CEM Algorithms for EMC/EMI Modeling: Electrically Large (Antennas on Platform) and Small (SI in ICs and Packagings) Problems

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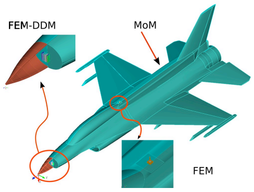
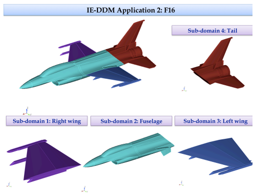


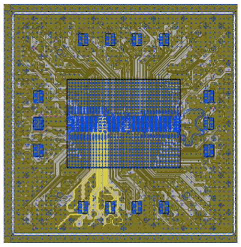
Modern antenna engineering often involves the use of metamaterials, complex feed structures, and conformally mounting on large composite platforms. However, such antenna systems do impose significant challenges for numerical simulations. Not only do they usually in need of large-scale electromagnetic field computations, but also they tend to have many very small features in the presence of electrically large structures. Such multi-scale electromagnetic problems tax heavily on numerical methods (finite elements, finite difference, integral equation methods etc.) in terms of desired accuracy and stability of mathematical formulations.

Another important electromagnetic application is the study of signal integrity in ICs. Recent advances in VLSI interconnect and packaging technologies, such as the increasing number of metal layers and the 3D integration, have paved the way for higher functionality and superior performances. During the reduction of the size, power, and cost in today's advanced IC interconnect and packagings, the signal integrity (SI) has become more crucial for system designers. Empirical or curve-fitted equivalent circuits used by conventional circuit simulation tools, such as SPICE and IBIS, are not suitable for higher and wider operating frequencies in terms of accuracy, flexibility, and reliability. The previous common practice adopted by industries, such as using only static parasitic RC or RLC equivalent networks for physical designs, are gradually abandoned. It has come to use full-wave computational electromagnetic (CEM) methods for the ultimate accuracy check.

In this lecture, we present our on-going efforts in combating the multi-scale electromagnetic problems, both electrically large (antennas on platform) and electrically small but complex (SI in ICs) through the use of non-conventional PDE methods that are non-conformal. The non-conformal numerical methods relax the constraint of needing conformal meshes throughout the entire problem domains. Consequently, the entire systems can be broken into many sub-problems, each has its own characteristics length and will be meshed independently from others. Particularly, our discussions will include the following topics:



- **Integral Equation Domain Decomposition Method (IE-DDM):** A very significant breakthrough that has been accomplished in our group recently is the IE-DDM formulation. For example, we show an electromagnetic plane wave scattering from the F-16 aircraft at 5 GHz by dividing the platform into 4 closed objects, and noting that they will be touching each other through common interfaces. Instead of applying the CFIE to one large problem as is traditionally done, we have employed MLFMM CFIE for each of the four regions separately, and iterated the numerical solutions until they converge.



- **Non-Conformal DDM with Higher Order Transmission Conditions and Corner Edge Penalty:** By introducing two second-order transverse derivatives, one for TE and one for TM, the derived 2nd order TC provides convergence for both the propagating and evanescent modes. Moreover, on the corner edges sharing by more than two domains, an additional corner edge penalty term needs to be added in the variational formulation. Consequently, the robustness of the non-conformal DDMs is now greatly improved.
- **Multi-region/Multi-Solver DDM with Touching Regions:** Many multi-scale physical problems are very difficult, if not impossible, to solve using just one of the existing CEM solvers. We have been pursuing a multi-region multi-solver domain decomposition method to effectively tackle such problems. Various CEM solvers are

now integrated into our MS-DDM code and collectively, it emerges as the only alternative for solving many real-life applications that are thought to be un-solvable today.

- **Discontinuous Galerkin Time Domain (DGTD) Method with GPU Implementation:** We shall also discuss in some details, our on-going efforts in the time domain simulation, the DGTD algorithm. Particularly, the use of graphical process unit (GPU) in speeding up the DGTD computations. Moreover, our implementations of lumped circuit elements will also be addressed.