and its impact on electronic control unit is investigated. A magnetic near-field scanner is used to inspect the penetration of the injected RF currents on an automotive module. Spectral and spatial scans are useful in investigation of the power distribution robustness. It is anticipated that spatial view of conducted RF currents in a printed circuit board can result into design practices that enhances the EMI robustness of a product and its functional quality.

Cable EMI Shielding Measurements using a Reverberation Chamber
J. Diepenbrock, B. Archambeault, IBM, Research Triangle Park, United States

The design and manufacturing of data cables to be used in high performance applications presents a number of challenges as the application speeds increase. Previous work by these authors has shown the potentially large impact of differential delay skew in the generation of common mode noise and therefore electromagnetic interference. This paper examines various methods for measuring the shielding effectiveness of such cables and discussing practical considerations involved in building and characterizing a reverberation chamber for such measurements.

TECHNICAL PAPER ABSTRACTS

Efficient Computation of the Shielding Effectiveness of Metallic Enclosures Loaded with Conductors

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The effects of conducting loads on the shielding effectiveness of rectangular metallic enclosures is investigated through an efficient formulation based on the method of moments. As expected, the analysis shows that the classical shielding effectiveness is a very tricky figure of merit which is seriously affected by the possible presence of loads inside the enclosure, especially in the frequency range above the first resonant frequency of the enclosure. Comparisons with rigorous full-wave results obtained through commercial software confirm the validity of the proposed technique and its high efficiency.

A Study for Grounding Effect to Improve Performance of WWAN

S. R. Yoon[1], S. K. Lee[1], K. S. Lee[1], O. S. Choi[1], N. D. Kim[1], K. C. Kim[2], Y. W. Park[2], [1]Samsung Electronics, Yongin-City, Republic of Korea, [2]Yeungnam University, Gyeongsan-City, Republic of Korea

Electromagnetic interference from a LCD panel deteriorates the performance of wireless network system (with wireless network cards: Wireless Wide Area Network card) in a notebook. One of the main EMI noise factor, for the wireless network system, is the grounding effect of the antenna in the system. In this paper, the approaches to solve the EMI noise of the system are introduced; by the use of grounding methods of the system. In order to measure the EMI noise of the WWAN itself, the standard JIG system is developed. All of grounding effects are confirmed experimentally.

Synchronous Rectified Step-Down Converter Susceptibility to Conducted and Radiated EMI

C. Rostamzadeh, Robert Bosch LLC, Plymouth, United States

In this paper the susceptibility of synchronous rectified step-down converters to electromagnetic interference (100 kHz – 500 MHz)is examined and evaluated by experimental measurements. Performance degradation of linear low dropout regulators due to RF rectification and non-linear effects of RFI on error amplifiers is well documented. SR buck converters exhibit system stability and poor transient response behavior due to low-level RF injection and a complete circuit failure operation in presence of high-level RF injection. The use of L-C filter for RFI solution must be designed carefully as it can degrade the converter's transient response.

HF RFID Electromagnetic Emissions and Performance

D. Novotny, J. Guererri , M. Francis, K. Remley, NIST, Boulder, United States

We examined the emissions of commercial HF(High-Frequency) proximity RFID (Radio Frequency Identification) systems and the performance of a typical RFID system in the presence of electromagnetic (EM) interference. Some initial investigations into security and reliability were also performed. These investigations highlight detectability and readability of an RFID transaction at a distance. We performed measurements to determine the power radiated by some commercial systems and monitored the RFID transaction in adverse EM environments.

Computational EM 2

Simulation and Measurement of Low Frequency Open Surface Magnetic Field Shielding

J. D. Brunett, V. V. Liepa, University of Michigan, Ann Arbor, United States

This paper details the simulation and measurement of low frequency (LF) magnetic field shielding by open surface structures. The approach of this paper is to develop equivalent electric sheet impedance boundary conditions for use by LF surface based electric field integral equation (EFIE) solvers. From these sheet impedance forms, a figure of merit is developed to determine the boundary condition applicability. Next, transmitting and receiving coil designs are analyzed and modifications are made to eliminate shield currents in measurement. Finally, simulated and measured magnetic field shielding is compared for electrically small open surface material disks.

Evaluation of Equipment-Level Enclosure Shielding Properties in a Reverberation Chamber: Numerical and Experimental Analysis

D. Fedeli, G. Gradoni, V. Mariani Primiani, F. Moglie, Universita` Politecnica delle Marche, Ancona, Italy

The paper focuses the attention on the reverberation chamber method for shielding properties evaluation of equipment-level enclosures. The whole testing situation, chamber plus enclosure under test, is numerically modeled by a in-house FDTD code able to predict the field inside the enclosure and the voltage captured by probes placed inside it. After the code validation, the effect of the probe position, on the enclosure shielding effectiveness, is examined. In particular a field normalization is introduced in the shielding effectiveness definition. Finally, the effect of a frequency stirring application is also investigated.

Domain Separation with Port Interfaces for Calculation of Emissions from Enclosure Slots.

C. Poschalko[1], S. Selberherr[2], [1]Robert Bosch AG, Vienna, Austria, [2]Technische Universität Wien, Vienna, Austria

An equivalent circuit method is used to define ports at the slots of enclosures to separate the external field domain from the internal over a broad frequency range. The aspect ratios of internal to external structures of electronic devices are usually difficult to handle in joint domain simulations. Our method provides the opportunity to simulate the domains separately and to connect the two models afterwards. We present an example for a cubical enclosure with a slot. We use a cavity model and an impedance network at the slot to consider the radiation loss. The results are compared with HFSS simulations.

TECHNICAL PAPER ABSTRACTS

EMC Management

An Electromagnetic Compatibility Course for Computer Engineers
N. Ida, The University of Akron, Akron, United States

An EMC course specifically designed for computer engineering students is proposed. The course is based on the electric and magnetic potentials rather than on fields. This approach emphasizes a circuit approach to electromagnetics so that students which do not have a background in electromagnetic field theory can gain a useful base in electromagnetic compatibility issues.

Problematic Concepts in the Introduction of EMC
A. S. de Beer, University of Johannesburg, Johannesburg, South Africa

This paper deals with specific and difficult concepts when introducing EMC to engineers and technicians. It is based on the authors experience in presenting introductory short courses. Some concepts are difficult to grasp for first time students as it emphasizes phenomena and techniques not necessarily found in other subjects. Five concepts are identified, discussed and possible solutions given for easier understanding.

Structure for the Introduction of EMC Design
A. S. de Beer, University of Johannesburg, Johannesburg, South Africa

This paper gives an outline useful for introducing EMC design to first time students. It is based on the universal interference model and the concept of zoning. It structures the introduction to circuit design, filters, connections and shielding. The contributions of grounding and management are also incorporated into the outline.

PCB Design 2

A Study of Grounded-Heatspreader for EMI Mitigation of ASIC IC Package

A. U. Bhobe, P. Sochoux, Cisco Systems, San Jose, United States

The thermal Heat Spreader (HS) is an essential part of an Integrated Circuit (IC) package. At SerDes data rates the physical dimensions of the heat spreader and that of the package are comparable to the operating clock frequencies. These structures behave as unintentional radiators and contribute to EMI. In this paper we investigate the radiated emissions of a high-speed SerDes IC package when its HS is grounded to its ground plane. Using a Transmission Line Matrix based full wave EM solver, it is shown that EMI radiation can be reduced by increasing the number of grounding posts. A 32 grounding post design reduces the total radiated power by 20+ dB in the frequency range of 1 – 15 GHz when compared to a non-grounded heat spreader case. It is also shown that the effectiveness of the grounded lid decreases as we increase the resistance of the posts.

PCB Ground Fill Design Guidelines for EMI

W. Pan[1], D. Pommerenke[1], S. Xu[2], J. Jia[2], [1]Missouri University of Science and Technology, Rolla, United States, [2]Huawei Technologies Co., Ltd., Shenzhen, China

This paper is to alert PCB designers about potential EMI problems caused by ground fills in outer layers of PCB. Ground fills are frequently used on top and bottom layers of PCBs for manufacturing or perceived shielding reasons. However, if not well applied they may cause EMI problem, especially if they form resonators. Several types of situations need to be distinguished, by (1) the resonating structure and (2) the excitation structure. Examples of problematic structures are shown by simulation and measurement. Possible guidelines for mitigating such problems are discussed.

Transient Detection Circuit for System-Level ESD Protection and Its On-Board Behavior with EMI/EMC Filters

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A new on-chip transient detection circuit for system-level electrostatic discharge (ESD) protection is proposed. The circuit performance of detecting fast electrical transients has been verified in a 0.18-um CMOS integrated circuit (IC). The experimental results have confirmed that the proposed on-chip transient detection circuit can detect positive and negative fast electrical transients during system-level ESD zapping. Three board-level noise filtering networks have been investigated their enhancement on detection range of the proposed on-chip transient detection circuit. The chip-level solution can be further co-designed with the board-level solution in order to meet high system-level ESD specification.

Advanced full wave ESD generator model for system level coupling simulation

Q. Cai[1], D. Pommerenke[1], B. Seol[2], J. Koo[1], A. Nandy[1], J. S. Lee[2], [1]UMR - EMCLAB mst, Rolla, United States, [2]Samsung Electronics, Suwon, Republic of Korea

System level ESD tests can only be performed after hardware is available. Simulating the ESD coupling into a circuit allows at least parametric and quantitative studies of the expected ESD behavior. A complete simulation requires modeling the ESD generator, the passive elements of the DUT and the response of the ICs to injected noise. Having the ultimate objective of combining IC soft error response models with the DUT structure and the ESD generator we report on progresses in modeling the ESD generator and its coupling. The model improves the useful frequency range from a few hundred MHz to about 3 GHz.

TECHNICAL PAPER ABSTRACTS

TECHNICAL PAPER ABSTRACTS

Noise coupling between signal and power/ground nets due to signal vias transitioning through power/ground plane pair

J. Fan[1], M. Cocchini[1], B. Archambeault[2], J. L. Knighten[3], J. L. Drewniak[1], S. Connor[2], [1]Missouri University of Science and Technology, Rolla, United States, [2]IBM Corporation, Research Triangle Park, United States, [3]NCR Corporation, San Diego, United States

Signal vias are often used to move a signal from one PCB layer to another. As a result, these vias can penetrate power/ground plane pair and cause noise coupling (crosstalk) between signal and power/ground nets. This paper studies the noise coupling mechanism using a segmentation approach combined with a via capacitance model and a plane-pair cavity model. Noise coupling from signal to power/ground, and vice versa, is demonstrated in the modeling results.

