EEE 540 FAST COMPUTATIONAL ELECTROMAGNETICS, 2016'S

Prerequisite: EEE 241/EEE 341 or consent with the instructor

Most real-world electromagnetic (EM) problems have no analytical solutions. Instead, fast numerical algorithms are developed by the IEEE MTT (microwave theory and techniques), IEEE AP (antennas and propagation), JCP (journal of computational Physics), SIAM (Society for industrial and applied mathematics) among other periodicals. Practical EM problems can be solved via commercial packages, e.g., ADS, HFSS, Ansys, Cadence, FEKO, Sonnet, etc. which are based upon the novelties of the fast numerical algorithms.

EEE 540 studies the fast algorithms from the principle and methodology point of view, and it is not a computer programming class. The class covers three major approaches:

- MoM (method of moment) converts an integral equation into a **dense** matrix equation. Then it solves the matrix equation via the direct (Gaussian elimination) method or iterative (conjugate gradient) method. FEKO is based on the MoM.
- FEM (finite element method) is based on the Rayleigh-Ritz or Galerkin's procedure, converting the partial differential equation of Maxwell/Helmholtz into an energy function and then minimizes it. The resulting matrix is sparse with much larger size than that from the MoM for the same problem. HFSS is an FEM software package.
- FDTD (finite difference time domain) is based on discretized Maxwell's two curl equations. The FDTD does not resort to matrix equations, but it works in a march-ontime manner. Its simplicity and versatility are great advantages.

In the course we reveal the pros, cons, applicability and limitation of individual software packages. We'll focus on stability, computational efficiency and precision while reducing the CPU time and memory consumption. To this end, we apply wavelets, adaptive integral method (AIM), RWG, or fast multi-pole method (FMM) to sparsify/partition

Course Topics:

Mathematical Preliminaries (Chapter I, treat as appendix)
Intuitive Introduction to Wavelets (Chapter II, 2 lectures)
Haar Wavelets
Orthogonality$\Rightarrow$ Diagonal Dominating
Multi-Resolution Analysis (MRA)
Orthogonal Wavelet Theory (Chapter III, 3 lectures)
Franklin Wavelets
Daubechies Wavelets
Coifman Wavelets
Meyer Wavelets
Method of Moments (Chapter IV, 8 lectures)
Integral Equations of 1st and 2nd Kind: EFIE (electric field integral eq) and MFIE.
Traditional MoM
Galerkin's Procedure

Gaussian quadrature
Matrix Transformation Approach
RWG discretization, Calderon, AIM (adaptive integral method)
Finite Difference Time Domain (Chapter V, 6 lectures)
Standard FDTD (Yee-FDTD)
Stability and Numerical Dispersion
Absorbing Boundary Conditions
Sampling-Orthogonal Time-Domain (SBTD)
ADI- and CN- FDTD
Finite Element Method using Multiwavelets (Chapter VI, 6 lectures)
Wavelet v.s. Multiwavelet
Dilation v.s., Analytic Expressions
Node- and Edge- Based Finite Element Method (FEM)

Multiwavelet Based FEM
Applications in, Radiation, Scattering, Electronic Packaging (Chapter VII-X, 4 lectures)
Section 7.1-7.4: Electrically large problems: Conjugate gradient method, Matrix condition, Parallel computing on Saguaro cluster.
Section 8.4, Wavelet in rough surface scattering: Tapered wave incident, Random profile generation. Wavelet sparsified matrix, Matrix pre-conditioning.
Section10.5, 10.6: Drift-diffusion model. Multiwavelet based MoM.