Fast Far-field Computations for Finite Element Domain Decomposition Method

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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 domain decomposition finite element method (DD-FEM) 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 extend the variational near-to-far-field transform that is based on a simple and elegant matrix representation of the near-to-far-field transform to DD-FEM. 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 domain decomposition (DD) method. Results from phased arrays and scattering problems will be used to showcase the accuracy and efficiency of the proposed methodology.