Numerical Investigation of Techniques for Reducing Radiated Emission of PCBs with Attached Cables in Complex Systems

S. Caniggia[2], F. Maradei[2], [1]EMC Consultant, Bareggio, Italy, [2]Sapienza University of Rome, Rome, Italy

Numerical simulations are used to quantify the effects of fixes such as EMI filter and grounding solutions for reducing radiated emission from a PCB with an attached cable in a complex digital system. The basic PCB and cable numerical models adopted in the full-wave simulations are validated by comparison with an analytical approach that was previously validated by measurements. The performed investigation shows that to reduce radiated emission from unshielded cable with its PCB within a shielded box, the best solution is to use common-mode filters with connection of the PCB ground plane to the chassis by the use of a certain number of stitches.

Measurement Techniques 2

Analysis of the MIL-STD-461E and MIL-STD-461F RE102 Test Setup Configurations below 100 MHz

D. D. Swanson, Lockheed Martin, Eagan, United States

RE102 testing below 100 MHz in a chamber presents a measurement repeatability challenge. In 2007, the Department of Defense revised MIL-STD-461. Among the changes, MIL-STD-461F introduced a new RE102 rod antenna setup. The antenna base is bonded to the ground plane through the cable shield and the height of the antenna is lowered. This RE102 setup is used to test both bench-top and floor-standing equipment. No change was made to the biconical antenna test setup. With the proliferation of EMI analysis software, it is possible to model, compare, and analyze three RE102 setups from MIL-STD-461E and MIL-STD-461F. The impact of many undefined variables may also be investigated, including the chamber size, the test bench size, and the type of absorber used in the chamber. This paper compares and analyzes the results from computer simulations of the MIL-STD-461E and MIL-STD-461F RE102 test configurations from 10 kHz to 100 MHz.

Time Synchronized Near-field and Far-field for EMI Source Identification

G. Feng, W. Wu, D. Pommerenke, J. Fan, D. G. Beetner, Missouri University of Science and Technology, Rolla, United States

Spectrum analyzer (SA) measurements alone make the identification of emission source difficult in case multiple noise sources are responsible for emissions at a particular frequency. If multiple near field signals and the far field signal are recorded using a high speed oscilloscope, it may become possible to identify the source of the radiated signal, by identifying the near field signal that best correlates to the far field signal. A variety of post processing methods have been investigated. The Short Term FFT (STFFT) is employed to visualize the time dependence of the frequency content, further envelope correlation, coherence factor, and cross-correlation methods are explained and tested for their ability to identify a source of emission problem.

Determination of coupling of UWB pulses into complex PCB line structures using multi-alignment measurements

K. A. Haake, J. L. ter Haseborg, Hamburg University of Technology , Hamburg, Germany

In this paper the coupling of UWB pulses into line structures will be investigated. It is of interest to study the coupling into different PCB line structures like they are used by standard PCB routing. Due to the complexity of the structures, it is difficult or even impossible to predict the transfer function over the frequency analytically. Therefore a mockup PCB with three structures has been built and placed inside of a GTEM cell. In order to study every possible superimposition of the coupling waves from different paths, the PCB will be turned into different positions and the maximum will be considered and discussed.

Analysis on Electrode Speed Correlation of Discharge Parameters Applying Short-gap Electrostatic Discharge Model

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Abstract—Electrostatic discharge(ESD) current waveforms in experiment measurement are sorted for charge voltage from 100V-3000V, whereas approach speed effects of discharge parameters are illustrated with the short-gap ESD model. Strong correlation exists between discharge parameters of electrostatic discharge and electrode approach speed. Two processes of surface process and gas electronic avalanche in short-gap ESD model are employed to analyze the possible mechanism caused the strong correlation.

TECHNICAL PAPER ABSTRACTS

Aspects of Using the IEC-61000-4-20 for Transient Testing with Broadband Signals

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This paper concentrates on the usage of the IEC 61000-4-20, the international standard for emission and immunity testing in transverse electromagnetic (TEM) waveguides. The specifications for transient testing in TEM waveguides according to Annex C of the norm are verified by measurements with different waveguides (GTEM 1250 and GTEM 3750) and various excitation signals with a large bandwidth up to several GHz. The measurement results show that the norm can be enlarged related to the defined limits of the applied test signals and the usable testing volume in the waveguide.

CISPR Specification and Measurement Uncertainty of the Time-domain EMI Measurement System

S. Braun, A. Frech, P. Russer, Technical University of Munich, Munich, Germany

In this paper the measurement uncertainty of FFT-based measurement systems are discussed. FFT-bases measurement have due to the digital implementation low calibration effort, however the measurement uncertainty of isolated pulses is dependent on the overlapping of the calculation during the Short time fast Fourier transform. The dynamic range is investigated, and it is shown that even the isolated pulse can be measured correctly in the quasipeak detector mode. The error in dependence of the overlapping for a gaussian window function is investigated and compared with the requirements in CISPR 16-1-1. Procedures are presented that allow to determine the measurement uncertainty caused by the the limited overlapping for FFT-based measurement systems. The procedures are applied to the time-domain EMI measurement system in the frequency range up to 1 GHz.

Open Forum 3

An Approach for The Prediction of Sensitive I/O Ports using Noise Distribution on PCB-Level

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In this contribution a methodology for the prediction of critical device pins at PCB level with respect to induced transient impulses is presented. The method proposed is based on the identification of the most dominant signal propagation paths using single shortest path algorithms. Thus, the noise distributed from a source to many device pins is determined simultaneously considering all coupling effects. The critical pins can be predicted depending on the amount of noise transmitted through the dominant paths. For a complete analysis, the connection matrix method is used to reduce the size of the circuit. The methodology is illustrated by a transmission line circuit.

An Optical Feeding Antenna with Wide Bandwidth for Evaluation of Radiated Emission Test Sites above 1 GHz

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In order to improve an optical feeding antenna with wide bandwidth above 1GHz for evaluation of radiated emission test site, we have developed tears-drop type antenna that is composed of a biconical antenna element with a sphere which utilize an optical feeding method by using UTC-PD (Uni-Traveling-Carrier Photodiode) as a photo detector instead of usual PIN photo diode. Radiated electric field was measured and compared with calculated values by using FI method.

A New Direct Method for SEdB Determination

M. T. Badic[1], L. Aciu[2], P. Ogrutan[2], [1]Research Institute for E.E., Bucharest, Romania, [2]Transilvania University of Brasov, Brasov, Romania

Phenomena taking place into an electromagnetic shield are complex (absorption, reflection, transmission). They are determined by material/shield macroscopic parameters (e, m, s), its thickness, radiation's frequency and incidence angle. The paper deals with an original method for visualization and measurement of shielding effectiveness. This method has the advantage of simplicity and validates for the first time theoretical predictions as opposed to TEM cell method based on mathematical isomorphism (infinite plane shield vs. coaxial transmission lines). Even if it is formally accurate, it has not been experimentally validated up to present, in the area of electrically thick samples, according to numerous works in the field.

A high sensitivity electromagnetic field sensor using resonance

H. Tsutagaya, S. Kazama, Taiyo Yuden Co., Ltd., Takasaki, Japan

High sensitivity electromagnetic field distribution mapping is useful for analyzing an intra-system EMC issue. We have developed a high sensitivity electromagnetic sensor for this mapping. The sensor uses resonance of loop inductance and chip capacitance. Sensitivity of the system using this sensor is improved about 16 dB than in a conventional one. This paper probes the resonance sensor and electromagnetic field mapping by using this sensor.

Assessment of the Robustness of Commercial Data Communication Interfaces to a Military EMI Environment
E. B. Joffe, KTM Project Engineering, Hod Hasharon, Israel

This Paper presents tests carried out on 600Mbps LVDS, 100BaseT and 1,000BaseT communication links, investigating their performance at the presence of electromagnetic interference representative of the environment characteristic of military airborne platforms, per MIL-STD-461E, methods RS103 and CS114/115/116. Results of the tests have shown that in the original configurations all types of communication links failed all tests. With the addition of an external overall braid (additional to the existing shield on the standard cables) results were significantly improved and in all but the 1,000BaseT, all susceptibility tests were completed successfully. The failure in the 100/1,000BaseT can probably be attributed to saturation of the magnetics in the twisted pair interface of the boards.

Suppression Method of Radiated Emission from Solar Cell on a Photovoltaic Power Generation System
M. Tomisawa, M. Tokuda, Musashi Institute of Technology, Setagaya-ku, Japan

As for a photovoltaic generation system, there is the problems that the power conditioner become a disturbance source radiating the electromagnetic wave. Since the method of suppressing the electromagnetic wave radiated from a solar cell has been examined in this paper. We pay attention in a current direction of the solar cell module whether the radiated electric field is able to be suppressed by setting up the direction alternately when two or more modules are arranged. As the result, it is revealed that a big suppressing effect of about 20 to 50 dB can be obtained by the assortment suppression model.

An Improved LC Filter for Reduction of WWAN Noise
S. K. Lee[1], K. S. Park[2], S. R. Yoon[1], K. S. Lee[1], O. S. Choi[1], N. D. Kim[1], M. Hayakawa[3], Y. Kami[4], [1]Samsung Electronics, Asan, Republic of Korea, [2]Samsung Electro-Mechanics, Suwon-City, Republic of Korea, [3]University of Electro-Communications, Choufu, Japan, [4]University of Electro-Communications, Choufu, Japan

A Common-Mode (CM) filter is usually used remove CM currents on differential-mode (DM) signal lines. However, in this paper we propose the application of an improved LC filter to reduce the EMI noise of DM signal lines. Three factors are studied for the improved LC filter; DC Resistance, shape of capacitor and dielectric constant. Because the LC filter is much chipper than the CM filter, the new LC filter is very useful for the products.

A Finite Element Method for Transient Analysis of Power Electronic Motor Drives Including Parasitic Capacitive Effect and External Circuit
W. Fu, S. Ho, The Hong Kong Polytechnic University, Hong Kong, Hong Kong

A two dimensional (2-D) finite element method (FEM) of transient electromagnetic field for modeling power electronic motor drives is presented. The proposed method takes into account the parasitic capacitive effect and can be coupled with arbitrarily connected circuits. The FEM formulation which includes the displacement current in the direction of the model's depth is deduced. The displacement current effect in the plane of the solution domain is represented by coupling the circuit of capacitances into the FEM equations. By introducing additional unknowns, the final set of the system equations has a symmetrical coefficient matrix. A method using electric charge as an excitation for the computation of the capacitance matrix is also proposed for reducing the computation time. The developed algorithm has been applied to simulate systems with power sources having high frequency and/or high dv/dt.

