Accuracy and Efficiency of Low-order Volume Integral Equation Techniques for Dielectric Bodies Modeled with Tetrahedral Cells

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Many computational techniques based on volume integral equations have been proposed for the analysis of heterogeneous dielectric bodies illuminated by electromagnetic fields. The Schaubert-Wilton-Glisson approach (1984) employed the electric field integral equation (EFIE) with an expansion of the *D*-field in divergence conforming basis functions. This is sometimes called an *EFIE-D* approach. The Sun-Chew formulation (2009) uses a curl-conforming expansion of the electric field; this has been called an *EFIE-E* approach. The author recently described an *EFIE-H* formulation (ACES-2013) where the magnetic field is expanded in curl-conforming bases and the *D*-field obtained from it; that approach produces a solenoidal (zero-divergence) representation for *D* like that previously described by Carvalho and Mendes (1999) and recommended by Botha (2006). An *EFIE-J* formulation using piecewise-constant basis functions was proposed by Markkanen et al. (2012). These formulations share the properties that they employ tetrahedral cells, and can easily be scaled to produce symmetric impedance matrices. Approaches employing the magnetic field integral equation are available but do not produce a symmetric impedance matrix. Formulations based on differential equations are also widespread for heterogeneous bodies, but volume integral formulations remain of interest due to the possibility of obtaining a well-conditioned set of equations for fast iterative solution.

By far the most widely-used formulation of the above is the Schaubert-Wilton-Glisson *EFIE-D* approach. However, that approach requires more unknowns for a given model (one per face) than the *EFIE-E* or *EFIE-H* discretizations (one per edge), although less than the *EFIE-J* approach (3 per cell). In addition, the *EFIE-D* formulation requires volume-volume, volume-surface, and surface-surface interaction integrals, some over fictitious charge. In contrast, the *EFIE-H* formulation can be implemented without volume integrations. These observations suggest that the *EFIE-D* approach may not be the best choice. However, to assess the relative efficiency of these formulations, one must investigate the trade-off between accuracy and computational cost for a given problem. In this presentation, the accuracy of results for internal fields and scattering cross section for several spherical dielectric bodies, as well as the execution times, will be used to compare the performance of the symmetric *EFIE-D*, *EFIE-E*, and *EFIE-H* formulations when used with tetrahedral-cell models.