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Signal Integrity, Electromagnetic Compatibility, Macromodeling, Digital Integrated Circuits, Transmission Lines, 3D Interconnects, Passivity 1 Introduction This paper presents a systematic methodology for the Signal Integrity and EMC simulation of distribution networks of digital signals in high-speed communication and information systems

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Merely said, the signal integrity and electromagnetic broadband packaging is universally compatible with any devices to read Principles and Techniques of Electromagnetic Compatibility-Christos Christopoulos 2018-10-03 Circuits are faster and more tightly packed than ever, wireless technologies increase the electromagnetic (EM) noise environment, new materials

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This interactive infographic uses short videos to explain the electromagnetic compatibility (EMC) and signal integrity (SI) issues affecting the design of a mobile phone. USB 3.2 offers data speed up to 20GBit/s. These fast signals create broadband noise that can affect other electronics systems even at radio frequencies (RF). This often leads to RF de-sense and crosstalk.

This dissertation proposal is concerned with the use of fast and broadband full-wave electromagnetic methods for modeling high speed interconnects (e.g, vertical vias and horizontal traces) and passive components (e.g, decoupling capacitors) for structures of PCB and packages, in 3D IC, Die-level

packaging and SIW based devices, to effectively modeling the designs signal integrity (SI) and power integrity (PI) aspects. The main contributions finished in this thesis is to create a novel methodology, which hybridizes the Foldy-Lax multiple scattering equations based fast full wave method, method of moment (MoM) based 1D technology, modes decoupling based geometry decomposition and cavity modes expansions, to model and simulate the electromagnetic scattering effects for the irregular power/ground planes, multiple vias and traces, for fast and accurate analysis of link level simulation on multilayer electronic structures. For the modeling details, the interior massively-coupled multiple vias problem is modeled most-analytically by using the Foldy-Lax multiple scattering equations. The dyadic Green’s functions of the magnetic field are expressed in terms of waveguide modes in the vertical direction and vector cylindrical wave expansions or cavity modes expansions in the horizontal direction, combined with 2D MoM realized by 1D technology. For the incident field of the case of vias in the arbitrarily shaped antipad in finite large cavity/waveguide, the exciting and scattering field coefficients are calculated based on the transformation which converts surface integration of magnetic surface currents in antipad into 1D line integration of surface charges on the vias and on the ground plane. Geometry decomposition method is applied to model and integrate both the vertical and horizontal interconnects/traces in arbitrarily shaped power/ground planes. Moreover, a new form of multiple scattering equations is derived for solving coupling effects among mixed metallic/dielectric vias. The advantage of this kind of form has much better property for making inverse operation to obtain accurate results. All the proposed methods developed in this thesis have been verified by comparing the S parameters with the results from Ansoft’s HFSS, for various via configurations and via array sizes in high density layout in benchmark simulations. It is shown that the hybrid method is accurate mostly within 5% difference from results of HFSS and is about tens to hundreds of times faster than running HFSS up to 100GHz

This dissertation is focused on research and development of an innovative Broadband Green's Function method and the applications to fast electromagnetic modeling and simulations of high-speed interconnects. Innovative solutions based on proposed broadband Green's function method are presented and demonstrated to solve the challenging problems in signal integrity, power integrity, and electromagnetic compatibility and interference for computer system designs. The main contents of this dissertation are twofold: to overcome the fundamental restrictions in the conventional Green's function methods through introducing the broadband Green's function method, to explore the applications of the broadband Green's function to modeling of high-speed interconnects in modern electronic devices and systems. In the first project, the method of broadband Green's function with low wavenumber extraction (BBGFL) is proposed for arbitrary shaped waveguide. The methodologies of BBGFL are derived for both Neumann and Dirichlet boundary conditions. In the second project, we combine the BBGFL with method of moment (MoM) for fast full wave modeling and simulations of scattering in arbitrary shaped waveguides. The method is applied to solve the problem of vias inside PCB power/ground plane waveguide. In the third project, a number of applications are investigated, including modeling of vias in arbitrary shaped power/ground planes, modeling of emissions from printed circuit boards, modeling of stripline connecting transition vias in power/ground planes, modeling of arbitrary shaped waveguide structures in microwave components. The proposed methods are compared to in-house method of moment program and commercial HFSS tool. Simulation results of various problems are illustrated. The present methods are verified by comparing the resonant frequencies, Green's functions, S-parameters, surface fields, and/or radiated emission for different problems. BBGFL has good agreement with MoM and/or HFSS on the numerical results. The computational efficiency is checked by comparing the CPU time. BBGFL is about two or three orders faster than MoM and HFSS for most cases in modeling of high-speed interconnects.