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Advanced EMC Modeling by Means of a Parallel MLFMM and Coupling with Network Theory
U. Jakobus, J. van Tonder, M. Schoeman, EM Software & Systems - S.A. (Pty) Ltd, Stellenbosch, South Africa

The application of a parallelized Multilevel Fast Multipole Method (MLFMM) is described and illustrated by means of examples for the solution of large scale and complex EMC problems. Furthermore, to reduce the modeling complexity of such EMC problems, we propose a combination of field with network theory to split large problems into smaller sub-problems which can be analyzed individually and then again assembled together by means of network theory.

Validation of MOM/FEM in Modelling Studies of Loaded Enclosures With Apertures
S. Yenikaya, Uludag University, Bursa, Turkey

In this paper to obtain of electromagnetic field distribution inside loaded enclosure with aperture, we present hybrid formulation which combines Method of Moments (MoM) and vector finite element method (FEM). While FEM is used for solving electromagnetic fields inside of the enclosure, MoM is used for solving the surface integrals related with the aperture field components using equivalent surface currents. To obtain efficiency of the proposed method, first applied to empty enclosure and the results are validated by comparing with literature. Then the method applied to loaded enclosure Shielding effectiveness, stored electrical energy and dissipated power in load are examined.

Statistical Analysis of Induced Ground Voltage Using the TLM+UT Method
J. B. Pereira, L. R. Menezes, G. A. Borges, UNB, Brasilia, Brazil

The effect of induced voltages due to electromagnetic pulses is studied with the combination of commercial electromagnetic simulation software (MEFISTo) and uncertainty modeling. The uncertainly is introduced using the Unscented Transform technique for two random variables: the relative permittivity and conductivity of the soil. These were modeled as independent random variables with uniform distribution. The results were the statistical moments of the induced voltage (expected value and standard variation) as well as an estimate of the cumulative distribution function.

Parameter Extraction of Eddy-current Magnetic Field – Circuit Coupled Problems Using Matrix Analysis Method
W. Fu, S. Ho, The Hong Kong Polytechnic University, Hong Kong, Hong Kong

An accurate equivalent circuit model to represent a 2-dimentional (2-D) eddy-current magnetic field is presented. The magnetic field can be coupled with stranded windings and solid conductors. To develop the formulations of impedance computation, two systematic matrix analysis methods based on the system equations, one using loop method and one using nodal method, are presented. In the proposed work it is pointed out that each solid conductor must be represented by a circuit branch. With this approach the effect of eddy-current can be fully included in the equivalent circuit model. The paper also presents the formulations for the computation of the total power loss for magnetic field – circuit coupled problems and discusses a common mistake in many applications.

TECHNICAL PAPER ABSTRACTS

Equivalent Radiation Source Extraction Method for System Level EMI and RFI Prediction

J. Shi[1], J. He[1], E. Chan[1], J. Zhao[2], K. P. Slattery[1], F. Zanella[3], J. Fejfar [3], [1]Intel Corporation, Santa Clara, United States, [2]Sigrity Inc., Santa Clara, United States, [3]CST of America, Boston, United States

A novel IC Component level radiation source extraction method is described in this paper. The extracted equivalent current source from the 2.5D full wave simulation is exported out for further 3D full wave system level EMI/RFI prediction. This approach solves high complexity computer system's EMI/RFI prediction challenges. This methodology was demonstrated by using a commercial 2.5D solver to simulate board and package near field emissions during early product design phase. The example used was a 4 inch Intel CK505 GTEM board where measured magnetic field was correlated to simulation. A commercial 3D solver was used for next level simulation and correlation. The methodology shows potential to be a useful tool for predicting near field emission using basic package and board information.

A mixed nodal-mesh formulation of the PEEC method based on efficient graph algorithms

G. Miscione, G. Antonini, D. Frigioni, University of L'Aquila, L'Aquila, Italy

In this paper a new mixed nodal-mesh formulation of the PEEC method is proposed. Based on the hypothesis that charges reside only on the surface of conductors and that current density is solenoidal inside them, a novel scheme is developed fully exploiting the physical properties of charges and currents. It comes out that the presented approach allows to reduce the number of unknowns while preserving the accuracy. An elegant and efficient algorithm, based on graph theory, is proposed to automatically search independent loops on three dimensional rectangular grids such as those arising in volumetric PEEC formulation. The method is validated through numerical results that confirm the accuracy of the proposed formulation from DC-to-daylight and its capability to provide memory saving.

Modeling Experiences with Full-Wave Frequency-Domain Modeling Software

C. Su, X. He, H. Zeng, H. Ke, T. H. Hubing, Clemson Vehicular Electronics Laboratory, Clemson, United States

When evaluating electromagnetic modeling software, there is usually a significant focus on the accuracy of the software. Differences between the results generated by the software and the correct solution are the result of several potential sources of error including: approximations made in order to represent the actual configuration as a structure that the software can understand; approximations made during the discretization and solution of Maxwell's equations; and differences between what the modeler wants to analyze and what the software is actually modeling. In this paper, three full-wave frequency-domain EM modeling codes are evaluated by analyzing three simple canonical problems. These codes employ the two most common frequency-domain modeling techniques; the Finite Element Method, and the Boundary Element Method. The three canonical problems are a center-driven dipole, a circuit board power-bus structure, and a power-bus structure with a cable attached.

TECHNICAL PAPER ABSTRACTS

Signal Integrity 2

Effects of Discrete Bypass Capacitors in Power/Ground Planes with EBG Structures

M. D. Farzan[1], O. M. Ramahi[2], [1]C-DOT Alcatel-Lucent Research Centre, Chennai, India, [2]University of WAterloo, Waterloo, Canada

Electromagnetic Bandgap (EBG) structures integrated into the parallel plane pairs are highly effective in mitigating the propagation of Electromagnetic noise. The intentional increase of the inductance in the EBG patterned plane pairs to create a bandgap affects the charge delivery to the switching devices from the nearby bypass capacitors. This paper analyses the charge delivery in Power/Ground planes patterned with EBG structure. To benchmark the results, a parallel plate waveguide (PPW) of similar dimension and bypass capacitor placement was simulated. It was found that the antiresonant peaks in the self impedance profile were shifted to lower frequencies in planes with EBG structures causing high transient noise.

Study on the Mitigation of the Resonance due to the Power-Bus Structure using Periodic Metal-Strip Loaded Sheets

S. Kahng, University of Incheon, Incheon, Republic of Korea

This paper investigates a method to tackle the resonance problems of the rectangular power-bus structure(PBS) using thin sheets loaded with periodic metal strips. The equivalent surface impedance of the proposed loading is calculated and involved in the expression of the impedance that accounts for in the PBS, in order to improve the resonance behavior of the original structure. The effects of the strips and the immediate surroundings are illustrated by a number of numerical experiments. Also the restrictions of the technique are addressed.

Fast Frequency Domain Crosstalk Analysis for Board-Level EMC Rule Checking and Optimization

M. Mondal[1], S. Connor[2], B. Archambeault[2], V. Jandhyala[1], [1]University of Washington, Seattle, United States, [2]IBM Corporation, Research Triangle Park, United States

A fast and accurate method for analyzing frequency domain crosstalk between signal lines in printed circuit boards is described in this paper. An integrated parasitic extraction and crosstalk analysis methodology has been employed since the parasitic elements are essential for the crosstalk noise analysis. The implementation of the integrated extraction and crosstalk analysis requires computation time of the order of milliseconds, which makes the technique suitable for EMC rule checking and EMC/crosstalk aware board level optimization. Trend analysis for variation of crosstalk noise with separation between the signal lines, for both striplines and microstrip lines, has been presented.

Slots on Ground Fillings of Multi-layer Printed Circuit Board for Suppressing Indirect Crosstalk between Digital Clock Line and RF Signal Line in Mixed Mode Mobile Systems

J. Pak[1], G. Kim[1], F. Hong[2], A. Kim[2], J. Kim[1], [1]KAIST, Daejeon, Republic of Korea, [2]SAMSUNG ELECTRONICS Co, Suwon, Republic of Korea

In this paper, slots on ground fillings of multi-layer printed circuit board is proposed for suppressing indirect crosstalk between digital clock line and RF signal line in mixed mode mobile systems, and their suppressing efficiency is evaluated by using 2 dimensional finite element method and a series of test vehicles including various slot structures and ground vias on ground fillings. Ground vias mitigate the indirect crosstalk by from 37 dB at 800 MHz to 15 dB at 1200 MHz, and the proposed slots and ground vias on ground fillings suppress the indirect crosstalk by from 57 dB at 800 MHz to 29 dB at 1200 MHz.

TECHNICAL PAPER ABSTRACTS

Using TWDP to quantify channel performance with frequency-domain S-parameter data

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This paper presents an approach to quantify channel performance using TWDP (Transmitter Waveform and Dispersion Penalty) with frequency-domain S-parameter data. TWDP is initially defined to characterize the performance of a transmitter in optical links. The same concept has been extended to quantify channel performance as well, especially in high-speed copper links. This paper focuses on channel characterization. Instead of using time-domain oscilloscope measurements as defined in the original approach, a new method is proposed by using the frequency-domain S-parameter data, obtained either from measurements or simulations. A parametric study on TWDP with respect to bit rate, number of samples per bit, rise/fall time, etc., is also presented with discussions.

Link path design on a block-by-block basis

F. De Paulis[1], J. Diepenbrock[2], B. Archambeault[2], S. Connor[2], A. Orlandi[3], J. Fan[1], [1]Missouri University of Science and Technology, Rolla, United States, [2]IBM Corporation, Research Triangle Park, United States, [3]University of L'Aquila, L'Aquila, Italy

In high-speed data communication systems, the complexity of link path between transmitters and receivers present a challenge for designers to maintain an acceptable bit error rate. An approach is presented in this paper to design the link path on a block-by-block basis. The unique advantage of this approach lies on the physics-based model of each block, which then relates performance to geometry and makes design improvement and optimization possible. An example link path involving a backpanel is investigated using the approach. The via stubs and the dielectric materials in the backpanel are demonstrated to be critical factors for link performance in certain situations.

