2012 ACES Short Course

Course Title: Non-overlapping and Non-conformal Domain Decomposition Method for Full Wave Solution of Time Harmonic Maxwell's Equations

Full Day

Instructors: Jin-Fa Lee & Zhen Peng

Instructor Name: Jin-Fa lee & Zhen Peng

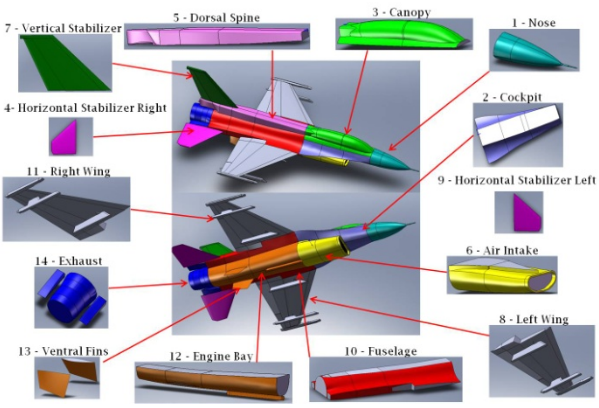
Instructor E-mail: lee.1863@osu.edu & peng.98@osu.edu

Instructor Phone: +1-614-292-7270 (Jin-Fa Lee) +1-614-302-8896(Zhen Peng)

1330 Kinnear Rd., ElectroScience Lab., ECE Dept., The Ohio State University

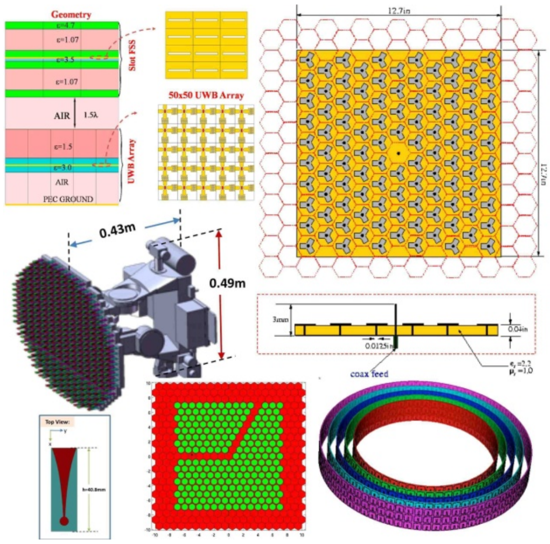
In this course, we present our on-going efforts in combating the multi-scale electromagnetic problems, both electrically large (electromagnetic scattering from aircrafts at X and Ku band) and electrically small but complex (3D integrated circuit and subsystems), through the use of non-conformal Domain Decomposition Method (DDM). The non-conformal DDM have received considerable attention because they provide effective, efficient preconditioned iterative solution algorithms for the numerical solution of time-harmonic wave problems. It tremendously relaxes the burden of mesh generation task, as the entire systems can be broken into many sub-problems with non-conformal meshes on the sub-domain interfaces. Each sub-domain 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**



The numerical study of time-harmonic electromagnetic scattering of a large and composite object is one of the key tasks in computational electromagnetics (CEM). However, these multi-scale problems poses a great challenge as they are very difficult or even impossible to solve using just one existing CEM solvers. Our group has been pursuing a multi-region multi solver DDM to effectively tackle such problems. Instead of applying the combined field integral equation formulation (CFIE) to one large problem, the entire model is broken into a number of sub-domains, while it is free to choose the most effective sub-domain solver based on each sub-domain's local geometrical features and electromagnetic characteristics. It is a significant breakthrough and emerges as the only alternative for solving many real-life applications that are thought to be un-solvable before. Furthermore, we have employed multilevel fast multipole method (MLFMM) to accelerate the coupling between sub-domains, and iterate the numerical solutions until they converge. As an example, we show a mockup fighter jet on the left, which has 45 sub-domains with 58 pairs of touching interfaces.

➢ Finite Element Domain Decomposition Method



One important CEM application relates problems with a finite number of different building blocks. Examples include antenna arrays, frequency selective surfaces, metamaterials, etc. These structures often involve complicated and multiscale geometrical features and they are usually electrically large. Thus, full wave analysis of such problems by traditional methods demands prohibitive computer resources. We will present a non-conformal finite element domain decomposition method for solving electromagnetic problems with significant repetitions: such as large finite antenna arrays, frequency selective surfaces, and metamaterials, to name just a few. To further improve the convergence in the DDM iterations, an optimal 2nd order transmission condition is introduced to enforce field continuities across domain interfaces. Consequently, the robustness of the non-conformal DDMs is greatly improved. Furthermore, the finite element tearing and interconnecting (FETI) method is employed to take advantage of the repetitions to drastically reduce the computational resources.

➢ Hybrid Finite element and boundary Integral Method

Moreover, many electromagnetic problems with repetitions are also electrically large. Consequently, the use of absorbing boundary condition may not be adequate as an accurate mesh truncation method. Herein, we combine directly the finite element domain decomposition method with a generalized combined field integral equation and form automatically the hybrid finite element and boundary integral (FE-BI) method. In accordance with the presented hybrid FE-BI method, the solution region is divided into the interior and the exterior regions. The interior region is approximated using the finite element domain decomposition method. However, the field solution in the exterior region is probably best computed using boundary integral domain decomposition method. These two solutions, FEM and BI solutions, are joined together through, once again, the Robin transmission conditions. The use of the boundary integral method, arguably, offers the best accuracy for modeling unbounded electromagnetic radiation and scattering problems, albeit at the increases of memory and CPU times.