Before putting digital systems for information technology or telecommunication applications on the market, an essential requirement is to perform tests in order to comply with the limits of radiated emission imposed by the standards. This book provides an investigation into signal integrity (SI) and electromagnetic interference (EMI) problems. Topics such as reflections, crosstalk, switching noise and radiated emission (RE) in high-speed digital systems are covered, which are essential for IT and telecoms applications. The highly important topic of modelling is covered which can reduce costs by enabling simulation data to demonstrate that a product meets design specifications and regulatory limits. According to the new European EMC directive, this can help to avoid the expensive use of large semi-anechoic chambers or open area test sites for radiated emission assessments. Following a short introduction to signalling and radiated interference in digital systems, the book provides a detailed characterization of logic families in terms of static and dynamic characteristic useful for modelling techniques. Crosstalk in multi-coupled line structures are investigated by analytical, graphical and circuit-based methods, and techniques to mitigate these phenomena are provided. Grounding, filtering and shielding with multilayer PCBs are also examined and design rules given. Written by authors with extensive experience in industry and academia. Explains basic conceptual problems from a theoretical and practical point of view by using numerous measurements and simulations. Presents models for mathematical and SPICE-like circuit simulators. Provides examples of using full-wave codes for SI and RE investigations. Companion website containing lists of codes and sample material. Signal Integrity and Radiated Emission of High-Speed Digital Systems is a valuable resource to industrial designers of information technology, telecommunication equipment and automation equipment as well as to development engineers. It will also be of interest to managers and designers of consumer electronics, and researchers in electronics.

Circuits are faster and more tightly packed than ever, wireless technologies increase the electromagnetic (EM) noise environment, new materials entail entirely new immunity issues, and new standards govern the field of electromagnetic compatibility (EMC). Maintaining the practical and comprehensive

approach of its predecessor, Principles and Techniques of Electromagnetic Compatibility, Second Edition reflects these emerging challenges and new technologies introduced throughout the decade since the first edition appeared. What's new in the Second Edition? Characterization and testing for high-speed design of clock frequencies up to and above 6 GHz Updates to the regulatory framework governing EM compliance Additional coverage of the printed circuit board (PCB) environment as well as additional numerical tools An entirely new section devoted to new applications, including signal integrity, wireless and broadband technologies, EMC safety, and statistical EMC Added coverage of new materials such as nanomaterials, band gap devices, and composites Along with new and updated content, this edition also includes additional worked examples that demonstrate how estimates can guide the early stages of design. The focus remains on building a sound foundation on the fundamental concepts and linking this to practical applications, rather than supplying application-specific fixes that do not easily generalize to other areas.

Coplanar waveguides (CPWs) provide effective transmission with low dispersion into the millimeter-wave frequencies. For high-speed signaling, differential transmission lines display an enhanced immunity to outside interference and are less likely to interfere with other signals, when compared to single-ended transmission lines. Common-mode (CM) conversion from the differential-mode (DM) signal energy can produce unintentional radiation as well as degraded board-level electromagnetic compatibility (EMC) and signal integrity SI environments. Due to the negative effects of CM signals, filtering structures are often used to suppress the propagation of these signals. The filtering structures introduced in this project all implement the same CM filter design concept. While the concept itself is not new, the physical design of the filter combined with broadside differential CPWs had not been explored at the time of writing this thesis. The CM filtering structures described herein demonstrated to offer broadband CM filtering together with effective DM transmission into millimeter-wave frequencies.

"This authoritative resource offers a complete understanding of state-of-the-art and cutting-edge techniques for designing and fabricating broadband microwave amplifiers. The book covers the complete design cycle, detailing each stage in a practical, hands-on manner." "This comprehensive reference illustrates the formulation of small- and large-signal device models to help professionals accurately simulate amplifier performance, and covers all the practical aspects and circuit components used in fabrication. Engineers find design examples of various types of amplifiers that are applicable in broadband systems such as optical communications, satellite communications, spread-spectrum communications, wireless local area networks, electronic warfare, instrumentation, and phased array radar. The book also provides an in-depth treatment of ultra-broadband microwave amplifiers." --Book Jacket.