Measurement Techniques 3

Broadband DCI as a multi usable EMC-Test Method

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The Direct Current Injection (DCI) Method offers in principle an advantage as an EMC Test Method to test systems against radiated low frequencies. This advantage has lead EADS-Military Air Systems to the plan to use this method also for higher frequencies and to eliminate the restriction to test only to the first half wave resonance. Therefore a research program with the German Federal Office of Military Technology and Procurement (BWB) was raised in 2003 to evaluate the multiple use of DCI for Indirect Lightning, HIRF (High Intensity Radiated Fields) and EMP (Electromagnetic Pulse).

Detecting E and H Fields with Microstrip Transmission Lines

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Microstrip-like transmission lines are used to detect transient electric and magnetic (E and H) fields. Theory and experiment are compared for three different cases. The method can detect E and H fields on a ground plane, or may be integrated into a closed platform for E-H measurements during EMC testing. An application example using a desktop computer is shown. In situ measurements in a closed platform during EMC testing show that system ESD failures are caused by E-H fields, and not by direct voltage or current stress. Therefore, E-H field information measured by using microstrip-like transmission lines on PCBs in a closed platform during EMC tests will give insights to the exact nature of system failures due to ESD.

A Study of Enclosure Shielding Effectiveness Measurement using Frequency Stirring in a Mode-Stirred Chamber

Y. He, A. C. Marvin, University of York, York, United Kingdom

Frequency stirring is an alternative way to mechanical stirring to achieve statistical field uniformity in an over-moded chamber or enclosure, and has the potential to be used in the shielding effectiveness measurements (SE) of enclosures. A detailed study is presented in this paper to show aspects of the practical application of frequency stirring in SE measurement. Tests are conducted in a large enclosure (0.6m * 0.7m * 0.8m) which allows different stirring approaches to be compared, whereas a small enclosure simulating a real computer case is used to investigate the stirring efficiency from the low frequency quasi-static to the over-moded higher frequency region. Factors influencing the measurement such as the mode density, stirring bandwidth and receiving antenna correction factor are also discussed.

The Effect of EUT Position on Gigahertz Transverse Electromagnetic (GTEM) Cell Correlation Algorithms

M. T. Reich[1], R. M. Nelson[2], C. Bauer-Reich[2], [1]North Dakota State University, Fargo, United States, [2]North Dakota State University, Fargo, United States

Previous work has shown that the transverse and longitudinal position of an emissions source within a Gigahertz Transverse Electromagnetic (GTEM) cell will affect the measured voltages at the apex of the cell. Since the emissions source(s) on an EUT may not always correspond with the measurement position origin, this may have an effect on the correlation algorithm used to simulate radiated emissions at an open-air test site (OATS). This paper analyzes why such measurement differences occur and shows the effect shifts in the emissions source location relative to the measurement position origin has on two correlation algorithms. Specifically, it examines the 3-position total radiated power algorithm and the 9-position multipole algorithm.

Non-contacting Near-field Mapping of Planar Circuits in Microwave Frequency Band

C. Chen[1], K. Sugawara[1], K. Li[2], H. Nihei[1], T. Anada[1], C. Christopoulos[3], [1]Kanagawa University, Yokohama-shi, Japan, [2]National Institute of Information and Communications Technology(NiCT), Koganei-shi, Japan, [3]Nottingham University, Nottingham, United Kingdom

An ultra-wideband near-field mapping system has been setup to scan the electromagnetic (EM) surface field above planar/PCB circuits. A semi-rigid coaxial electric probe is employed to measure the electric field up to 18GHz and an improved CPW loop-type magnetic probe with resonance-suppression characteristics is used to measure the magnetic field up to more than 10GHz. The comparison between the measured results and the reference data validate the good performance of our probes. In addition, a further study on extracting the effective dielectric constant of the substrate by our new system is also demonstrated with the experimental validation.

Defining and Assessing the Uncertainty Contributions in the Line-Injection Measurements of Transfer Impedance

C. F. Carobbi[1], M. Cati[2], C. Panconi[1], [1]Universita' di Firenze, Firenze, Italy, [2]Esaote S.p.A., Firenze, Italy

The shielding effectiveness of the coaxial transmission lines is currently quantified in terms of transfer impedance, a lumped-element concept. Its measurement is based on two methods, the more recent of which, the line injection method, is intended to extend the technique to higher frequencies. In doing so, wave propagation effects are introduced which produce potential distortion of the quantity we intend to observe. Also, the test arrangement is imperfectly grounded, thus unpredictable common-mode coupling may be present. This paper describes the approximations of the basic equations involved and the uncertain-ties related to the experimental equipment. A configuration of the injection line intended to minimize common-mode effects, and improve the predictability and repeatability is adopted. An experimental verification based on the comparison with the traditional and more closely defined method of the triaxial coupler is offered.

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The Impact of Common Mode Currents on Signal Integrity and EMI in High-Speed Differential Data Links
S. Connor[1], B. Archambeault[1], M. Mondal[2], [1]IBM Corp., Research Triangle Park, United States, [2]University of Washington, Seattle, United States

The high-speed, differential signals in today's multi-board systems often carry significant amounts of common mode current. Neglecting the common mode currents in signal integrity and electromagnetic simulations can produce inaccurate results. A couple cases will be shown that illustrate the impact of common mode currents and mode conversion on the signal integrity of a link path. Effective and accurate methods for quantifying the amount of common mode current, the amount of inductance in the common mode current return path, and the impact of the common mode noise on the differential signal are proposed to ensure better design practices.

Experimental Study on DC Biasing Impact on Transforer's Vibration and Sound
H. Ma, J. He, R. Zeng, B. Zhang, S. Chen, L. Cao, Tsinghua University, Beijing, China

DC biasing current through the neutral point of ac power transformer would lead the power transformer to generate more vibration and sound, this will do harm on power transformers' core pieces or windings and finally will threaten the safe operation of the transformers. This paper described the principle of DC biasing, designed a new DC biasing experiment to analyze how the experimental transformer's vibration and sound change along with the value of DC biasing current or windings voltage and finally some curves were given in order to show the direct connection between vibration peak value, sound pressure and DC current.

Generation and Measurement of a Reference Field for Round-Robin Comparison Purposes
C. F. Carobbi[1], M. Cati[2], C. Panconi[1], [1]Universita' di Firenze, Firenze, Italy, [2]Esaote S.p.A., Firenze, Italy

An accurately known reference field is often the reference quantity in round-robin comparisons of electromagnetic field measurements. The limits of accuracy inherent to the definition and measurement of a reference electromagnetic field are here discussed and quantified in the case of measurements at 3 m distance from the field source and in the 30-300 MHz frequency range. The insertion loss between the transmitting and receiving antenna is considered here as an alternative reference quantity. A method of validation of insertion loss predictions deliver-ing an accuracy of a few tens of dB is described and ex-perimentally demonstrated. Reference to a practical selec-tion of field source and receiving antenna is made for gen-eral applicability of the results here obtained.

Prediction of Parasitic Components in an Automotive Environment
S. Alexandersson, H. Bängtsson, M. Alaküla, Lund University, Lund, Sweden

The amount of electrical loads and the complexity of the electric system in a vehicle is increasing at the same time as the development time is constantly decreasing. Possibilities to predict the electromagnetic behaviour is therefore of great importance. This paper addresses the problems with low frequency electromagnetic crosstalk between cables in a harness. Analytical expression for an estimation of the parasitic inductances and capacitances are employed and compared to measured as well as simulated results.

On Determination of Conducted RF Immunity Test Methodology for Automotive Remote Keyless Entry Receivers

C. Rostamzadeh, F. Pavatich, Robert Bosch LLC, Plymouth, United States

The performance of automotive remote keyless entry systems under the influence of conducted RF injection is investigated. An RF receiver for automotive applications in the 314.9 MHz fre-quency band was designed to operate with a 100 meter range, and -110 dBm of sensitivity requirements. RF receiver was subjected to conducted RF noise by Bulk Current Injection test technique over the frequency span of 1 MHz – 400 MHz. Bulk current injec-tion RF amplifier is a source of a broadband noise rich in har-monic content. BCI amplifier harmonics occurring within the SAW and IF filter bandwidth of RF receivers can severely de-grade the performance of the UHF sensitive circuits and result into functional performance problems. The use of external filters introduced at the output of a BCI RF amplifier to alleviate the impact of the test equipment is measured and discussed.

Investigation on the Shielding Effectiveness of Planar Microstructured Screens

G. Lovat, S. Celozzi, "La Sapienza" University of Rome, Roma, Italy

The shielding performance of planar screens made of microstructured materials are investigated. In particular, the considered microstructured materials may consist of periodic or random arrangements of small metallic and/or dielectric particles. The canonical problem of normal plane-wave incidence is studied by means of homogenized approaches and/or through full-wave calculations. The role of the effective constitutive parameters in determining the shielding properties of the microstructured screens is investigated in detail.

Impact of thermal stress on the characteristics of conducted emissions

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This work presents and discusses the results of a measurement campaign aimed at demonstrating the influence of aging on the spectrum produced by an electronic device. The evaluations evidence a high spectrum sensibility to the aging, which can be used for apparatus monitoring, but the electromagnetic signature, although modified, re-mains identifiable. The results presented refer to an extensive measurements campaign aimed at verifying the influence of thermal cycles, used to simulate the aging, on the spectral signature of a device, in order to evaluate its modification and to identify the device by signature.

Defining a measure for the immunity of analogue to digital converters exposed to electric fields

T. Aurand, J. F. Dawson, M. P. Robinson, A. C. Marvin, University of York, York, United Kingdom

The paper describes a method to measure the error in samples of an analogue to digital converter when exposed to RFI. Rather than defining a change from an undisturbed value as an error alone, we will show that both 'ordinary' bit errors as well as the shape of the histogram around the undisturbed value can to be taken into account. How these errors can be measured and why the two types have to be dealt with separately is explained.

Computational EM 4

Closed-form expressions for determining approximate PMC boundaries around an aperture in a metal cavity wall

F. De Paulis[1], J. Mix[2], X. Dong[2], D. Hua[2], K. Slattery[2], Y. Zhang[1], J. Fan[1], [1]Missouri University of Science and Technology, Rolla, United States, [2]Intel Corporation, Hillsboro, United States

Modern electronic systems may use mixed RF/digital technologies to achieve various functionalities, which leads to various intra-system interference problems including the RF interference from noisy digital circuits to sensitive RF receivers, especially when the overall system is contained in a metal enclosure. A fast method based on a cavity formulation can be used to estimate the internal noise coupling mechanisms inside the enclosure. This method assumes that only the TMz0 mode exists inside the enclosure, i.e., the electric field along the z-direction is constant. The cavity formulation fails in the region adjacent to an aperture in an enclosure wall, since the aperture introduces higher order modes. The developed closed-form expressions compute the Ez-field variation along the z-direction. Thus, they can be used to estimate the breakpoint where the cavity method is no longer effective.

