Fast Finite Element Far-Field Computations for Electromagnetics

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Often the end product of an electromagnetic simulation is a far-field quantity such as antenna gain, radiated power or radar cross section (RCS). When the underlying CEM solver is a frequency domain finite element method which solves for the near-field electric fields, an extra near-to-far-field transformation step must be invoked for each frequency and excitation. Traditionally this step involves the integration of equivalent electric and magnetic currents over a surface enclosing the object under investigation. However, the challenge of evaluating such radiation integrals is two-fold: (1) The presence of the *curl* operator in the evaluation of the equivalent electric currents reduces its effective approximation order leading to inaccuracies; (2) The numerical integration of the radiation integrals could be time consuming since the integration work for a single observation direction scales quadratically with electric size, i.e. $O(kd)^2$ and the angular sampling of the Ewald sphere increases linearly $O(kd)$, leading to a total of $O(N^2)$ operations (where N is the number of equivalent surface current samples). These effects are further exacerbated over wide bandwidths, and multi-port excitations, severely slowing down computations.

To combat this unfavorable complexity, Stephenson in (M. Stephenson, OSU, Thesis, 2007) used a divide-and-conquer algorithm along with fast interpolations, similar in spirit to the fast multipole method, to compute the radiation integrals over the Ewald sphere at $O(N^{1.5})$ cost. Following a completely different vision, Monk in (P. Monk et al., Journal of Computational Physics, pp.614-641, 2001) proposed a variational computation of the near-to-far-field transform for TVFEM that improves accuracy.

Following Monk's approach, we propose a variational near-to-far-field transform that leverages the benefits of model order reduction (MOR) in both frequency and observation angle parameters. The method is based on a simple and elegant matrix representation of the near-to-far-field transform that requires only sparse matrix vector multiplications instead of integral evaluations. The talk first will outline previous research on this topic, and then proceed by formulating the fast near-to-far-field transformation in the context of second-order tangential vector finite elements. Results from phased arrays and scattering problems will be used to showcase the accuracy and efficiency of the proposed methodology.