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Review of Multi-Scale Electromagnetic Modeling

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5:30pm: Light refreshment
6:00pm: IEEE lecture

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Solving electromagnetics problem is a challenging task, especially when the structure is multi-scale. This kind of structures is often encountered in circuits in electronic packaging, small antenna designs, as well as small sensor designs. Computational electromagnetics research is important for producing simulation software that has been used as virtual laboratories for the design of major electrical and electronic components.

A challenging problem in computational electromagnetics is in solving problems in the low frequency regime, especially the regime between static and electrodynamics. When the wavelength is much longer than the size of the structure, the physics of the electromagnetic field resembles those of circuits, and hence, this is in the circuit physics regime. When the wavelength is sizeable compared to the structure, than wave physics becomes important, and it is important that a simulation method can capture the wave physics interaction. When a structure is multi-scale, and has parts that are small compared to wavelength, but at the same time, is on the order of wavelength, then both circuit physics and wave physics are important. A simulation method has to capture both physics.

In this presentation, we will discuss the use of the equivalence principle algorithm (EPA) to capture the multi-scale physics of complex structures. In this method, complex structures are partitioned into parts by the use of equivalence surfaces. The interaction of electromagnetic field with structures within the equivalence surface is done through scattering operators working via the equivalence currents on the equivalence surfaces. The solution within the equivalence surface can be obtained by various numerical methods. Then the interaction between equivalence surfaces is obtained via the use of translation operators. When accelerated with the mixed-form fast multipole method, large multi-scale problems can be solved in this manner.

We will also discuss the augmented electric field integral equation (A-EFIE) approach in solving the low-frequency breakdown problem as encountered in circuits in electronic packaging. In this method, the EFIE is augmented with an additional charge unknown, and an additional continuity equation relating the charge to the current. The resultant equation, after proper frequency normalization, is frequency stable down to very low frequency. This method apparently does not suffer from the low-frequency breakdown, but it does have the low-frequency inaccuracy problem. We will discuss the use of the perturbation method to derive accurate solutions when the low-frequency inaccuracy problem occurs. We will also discuss the hybridization of EPA and A-EFIE to tackle some multi-scale problems.

When the frequency is extremely high such that the wavelength is much shorter than the object, we are in the regime of ray optics. In this regime, electromagnetic wave or light behaves like a particle. Different strategies need to be adopted to solve problems in this regime. When the wavelength is short, and the structure is complicated, then the phase of the wave due to multiple scattering becomes random. In such a case, the scattering from different parts of the scatterer becomes incoherent, and we may be able to add the phase of the wave incoherently. Electromagnetic wave thus evolves from its wave nature to its particle nature.

Weng Cho Chew received the B.S. degree in 1976, both the M.S. and Engineer's degrees in 1978, and the Ph. D. degree in 1980, all in electrical engineering from the Massachusetts Institute of Technology, Cambridge, MA. He has been with the U of Illinois since 1985.

He served as the Dean of Engineering at The University of Hong Kong (2007-2011). Previously, he was the Director of the Center for Computational Electromagnetics and the Electromagnetics Laboratory at the University of Illinois (1995-2007). Before joining the University of Illinois, he was a department manager and a program leader at Schlumberger-Doll Research (1981-1985). He served on the IEEE AdCom for Antennas and Propagation Society as well as Geoscience and Remote Sensing Society. He has been active with various journals and societies.

His research interests are in the areas of wave physics and mathematics in inhomogeneous media for various sensing applications, integrated circuits, microstrip antenna applications, and fast algorithms for solving wave scattering and radiation problems. He is the originator several fast algorithms for solving electromagnetics scattering and inverse problems. He led a research group that developed computer algorithms and codes that solved dense matrix systems with tens of millions of unknowns for the first time for integral equations of scattering.

He has authored a book entitled *Waves and Fields in Inhomogeneous Media*, coauthored two books entitled *Fast and Efficient Methods in Computational Electromagnetics*, and *Integral Equation Methods for Electromagnetic and Elastic Waves*, authored and coauthored over 350 journal publications, over 400 conference publications and over ten book chapters.

He is a Fellow of IEEE, OSA, IOP, Electromagnetics Academy, Hong Kong Institute of Engineers (HKIE), and was an NSF Presidential Young Investigator (USA). He received the Schelkunoff Best Paper Award for AP Transaction, the IEEE Graduate Teaching Award, UIUC Campus Wide Teaching Award, IBM Faculty Awards. He was a Founder Professor of the College of Engineering (2000-2005), and the First Y.T. Lo Endowed Chair Professor (2005-2009). He has served as an IEEE Distinguished Lecturer (2005-2007), the Cheng Tsang Man Visiting Professor at Nanyang Technological University in Singapore (2006). In 2002, ISI Citation elected him to the category of Most Highly Cited Authors (top 0.5%). He was elected by IEEE AP Society to receive the Chen-To Tai Distinguished Educator Award (2008). He is currently the Editor-in-Chief of JEMWA/PIER journals, and on the board of directors of Applied Science Technology Research Institute, Hong Kong.