Efficient Simulation of Narrow Weakly Nonlinear Bandpass System

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One of the important aspects in simulating the effects of electromagnetic interference (EMI) of a narrow weakly nonlinear band pass system is selection of sampling frequency. The sampling frequency used in simulations needs to be sufficiently large enough to avoid aliasing distortion. However, it should be low as well to reduce computer simulation run time. Hence, in this paper attention is devoted to the EMI analysis of narrow weakly nonlinear band pass systems. An expression is developed for the complex envelope of the output of a weakly nonlinear system. Because the complex envelopes are baseband signals, analysis of narrow band pass weakly nonlinear systems can be carried out baseband. Therefore, the equivalent baseband EMI analysis provided in the paper enables narrow weakly nonlinear pass band systems to be simulated by using sampling frequency at baseband frequency. The concept is illustrated by means of a simple example.

Fundamental Examination about Cooling Approach for a Heated EM-Wave Absorber under High Power Injection

S. Watanabe, A. Taniguchi, O. Hashimoto, Aoyama Gakuin University, Sagamihara, Japan

In this paper, for the fundamental examination, the wind-chill factor by sending air to a heated lambda/4 EM-absorber is evaluated, by measuring against the temperature distribution when the air is not sent. As a result, the maximum temperature 78 deg. C is confirmed on the surface of the absorber in calm environment. Meanwhile the maximum temperature degrees 70 deg. C on the surface of the absorber in air blasting environment. Therefore, the wind-chill factor is certified by the air blasting.

TECHNICAL PAPER ABSTRACTS

High-resolution time-Domain site attenuation measurements using common types of EMC test antennas—a numerical study

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This paper explores the use of conventional EMC test antennas to perform high-resolution time-domain site attenuation measurements. The objective of this research is to provide EMC engineers with a tool perform evaluations of radiated emissions test sites. Numerical simulations are used to model site attenuation behavior using biconical antennas, log-periodic dipole arrays, and dipoles. A two-step measurement procedure and data processing sequence are used to generate high-resolution time-domain waveforms. The results are promising and demonstrate that high-resolution waveforms can be obtained using common types of EMC antennas.

HF model of DC motor impedance (EMC problems in automotive applications)

R. Kahoul[1,2], Y. Azzouz[2], P. Marchal[1], B. Mazari[2], [1]Faurecia, Audincourt, France, [2]Irseem, St Etienne du Rouvray, France

A high frequency (HF) modeling method of low-voltage DC motor impedance is proposed. The model suggested is dedicated to the estimation of conducted electromagnetic interferences (EMI) within the car body and combines the advantages of both an analytical and a behavioral approach. It can simulate the motor's complex impedance from the continuous up to a frequency of approximately 1 GHz. Moreover, this model takes into account the skin effect in the winding and the eddy current effect in the laminated iron core. A parametric identification method was developed in order to improve the model.

Time varying instruction current EMC simulation improvement

S. Yuan, H. Chung , C. Chen, S. Liao , Feng Chia University, Taichung, Taiwan

Other papers have suggested that different application programs running on a digital system have their own EMC effects. This paper proposes two efficient and flexible techniques to improve the simulation efficiency of techniques instruction current waveform proposed by our laboratory. Experimental results show the efficiency is improved while the simulation quality remains the same.

TECHNICAL PAPER ABSTRACTS

Electromagnetic Coupling

Transient analysis of crosstalk coupling between high-speed carbon nanotube interconnects
M. D'Amore, M. Sarto, A. Tamburrano, University of Rome Sapienza, Rome, Italy

The scaling of copper wires and the increase in signal switching speed produce transient crosstalk coupling between interconnect lines, which causes overshoots and additional time delay. Nano-interconnects made by single wall carbon nanotube (SWCNT) bundles can be good candidates for VLSI circuits. In this paper SWCNT bundles are simulated by means of the multiconductor transmission line (MTL) model and the equivalent single conductor (ESC) one, which is derived by applying a concurrent multiscale approach. The output voltages to fast input step voltages are predicted considering a different number of conductive tubes in the bundles and different values of the load capacitance. The sensitivity analysis of the crosstalk effects is performed. The 50% time delay of the output responses is computed for the considered nano-interconnect configurations. The results obtained by applying the MTL model and the simplified ESC approach are in good agreement.

Modeling of the Substrate Coupling Path for Direct Power Injection in Integrated Circuits
A. Alaeldine[1,2], R. Perdriau[1], M. Ramdani[1], E. Sicard[3], M. Drissi[2], A. M. Haidar[4], [1]ESEO Angers - LATTIS, Angers Cedex 01, France, [2]IETR - INSA de Rennes, Rennes Cedex, France, [3]LATTIS - INSA de Toulouse, Toulouse Cedex 04, France, [4]Beirut Arab University, Faculty of Engineering, Beirut, Lebanon
This paper presents a substrate coupling path model for the direct power injection (DPI) of EMI disturbances into the substrate of an integrated circuit (IC). This modeling is achieved on a 0.18 µm test chip composed of several functionally identical cores, differing only by their EMI protection strategies (RC protection, isolated substrate), and takes into account these different strategies. The comparison between simulation results and related measurements demonstrates that, once combined with the complete model of the injection set-up itself, these models are helpful to choose the best protection strategy against electromagnetic disturbances.

An estimation of the backdoor coupling of UWB pulses on commercial wireless USB adapters
C. Kluender, J. ter Haseborg, Hamburg University of Technology, Hamburg, Germany

This paper describes the performed measurements to estimate a possible backdoor coupling on commercial wireless USB adapters using the 2.4 GHz ISM band caused by UWB pulses. Different commercial adapters (Bluetooth and WLAN) have been stressed by UWB pulses in a GTEM cell by using different setups. The coupled voltage into the different USB conductors (Data+, Data- and VCC) has been measured and compared to the standard voltage levels of the USB connection. It has been shown that backdoor coupling of the UWB pulses can have wide influences on the wireless USB adapters.

A Study on Electromagnetic Coupling between Transmission Line on Model Chip
Y. Kayano, H. Inoue, Akita University, Akita, Japan

To clarify the electromagnetic compatibility (EMC) problems that related to the interconnection in the integrated circuit (IC) chip, transmission characteristics and electromagnetic coupling between wirings in the specially designed model transmission lines in IC chip were investigated. At first, model transmission lines, designed on the bear chip with the size of 4800micrometer square, were created as model parallel transmission lines with straight, right angle and bending lines. The measurement methods, usually used for transmission line on the printed circuit board, are applied to the sample IC. It was demonstrated that decrease of transmission coefficient and dramatically large far-end cross-talk enough to cause serious errors arise at gigahertz frequency band.

TECHNICAL PAPER ABSTRACTS

Test Facilities and Instrumentation

Influence of the Receiving Antenna Pattern on the Site VSWR Validation Procedure above 1 GHz

S. Battermann, H. Garbe, Leibniz Universität Hannover, Hannover, Germany

This paper deals with the influence of the receiving antenna type used for the Site-VSWR method on the validation of test sites above 1 GHz. The significant effect of the receiving antenna radiation pattern on the Site-VSWR value will be shown. Furthermore the dependence of the used antenna types will be presented. The results are not only important for the validation method but also for the uncertainty budget of emission measurements that depends on the characteristics of the receiving antenna, also.

Absorber Loading Study in FOI 36.7 m3 Mode Stirred Reverberation Chamber for Pulsed Power measurements.

O. Lunden[1], M. Backstrom[2], [1]Swedish Defence Reseach Agency, Linkoping, Sweden, [2]Saab Communication, Linkoping, Sweden

A feasibility study was conducted to gain better understanding of the influence of different Q values of a 36.7 m3 reverberation chamber. The chamber was loaded with different types and numbers of microwave absorbers. For different chamber Q-values, the lowest usable frequency for 200 uncorrelated stirrer positions the agreement with the expected exponential power distribution, the chamber time constant and field build up process, has been studied. The time to get a steady field state in the unloaded chamber, due to the high Q-value, will normally be about 10 – 20 μs. Test requirements, according to the aviation test standard RTCA DO-160, state that the chamber shall be loaded so that the time constant is 40% of the pulse duration. This has also been investigated. In particular, our interest was to investigate expected field-levels for an ordinary radar source. The 700 kW S-band radar we have at our disposal has typical pulse duration of 1 μs.

Shielding Effectiveness of flat samples and conductive gaskets: new measuring cell for the frequency range 1-18 GHz

J. A. Catrysse, Khbo, Oostende, Belgium

In the past, different methods have been defined and some standardised for the characterisation of flat samples of shielding materials. Basically, the methods are based on three principles: coaxial cell methods simulating far field conditions, near-field cells (especially magnetic near field) and methods based on a modified Mil Std 285 design. The first two are typically restricted upto the frequency of around 1 GHz, and only the latter one allows measurements above 1 GHz. There is a lack of simple measuring setups in order to characterise the shielding effectiveness of small flat samples in this frequency range of 1- 18 GHz. In this paper, the design and construction of such a measuring is cell is discussed and a first set of measurements is summarised.

TECHNICAL PAPER ABSTRACTS

Response of a Magnetic Loop Probe to the Current and Voltage on a Microstrip Line

M. Spang[1], G. Schubert[2], M. Albach[1], [1]Friedrich-Alexander University, Erlangen, Germany, [2]Continental Automotive Systems, Nuremberg, Germany

This paper presents a method to determine the coupling of the current and the voltage on a microstrip trace into a magnetic field probe located above the trace. The application of different load impedances to the trace yields different ratios between current and voltage and therefore allows to identify the responses of the probe to both values separately. In the ideal case the output voltage of the loop probe should only be caused by the trace current via magnetic coupling, but in reality parasitic electric field coupling leads to an additional probe signal proportional to the voltage on the device under test (DUT). The transfer functions extracted from network analyzer measurements are discussed and compared to simulation results.

The Repeatability of System Level ESD Test and Relevant ESD Generator Parameters

J. Koo[1], Q. Cai[1], K. Wang[2], J. Mass[3], M. Hirata[4], A. Martwick[2], D. Pommerenke[1], [1]Missouri University of Science and Technology, Rolla, United States, [2]Intel Corporation, Hillsboro, United States, [3]IBM Corporation, Rochester, United States, [4]Fuji Xerox Corporation, Kanagawa, Japan

Some system level ESD test do not repeat well if different ESD generators are used. For improving the test repeatability, ESD generator specifications were considered to be changed and a world wide Round Robin test were performed in 2006 to compare the modified and unmodified ESD generators. The test results show the failure level variations up to 1:3 for an EUT among eight different ESD generators. Multiple ESD parameters including discharge currents and transient fields have been measured. This paper tries to find which parameters would predict the failure level the best in general. The transient fields show large variations among different ESD generators. The voltage induced in a semi-circular loop and the ringing after first discharge current peak show the best correlation to failure levels. The regulation on the transient field is expected to improve the test repeatability.