As operating frequencies and signal speeds continue to increase in modern devices, the effects of packages and interconnects on the overall signal integrity become increasingly important. The complex electromagnetic behaviors of these often complicated structures must be characterized in order to take their effects into account. Broadband macromodeling deals with the generation of network models of these devices in order to accurately predict their behaviors in circuit simulators. This often involves the generation of passive rational function representations of the system from the measured port responses. In this thesis, we will employ the vector fitting algorithm to generate a rational function representation of the system along with its state space model. Various issues on the subject will be discussed, including the recently developed fast fitting method for multiport devices. Passivity of the model, which is one of the most prominent issues on the subject, will be addressed. A robust algorithm, via residue perturbation, to enforce passivity in nonpassive models will be presented. Finally, numerical results will be presented to demonstrate the performance of the overall process.

Every day, companies call upon their signal integrity engineers to make difficult decisions about design constraints and timing margins. Can I move these wires closer together? How many holes can I drill in this net? How far apart can I place these chips? Each design is unique: there’s no single recipe that answers all the questions. Today’s designs require ever greater precision, but design guides for specific digital interfaces are by nature conservative. Now, for the first time, there’s a complete guide to timing analysis and simulation that will help you manage the tradeoffs between signal integrity, performance, and cost. Writing from the perspective of a practicing SI engineer and team lead, Greg Edlund of IBM presents deep knowledge and quantitative techniques for making better decisions about digital interface design. Edlund shares his insights into how and why digital interfaces fail, revealing how fundamental sources of pathological effects can combine to create fault conditions. You won’t just learn Edlund’s expert techniques for avoiding failures: you’ll learn how to develop the right approach for your own projects and environment. Coverage includes • Systematically ensure that interfaces will operate with positive timing margin over the product’s lifetime–without incurring excess cost • Understand essential chip-to-chip timing concepts in the context of signal integrity • Collect the right information upfront, so you can analyze new designs more effectively • Review the circuits that store information in CMOS state machines–and how they fail • Learn how to time common-clock, source synchronous, and high-speed serial transfers • Thoroughly understand how interconnect electrical characteristics affect timing: propagation delay, impedance profile, crosstalk, resonances, and frequency-dependent loss • Model 3D discontinuities using electromagnetic field solvers • Walk through four case studies: coupled

differential vias, land grid array connector, DDR2 memory data transfer, and PCI Express channel • Appendices present a refresher on SPICE modeling and a high-level conceptual framework for electromagnetic field behavior Objective, realistic, and practical, this is the signal integrity resource engineers have been searching for. Preface xiii Acknowledgments xvi About the Author xix About the Cover xx Chapter 1: Engineering Reliable Digital Interfaces 1 Chapter 2: Chip-to-Chip Timing 13 Chapter 3: Inside IO Circuits 39 Chapter 4: Modeling 3D Discontinuities 73 Chapter 5: Practical 3D Examples 101 Chapter 6: DDR2 Case Study 133 Chapter 7: PCI Express Case Study 175 Appendix A: A Short CMOS and SPICE Primer 209 Appendix B: A Stroll Through 3D Fields 219 Endnotes 233 Index 235

The First Comprehensive, Example-Rich Guide to Power Integrity Modeling Professionals such as signal integrity engineers, package designers, and system architects need to thoroughly understand signal and power integrity issues in order to successfully design packages and boards for high speed systems. Now, for the first time, there's a complete guide to power integrity modeling: everything you need to know, from the basics through the state of the art. Using realistic case studies and downloadable software examples, two leading experts demonstrate today's best techniques for designing and modeling interconnects to efficiently distribute power and minimize noise. The authors carefully introduce the core concepts of power distribution design, systematically present and compare leading techniques for modeling noise, and link these techniques to specific applications. Their many examples range from the simplest (using analytical equations to compute power supply noise) through complex system-level applications. The authors Introduce power delivery network components, analysis, high-frequency measurement, and modeling requirements Thoroughly explain modeling of power/ground planes, including plane behavior, lumped modeling, distributed circuit-based approaches, and much more Offer in-depth coverage of simultaneous switching noise, including modeling for return currents using time- and frequency-domain analysis Introduce several leading time-domain simulation methods, such as macromodeling, and discuss their advantages and disadvantages Present the application of the modeling methods on several advanced case studies that include high-speed servers, high-speed differential signaling, chip package analysis, materials characterization, embedded decoupling capacitors, and electromagnetic bandgap structures This book's system-level focus and practical examples will make it indispensable for every student and professional concerned with power integrity, including electrical engineers, system designers, signal integrity engineers, and materials scientists. It will also be valuable to developers building software that helps to analyze high-speed systems.