Overview of State-of-the-Art Computational Electromagnetics Techniques for the Domain of Radio Astronomy

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In this contribution, we would like to give an overview of state-of-the-art computational electromagnetics (CEM) techniques for the domain of radio astronomy as implemented in Altair Feko [1], both presenting a high level theoretical overview of the algorithms and comparing their advantages / disadvantages in terms of accuracy and numerical effort (memory and run-time requirements) as applied to complex, real world examples of antennas, arrays, and microwave components as found in radio telescopes and related applications.

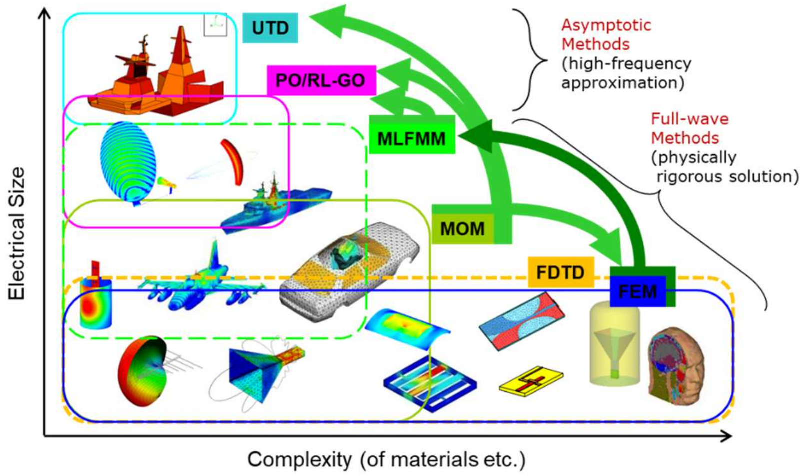

Figure 1. Overview of CEM methods in Altair Feko.

The CEM methods in Fig. 1 can be classified as rigorous full-wave methods (an introduction can be found in [2]) including accelerated versions (multilevel fast multipole method MLFMM [3], H-matrices in adaptive cross approximation ACA, or the characteristic basis function method CBFM) and high frequency asymptotic methods such as physical optics PO or ray-launching geometrical optics RL-GO. Both classes of methods have a strong relevance for radio astronomy applications. Of particular importance are hybrid methods, bringing both these domains together for electrically large problems (like a reflector) combined with complex / small structures (like the feed structures) taking the full bi-directional coupling into account, as indicated by the green arrows in Fig. 1.

The presentation will also touch on advanced CEM topics such as model and domain decomposition, special techniques for radome modeling, advanced computational algorithms (higher order basis functions, large element physical optics, etc.), and the relevance of high-performance computing (parallelization aspects for clusters, GPU acceleration [4]) to allow the practical solution of real-world radio astronomy problems.

1. Altair Engineering, Inc., "Altair Feko," https://www.altair.com/feko.

2. David B. Davidson, "Computational Electromagnetics for RF and Microwave Engineering," Cambridge University Press, Cambridge, 2nd edition, 2011.

3. R. Coifman, V. Rohklin, and S. Wandzura, "The fast multipole method for the wave equation: A pedestrian prescription," IEEE Transactions on Antennas and Propagation, vol. 35, no. 3, pp. 7–12, 1993.

4. U. Jakobus, "Benefits and Challenges of GPU Accelerated Electromagnetic Solvers from a Commercial Point of View," ACES Journal, vol. 33, no. 2, February 2018.