Orthogonal Loops Probe Design and Characterization for Near-Field Measurement

T. Li, Y. Ho, D. J. Pommerenke, Missouri University of Science and Technology, Rolla, United States

Near-field probes are often used to measure the electric and magnetic fields above a printed circuit board in order to identify the sources and coupling paths of an electromagnetic interference (EMI) problem. It is the objective of this paper to propose a rapid E-, Hx- Hy- and circular H-fields measurement using an orthogonal loops probe design. The effects of this probe are analyzed using full-wave simulations and measurements.

TECHNICAL PAPER ABSTRACTS

Computational EM 5

A Fast Radiated Emission Model for Arbitrary Cable Harness Configurations Based on Measurements and Simulations

H. M. Rebholz, S. Tenbohlen, Universität Stuttgart, Stuttgart, Germany

Within a functional EMC simulation for automotive component tests, the cable harness shows significant influence to the radiated emissions. Detailed harness models, including a radiation pattern, can be generated with the help of a full wave simulator within the frequency range. Unfortunately the calculation process is a very time intensive task, especially if the complete setup in respect to CISPR25 for radiated emissions is considered, within the frequency range from 0.15 - 1000MHz. With the help of one simplified simulation and calibration measurements, it is possible to speed up the model generation process of the harness and to consider the ambient and auxiliary measurement structures. If the transfer function between the simulation model and the real measurement structure is known, every arbitrary simulation model can be extrapolated to the real setup. The method is presented for different harness structures and tested for assemblies with up to ten wires.

Electromagnetic PCB Pattern Modeling Techniques for RF Hardware Simulation of Mobile Phones

Y. Kim, S. Kwon, A. S. Kim, Samsung Electronics Co., ltd., Suwon, Republic of Korea

Various different types of PCB pattern modeling methods for new RF co-simulation technique are presented and applied to wireless phone application. PCB electromagnetic (EM) modeling is essential part of new RF combinational simulation - RF components plus PCB 3D pattern concurrently modeled, however, it takes typically few-hours burdensome modeling time. In this paper, several intermediate forms of PCB modeling methods are evaluated in terms of S-parameters and RF specification such as WCDMA adjacent channel leakage ratio (ACLR) and PCB pattern was pick up from actual mobile phone design in 10-layered FR4 PCB stack-up. Compared to full 3D PCB pattern models, divided pattern model shows competitive accuracy within 0.6~2.0dBm, ACLR average difference and seems to be worthy to replace full PCB pattern models. Experimental data shows that divided pattern modeling technique requires only about 12% of practical full 3D PCB modeling time.

Radiated Emission of Bent Microstrip Line Using Hertzian Dipole Method

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Electromagnetic Interference (EMI) and Signal Integrity (SI) issues have generated challenges to the high speed digital circuit designer as the operating clock frequency of the system continue to increase to accommodate broadband applications. Discontinuity due to microstrip bents which appear frequently in most VLSI design requires thorough understanding on the current distribution in order to generate the immunity and emission characteristic of the circuit. In this paper, the focus will be on the bent microstrip transmission line based on the forward-backward travelling wave mode method (TWM) by Xilei Liu et. al. Their approach will be modified by adding equivalent wire model to suit for the case of microstrip line. The expanded hertzian dipole method was then used to determine the inadmissible radiated emission that annoys the external circuits. Computer simulation using MICROWAVE STUDIO® will be implemented for validation of the modeling technique.

TECHNICAL PAPER ABSTRACTS

Prediction of the Common-mode Radiated Emission from the Board to Board Interconnection through Common-mode Antenna Model

M. Torigoe[4,1], A. Sadatoshi[1], T. Watanabe[2], K. Iokibe[1], Y. Toyota[1], R. Koga[1], O. Wada[3], [1]Okayama University, Okayama, Japan, [2]Industrial Technology Center of Okayama Prefecture, Okayama, Japan, [3]Kyoto University, Kyoto, Afghanistan, [4]Hitachi, Ltd., Hitachi, Japan

In this paper, the common-mode antenna model, which can estimate the amount of common-mode radiation quickly and accurately, was applied to a board-to-board interconnection structure with a connector. The inductor model is introduced as the connector model for improving accuracy of the common-mode antenna model. By using the inductance, which was calculated with the commercial electromagnetic field simulator, the radiated emissions estimated by the model agreed with the measurement results within an error of 3 dB around the peak emission levels.

EMC Macro-modeling of CMOS Inverter Using LECCS-I/O Model with Additional Current Source

K. Iokibe[1], A. Osaki[1], O. Wada[2], Y. Toyota[1], R. Koga[1], [1]Okayama Univ., Okayama, Japan, [2]Kyoto Univ., Kyoto, Japan

The authors investigated an EMC macro-model of the CMOS logic inverter gate, named LECCS-I/O that consists of linear equivalent circuit and current sources. This paper modifies the macro-model by adding another current source to express the short-circuit current in the inverter. The macro-model was determined from SPICE calculations of impedance and power current by using a device model of an inverter IC. The modified model was tested with several load capacitances in SPICE simulation. The results showed that the macro-model predicts the power current with good accuracy in the range up to 3 GHz except for frequencies at which inductances of the package and of traces on printed circuit board and capacitance of the load caused resonances.

TECHNICAL PAPER ABSTRACTS

Emissions and Immunity

Improvement of Dispersion of Radiated Emission Measurement Results by VHF-LISN

C. Miyazaki[1], K. Tanakajima[2], M. Yamaguchi[3], S. Satake[4], J. Kawano[5], [1]Mitsubishi Electric Corporation, Kanagawa, Japan, [2]Intertek Japan K.K., Ibaraki, Japan, [3]EMC Education, Tokyo, Japan, [4]Hitachi, Ltd., Tokyo, Japan, [5]VCCI, Tokyo, Japan

VCCI Technical Sub-committee has investigated the dispersion of radiated emission measurement results. It was confirmed that one of the main cause of the dispersion of radiated emission measurement results was the difference of the power line-to-ground impedance of the power supply for the equipment under test. For the improvement of the dispersion, VCCI manufactured the experimental VHF-LISN. And we confirmed the validity of this VHF-LISN.

Assessing the performance of ZigBee in a reverberant environment using a mode stirred chamber

D. Hope[1], J. Dawson[1], A. Marvin[1], M. Panitz[2], C. Christopoulos[2], P. Sewell[2], [1]University of York, York, United Kingdom, [2]University of Nottingham, Nottingham, United Kingdom

The application of ZigBee networks to highly reverberant environments has been investigated using a reverberation chamber. Different Q-factors were set up, by loading the chamber, and the performance of a COTS ZigBee system was recorded. It has been found that the ZigBee system tested is capable of working in highly reverberant environments and is only seriously limited for a value of Q-factor above 5000. The packet error rate (PER) was generally found to be very low for Q-factors between 1000 and 5000, with the possibility a high PER for some combinations of stirrer and antenna positions. With a Q of below 1000 the transceivers were found to work with a PER below 1% regardless of antenna and stirrer positions and the corresponding fading is nearly flat over a data symbol's bandwidth. Radio performance is presented in terms of the packet error rate and this is related to the measured and simulated channel impulse response.

EMC Characterization for Switching Noise Investigation on Power Transistors

E. Batista[1], J. Dienot[2], [1]Power Electronics Associated Research Laboratory, Semeac, France, [2]University Institute of Technology, Tarbes, France

This paper proposes a complete characterization approach for switching noise effects study on a new Electromagnetic Compatibility (EMC) multi-domain problematic with electronics embedded systems, mixing power components and integrated circuits in common volumes. In this context EMC 3D couplings effects, i.e. between power converter chip (MosPower, Insulated Gate Bipolar Transistor (IGBT)) and digital Printed Circuit Board (PCB) with Pulse Width Modulation (PWM) pattern, take place in more and more wide range of frequency, as 1kHz – 1GHz. Based on a general methodology called XVICE, the modeling approach is also presented.

Measured Radiated Field From UWB Signal Over Powerline Channel

G. Mekuria, H. Hirsch, Universität Duisburg-Essen, Duisburg, Germany

Mitigation of radiated interferences from Power line channel using carrier-less UWB pulse transmission is addressed in this paper. Results presented show that radiated field strength can be reduced significantly for the Broadband Powerline frequency range of below 30 MHz by transmitting carrier-less UWB pulses instead of carrier-based transmissions.

Evaluation of Interference between MB-OFDM UWB and Wireless LAN Systems using a GTEM Cell

H. Kamiya[1], M. Yamada[1], S. Ishigami[2,2], K. Gotoh[2,2], Y. Matsumoto[2,2], M. Tokuda[1], [1]Musashi Institute of Technology, Setagaya-ku, Japan, [2]National Institute of Information and Communications Technology, Koganei-shi, Japan

In this study, an electromagnetic interference of an MB-OFDM UWB system with an IEEE802.11a wireless LAN was evaluated using a GTEM cell. As a result, when Band #4 (in-band radiation for 11a) in the band plan of the MB-OFDM UWB system, although the interference power of the MB-OFDM UWB was less than the receiver noise, the MB-OFDM UWB system interfered with the wireless LAN. In addition, the separation distance was evaluated from the power inputted to the GTEM cell. As a result, for the vicinity of the minimum receiver sensitivity of the wireless LAN, the separation distance was about 3 m. Finally, the amplitude probability distribution (APD) of the MB-OFDM UWB system that was the interference source was evaluated. As a result, the APD characteristics of MB-OFDM UWB was slight different from the additive white Gaussian noise (AWGN).

TECHNICAL PAPER ABSTRACTS

Shielding

Fundamental Models for Near Field Shielding
R. J. Mohr, R. J. Mohr Associates, Inc., Northport, United States

Models for fundamental shielded enclosures are developed. The models clearly show the dependence of the emissions from a shielded enclosure on the nature of the basic sources of emissions within the enclosure. The models clarify certain aspects of Schelkunoff's approach to shielding analysis which are often questioned. Available test data is shown to confirm the models.

EMI Gasket Shielding Effectiveness Evaluation Method Using Transmission Theory
D. Moongilan, E. E. Mitchell, Alcatel-Lucent, Murray Hill, United States

This paper provides method for measuring Shielding effectiveness (SE) of EMI gaskets using transmission theory. The method described in this paper uses controlled impedance TEM fields and therefore it is more accurate and repeatable. Measurement error estimation method is explained. A GTEM and a semi-anechoic chamber are used for test field generation and leakage field measurements. The SE of Copper-Nickel foam gaskets and Beryllium Copper finger-stock gaskets that are used between seams of circuit pack faceplates are computed with resulting data presented and discussed.

Using Conductive Plastic for EMC Cover Shielding
T. L. McMillan, IBM, Rochester, United States

This paper describes the use of conductive plastic (stainless steel fibers in plastic) as part of the EMI cover shielding. It describes the experiences learned when going to conductive plastic covers in place of metal plated covers.

Shielding Effectiveness with a Twist
P. F. Keebler, K. O. Phipps, EPRI, Knoxville, United States

Traditionally Schelkunoff’s shielding effectiveness equation is used universally in teaching and practice throughout the EMC community as a whole. In this paper three basic classic problems of Schelkunoff’s are reviewed. The results of previous papers and government reports on near and far field shielding experiments are discussed. Through practical laboratory testing, experiments and discussion are presented in support of explaining the case where the expression SE = SE(H) = SE(E) is not a valid axiom in the near field and SE = SE(H) = SE(E) is valid in far field in support of understanding shielding concepts. Discussion on the application of Leontovich Boundary Conditions is included when relevant in support of basic shielding theory. No attempt however will be made to re-derive a closed mathematical expression or to provide a new comprehensive shielding theory.

Shielding Analysis of Enclosure with Aperture irradiated by Plane Wave with arbitrary incident Angle and Polarization Direction

D. Shi[2], Y. Shen[2], F. Ruan[2], Z. Wei[1,2], Y. Gao[2], [1]Beijing Unversity of Posts & Telecommunications, Beijing, China, [2]Zhongan Company, Guang Zhou, China

An analytical formulation has been developed for the shielding effectiveness of rectangular enclosure with off-center enclosure. It deals with more general case including arbitrary located aperture and high frequency incident wave by making use of high-order TEM mode transmission line model. The incident electromagnetic field impinges on the enclosure with arbitrary incident angle and polarization direction. Oblique incident wave is investigated by decomposing it into perpendicular polarization component and parallel polarization component. Relationship between shielding effectiveness and incident angle, polarization direction, aperture size, test point location as well as frequency are investigated.

Product Safety

Effects of Thermoregulatory Mechanisms on the Eye Thermal Elevation Produced by Intense RF Exposures
V. De Santis, M. Feliziani, University of L'Aquila, L'Aquila, Italy

A numerical study is proposed to investigate on the maximum temperature increase in the human eye produced by intense radiofrequency (RF) exposure. In particular, the ICNIRP limits prescribed in terms of local specific absorption rate (SAR) on the human head for occupational exposure have been employed as reference values. The purpose is to establish a rationale relationship between the maximum admissible SAR value (dose) and the corresponding temperature rise (effect). To this aim, an accurate thermal model based on the bio-heat equation (BHE) together with a complex thermoregulatory system has been developed. A detailed modeling of the ocular cooling mechanisms has been also considered for the first time under several kinds of exposure and environmental conditions. The obtained results show that the maximum temperature increases in the lens for the ICNIRP limits are 1.38-1.51 °C.

EMC for the Functional Safety of Automobiles Why EMC Testing is Insufficient, and What is Necessary
K. Armstrong, Cherry Clough Consultants, Stafford, United Kingdom

'Functional safety' means the achievement of acceptable risks due to operational (functional) errors or malfunctions over the anticipated lifetime of a product. Electromagnetic Compatibility (EMC) is validated by testing product characteristics using standardized test methods in an EMC laboratory. There have long been concerns [1] that this is inadequate for functional safety. In all safety-engineering disciplines it is considered insufficient to rely totally on product testing. Instead, acceptable safety risks are validated using a variety of methods (including, but not limited to testing) to verify the safety design. Part II of this paper describes twelve reasons why 'traditional' automotive EMC testing is insufficient as the sole means of demonstrating the necessary EM characteristics. Part III describes what EM engineering and verification techniques are required, where errors or malfunctions in electronics (hardware and firmware) could impact functional safety.

Assessment of Active Implantable Medical Device Interaction in Hybrid Electric Vehicles
J. J. Nelson[1], W. Clement[2], B. Martel[3], K. H. Nelson[4,5], [1]Daimler AG, Stuttgart, Germany, [2]Medtronic Inc., Minneapolis, United States, [3]General Motors, Milford, United States, [4]Detroit Medical Center , Detroit, United States, [5]Wayne State University, Detroit, United States

New technologies tend to heighten public concerns regarding EMF, especially in RF and high power industries. Vehicles with electrical propulsion and assist, such as hybrid electric vehicles, have increased electrical power output compared to non-hybrid electric vehicles. An investigation of nine current production hybrid electric vehicles has been conducted and found no inappropriate interaction between worst-case vehicle operating conditions and active implantable medical devices. The study utilized a human body phantom allowing for realistic device lead routing and placement of the active implantable medical devices. Additionally, all measured continuous magnetic fields in the passenger cabin were beneath ICNIRP Public Guidelines.

Antenna performance of mobile phone and corresponding human exposure inside fully and partially enclosed metallic elevator

C. Tang, K. Chan, L. Fung, S. Leung, City University of Hong Kong, Hong Kong, SAR, Hong Kong

The effects of using mobile phone inside both fully and partially enclosed metallic elevators on the antenna performance and the human exposure have been studied by using FDTD numerical method. It has been found that the antenna performance is degraded in all the enclosed metallic elevators studied due to the low radiation efficiency. Results have also shown that, for the human exposure, the electric field strength and the peak SAR of mobile phone user in the fully enclosed metallic elevator is the largest due to the resonance effect.

TECHNICAL PAPER ABSTRACTS

Special Session:
Validation of Simulation/Modeling Results

Proper Model Validation is Important for all EMI/EMC Applications

B. R. Archambeault, S. Connor, IBM, Research Triangle Park, United States

The need to perform validation of simulation results is often ignored because commercial (and non-commercial) software tools are 'trusted' due to previous results. However, previous results from different models do not indicate the current model was created properly. This paper discusses the need to validate simulations and discusses various means for the quantification of the agreement between different simulations used for validation.

Differential Vias Transition Modeling in a Multilayer Printed Circuit Board

M. Cocchini[1], W. Cheng[2], J. Zhang[2], J. Fisher[2], J. Fan[1], J. Drewniak[1], Y. Zhang[1], [1]UMR/MST EMC Laboratory, Missouri University of Science and Technology, Rolla, United States, [2]Cisco Systems, San Jose, United States

A 26-layer printed circuit board including several test sites has been analyzed. All the sites have a transition from coupled microstrips to coupled striplines through signal vias. Differential measurements have been performed on some of these test sites to estimate the effect on S-parameters and eye diagrams due to via and antipad radius variation, and different lengths of via stub. At the same time, a physics based circuit model has been assembled in a spice-based simulation tool and a full-wave model has been generated as well. The simulation results have been compared with the measurements for both differential and single ended cases. A brief discussion about possible issues associated with fabrication tolerances is presented in the last chapter.

Time-Domain Modeling Techniques for Periodic Structures

R. Qiang[1], D. Jackson[1], J. Chen[1], W. Kainz[2], [1]ECE, Houston, United States, [2]FDA, Silver Spring, United States

Novel time-domain modeling techniques for periodic structures are described in this paper. These methods can be used to investigate electromagnetic propagations and scatterings from infinite artificial periodic arrays from arbitrary electromagnetic source illumination and extract the equivalent electric properties of composite structures. . Using this method, only a single periodic cell is required in the modeling using finite-difference time-domain method. Several periodic structures are analyzed by this proposed method to testify its computational efficiency in terms of computer memory and computing time.

Progress in the Development of a 2D Feature Selective Validation (FSV) Method

A. Orlandi[1], G. Antonini[1], C. Polisini[1], A. Duffy[2], H. Sasse[2], [1]University of L'Aquila, L'Aquila, Italy, [2]De Montfort University, Leicester, United Kingdom

The Feature Selective Validation (FSV) Technique is becoming a favored approach to quantifying the comparison of numerical and / or experimental data for validation purposes. It is a heuristic approach and, therefore, has scope for developments, enhancements and refinements from researchers particularly interested in formal validation, particularly of computational electromagnetics. One area that is clearly ripe for development is in extending the current '1D' FSV approach to two or more independent axes, for example to compare surface currents over a whole body. As the central tenet of FSV is to mirror the perceptions of a group of experts, higher levels of dimensionality provide substantial challenges for calibration. However, a first step in this development is gaining experience and understanding of the quantification of multidimensional data. Building on previous work, this paper concludes with a set of recommendations for the full development of two dimensional FSV.

TECHNICAL PAPER ABSTRACTS

Special Session:
Recent Advances in Jitter and BER Analysis in High Speed Serial Links

Jitter Modeling in Statistical Link Simulation

Y. Chang, D. Oh, C. Madden, Rambus Inc., Los Altos, United States

Modern high-speed I/O link design requires accurate modeling and simulation of various jitter types including both deterministic and random jitter components. Transient simulators such as SPICE have successfully modeled deterministic jitter but they have limited capabilities to model random jitter. A statistical approach has been recently employed to handle jitter more efficiently. This paper presents a general jitter model suitable for a statistical simulation framework. The proposed model can accurately account for transmitter and receiver random jitter with any distribution and power spectrum density. We have also extended the proposed model to derive a closed-form formula for modeling transmitter clock jitter. The presented methodology is validated using both time-domain simulation and lab measurement.

Estimation of Very Low BER Using Quasi-Analytical Method

D. Lu, S. Gupta, M. Marcu, Agilent Technologies Inc., Santa Rosa, United States

This paper proposes to estimate very low system BER using Quasi-Analytical (QA) method. The results from both theoretical analysis and simulation show that QA estimation is unbiased. Based on calculation of the simulation variance and improvement ratio for QA estimation, the QA is very effective for estimation of very low BER for system with inter-symbol interference (ISI), jitter and additive noise.

Crosstalk Analysis of a System Based on XAUI HM-Zd Evaluation Backplane Data

B. Katz, M. L. Steinberger, T. Westerhoff, Signal Integrity Software, Inc., Maynard, United States

This paper presents the results of a performance analysis of a system based on measured backplane data published for the XAUI HM-Zd evaluation backplane. This analysis traces the impact of near and and far end crosstalk on bit error rate, and presents some crosstalk metrics which can be applied early in the system design process.

A Flexible and Efficient Bit Error Rate Simulation Method for High-Speed Differential Link Analysis Using Time-domain Interpolation and Superposition

K. Xiao[1], B. Lee[2], X. Ye[3], [1]Intel Corporation, DuPont, United States, [2]Intel Corporation, Santa Clara, United States, [3]Intel Corporation, Hillsboro, United States

In this paper, a flexible and efficient time-domain method for calculating the bit error rate of high-speed differential links is presented. The method applies interpolation and superposition to the step response of a channel to construct the jittery data or/and clock waveforms at the receiver. With the statistics of the actual reference-crossing points extracted from the constructed receiver waveforms, the bathtub curves can be derived and extrapolated to get the eye margin at the given bit error rate. A software has been developed and applied for high-speed differential link design using the method. Good correlation has been achieved between the simulated results using this method and the measurement data with a bit error rate tester.

TECHNICAL PAPER ABSTRACTS

Statistical Channel Modeling Inclusive of Cross Talk Effects for Bit Error and Eye Analysis

S. G. Pytel[1], *G. Barnes*[1], *R. I.* Mellitz[2], M. Tsuk[1], R. Holoboff[1], [1]Ansoft, Gilbert, United States, [2]Intel Corporation, Columbia, United States

This paper describes a SerialATA 3.0 Gb/s channel created using one-, two-, and three-dimensional models. These various models have been combined with circuit simulation techniques to provide channel bit error rates (BER) under different de-emphasis settings. Analysis of the channel was performed using an aggressor-victim-aggressor simulation strategy that included Gaussian random jitter (RJ) and deterministic jitter in the form of duty cycle distortion (DCD). Finally, upon completion of the statistical solutions, various bit patterns and edge rates are chosen to act as the excitation source for near- and far-field plots on a backplane board. This technique provides an innovative simulation strategy that combines full channel analysis including radiated emissions dependent on drive strength and bit patterns.

Duty-Cycle Distortion and Specifications for Test-Signal Generation

M. Marcu, S. Durbha, S. Gupta, Agilent Technologies, Inc., Santa Rosa, United States

Duty-cycle distortion is one of the causes of deterministic jitter. Clarification and refinement of this jitter type is presented here. The jitter-tree is then updated with the jitter types discussed. Predicting the behavior of electrical systems under stress from jitter through simulations is limited by the availability of signal sources with controllable and flexible jitter properties in the design environment. A jitter specification method for ISI and DCD is recommended.

TECHNICAL PAPER ABSTRACTS

Special Session:
Parallel Processing Algorithms

Advanced Parallel Algorithm for the System-Level EMC Modeling of High-Speed Electronic Package
*E. Li, X. Wei, E. Liu, Z. OO, A*STAR Institute of High Performance Computing, Science Park II, Singapore*

This paper presents a novel algorithm for EMC simulation of electronic package integration. This algorithm is based on hybridizing method of moments with analytical method, modal expansion technique. The entire electronic package domain is divided into two networks: the signal distribution network(SDN) and the power distribution network(PDN). SDN is simulated using the method of moments, where the equivalent RLCG parameters of the signal traces are extracted. The PDN is simulated by using the modal expansion technique, where the equivalent circuit of the power distribution network is obtained. With the proposed method, the system-level EMC modeling of the package can be performed efficiently. Numerical examples demonstrate that this approach is able to provide fast yet accurate simulation for signal and power integrities analysis of multilayered electronic packages. The parallel process of the proposed method is implemented in our institute's high performance computer.

The Discontinuous Galerkin Finite Element Time Domain Method (DGFETD)
S. D. Gedney[1], J. A. Roden[2], C. Luo[1], J. A. Miller[2], J. Beggs[2], B. Guernsey[2], R. D. Crawford[2], T. Kramer[1], [1]The University of Kentucky, Lexington, United States, [2]The Aerospace Corporation, Chantilly, United States

The Discontinuous Galerkin Finite-Element Time-Domain method is presented. The method is based on a high-order finite element discretization of Maxwell's time-dependent curl equations. The mesh is decomposed into contiguous sub-domains of finite-elements with independent function expansions. The fields are coupled across the sub-domain boundaries by enforcing the tangential field continuity. This leads to a locally implicit, globally explicit difference operator that provides an efficient high-order accurate time-dependent solution. An efficient implementation of the perfectly matched layer media boundary truncation is also presented that allows general tetrahedral meshing through the PML region.

Simple Load Balancing in Binary-Tree Based Parallel Multilevel Low-Rank Compression Techniques
M. Astner, H. Bruens, H. Singer, TU Hamburg-Harburg, Hamburg, Germany

This paper discusses the parallel implementation of a multilevel low-rank compression technique applied to the electric field integral equation (EFIE) discretized by means of the Method of Moments (MoM). Due to the unpredictable rank of the blocks to be compressed, special attention is paid to the load balancing of the setup phase where different approaches are presented. The efficiency of these approaches is compared by means of two different structures. Also performance and speedup results are shown for both the setup and resolution phase.

TECHNICAL PAPER ABSTRACTS

A Fast and Parallel Stroud-Based Stochastic Collocation Method for Statistical EMI/EMC Analysis
H. Bagci[1], C. Yavuz[1], A. C. Yucel[1], J. S. Hesthaven[2], E. Michielssen[1], [1]Radiation Laboratory, Ann Arbor, United States, [2]Scientific Computing and Numerical Analysis Group , Providence, United States

A fast and parallel Stroud-based stochastic collocation method for statistically characterizing electromagnetic interference and compatibility (EMI/EMC) phenomena on loaded multiscale platforms with uncertain system configurations and subject to variable electromagnetic excitations is described. The proposed method uses a previously developed hybrid time domain integral equation based field-cable-circuit to carry out deterministic EMI/EMC simulations permitting the statistical characterization of pertinent observables. The number of simulations required by the proposed method is far fewer than those needed by Monte-Carlo methods. The proposed method is used to characterize cable-induced coupling onto PC cards located in shielding enclosures. Both the hybrid simulator and the stochastic collocation code execute with near-full efficiency on distributed memory clusters.

Enhanced Hybrid MPI-Open-MP Parallel Electromagnetic Simulations Based on Low-Rank Compressions
X. Wang, V. Jandhyala, Applied Computational Engineering Lab, Seattle, United States

Existing and emerging parallel computing clusters have nodes with multiple-core CPUs. The distributed-memory property across nodes and shared-memory property within a node coexist with each other. The hybrid architecture can be well exploited by combining the MPI (message passing interface) and OpenMP libraries. This combination is able to reduce memory usage and communication costs compared with either individual approach. In addition, the proposed hybrid static-dynamic load scheduling can yield excellent load-balancing without introducing extra cost. Careful implementation of OpenMP threads can diminish parallel overhead significantly, and expedite the iterative solver in several ways. Numerical experiments validate the high performance of the presented hybrid approach.

A New Frequency Domain Waveform Relaxation Algorithm for PEEC Models
G. Antonini[1], A. E. Ruehli[2], [1]University of L'Aquila, L'Aquila, Italy, [2]IBM, Yorktown Heights, United States

Waveform Relaxation (WR) is conventionally a time domain algorithm for the solution of linear and nonlinear partial and ordinary differential equation problems. It is especially suited for large systems and parallel processing due to the large compute-to-communication ratio and its ability to break up large problems into smaller ones. In this paper, we investigate the new application of WR to linear frequency domain problems. We show that we can use the insights gained from the extensive time domain WR research results to come up with a new frequency domain approach. For this purpose, we compute frequency response waveforms rather than time domain waveforms. Fortunately, some techniques such as partitioning are similar for both approaches. In this paper, we test some of the new algorithms for the frequency domain analysis. The new approach is aimed at the solution of large problems using single and parallel processor solutions.

TECHNICAL PAPER ABSTRACTS

Special Session:
Impact of External Noise Sources on High Speed Signal Integrity

Quantifying EM noise coupling to antenna coax cable placed in a digital device
S. Ikami, A. Sakurai, IBM Japan, Ltd, Yamato, Japan

We clarified a coupling mechanism through the air of electromagnetic noise generated a LSI mounted in the printed circuit board to the antenna coaxial cable placed in the same digital device. It is quantified with experiment and numeric simulation that how much noise power can be transferred to the coaxial cable and its terminal ends. Shield characteristics of the coaxial cable placed near a noise source is also examined and presented interesting results that will be usable for product design.

Signal Integrity Testing using Multiple Out-of-Band Sources in a Reverberation Chamber
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This paper considers the use of the reverberation chamber as a possible facility to test equipment, illuminated by multiple sources, in order to ascertain their susceptibility to in-band effects caused by intermodulation from two or more out-of-band signals. The work is premised on the fact that issues with signal integrity may not be dominated with direct single-source threats but may be substantially affected by intermodulation from two or more signals that would, themselves be filtered out of the system, combining through active (or possibly passive) intermodulation to give rise to a noise signal that is within the consideration band of the signal whose integrity is paramount. The purpose of the paper is to present the results of a first series of simulation experiments that indicate that a simple approach to multiple source testing may be effective as a basis for a more extensive set of tests.

The Impact of External RF Energy on High-Speed Differential Signal Quality of Long Cables
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As voltage levels decrease and data rates increase and the electromagnetic environment becomes more noisy for high-speed, differential, I/O data buses in data centers, the electromagnetic susceptibility of these data links increases. Signal integrity and EMC engineers need a way to quantify the risk of data errors given a certain level of external noise and an I/O cable's characteristics. This paper proposes a methodology by which an engineer can calculate a transfer function that enables one to determine the differential noise signal created by an external field or conversely to determine the external field strength necessary to create a differential signal capable of causing data errors.

TECHNICAL PAPER ABSTRACTS

Noise Coupling Between Power/Ground Nets Due to Differential Vias Transitions in a Multilayer PCB

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Due to increasing board density, routing traces on different layers is becoming a widely used strategy. This means the vias penetrate power/ground plane pairs and cause noise coupling between signal and power/ground nets. At the same time, the need of a clean signal transmitted to the receiver is involving a large use of differential signals. This paper studies the noise coupling mechanism using cavity and via-to-antipad capacitance models for a single power-plane pair and connecting the layers using a segmentation approach. A 26-layer board stack-up and a pair of differential vias have been modeled and simulated showing the impact of ground vias nearby the signal and via stub length.