

## Higher Order, Hybrid BEM/FEM Methods Applied to Antenna Modeling

P. W. Fink\*  
NASA-JSC  
Houston, TX 77058  
pfink@ems.jsc.nasa.gov

D. R. Wilton  
University of Houston  
Houston, TX 77204-4793  
wilton@uh.edu

J. A. Dobbins  
NASA-JSC  
Houston, TX 77058  
jdobbins@ems.jsc.nasa.gov

In this presentation, the authors address topics relevant to higher order modeling using hybrid BEM/FEM formulations. The first of these is the limitation on convergence rates imposed by geometric modeling errors in the analysis of scattering by a dielectric sphere. The second topic is the application of an Incomplete LU Threshold (ILUT) preconditioner to solve the linear system resulting from the BEM/FEM formulation. The final topic is the application of the higher order BEM/FEM formulation to antenna modeling problems.

The authors have previously presented work on the benefits of higher order modeling. To achieve these benefits, special attention is required in the integration of singular and near-singular terms arising in the surface integral equation. Several methods for handling these terms have been presented. It is also well known that achieving the high rates of convergence afforded by higher order bases may also require the employment of higher order geometry models. A number of publications have described the use of quadratic elements to model curved surfaces. The authors have shown in an EFIE formulation, applied to scattering by a PEC sphere, that quadratic order elements may be insufficient to prevent the domination of modeling errors. In fact, on a PEC sphere with radius  $r = 0.58 \lambda_0$ , a quartic order geometry representation was required to obtain a convergence benefit from quadratic bases when compared to the convergence rate achieved with linear bases. Initial trials indicate that, for a dielectric sphere of the same radius, requirements on the geometry model are not as severe as for the PEC sphere. The authors will present convergence results for higher order bases as a function of the geometry model order in the hybrid BEM/FEM formulation applied to dielectric spheres.

It is well known that the system matrix resulting from the hybrid BEM/FEM formulation is ill-conditioned. For many real applications, a good preconditioner is required to obtain usable convergence from an iterative solver. The authors have examined the use of an Incomplete LU Threshold (ILUT) preconditioner to solve linear systems stemming from higher order BEM/FEM formulations in 2D scattering problems. Although the resulting preconditioner provided an excellent approximation to the system inverse, its size in terms of non-zero entries represented only a modest improvement when compared with the fill-in associated with a sparse direct solver. Furthermore, the fill-in of the preconditioner could not be substantially reduced without the occurrence of instabilities. In addition to the results for these 2D problems, the authors will present iterative solution data from the application of the ILUT preconditioner to 3D problems.

Recent publications on higher order modeling have focused on separable geometries so that numerically derived solutions could be compared with exact results. Other publications have examined convergence of the RCS solution. Recently, researchers have begun applying higher order methods to antenna models. For example, higher order bases have been applied in a surface integral formulation to analyze multilayer, microstrip antennas (Ling, F., Jin, J.-M., *Antennas, Propagation, and EM Theory, 2000*. Proceedings. ISAPE 2000). In this presentation, the authors provide results from the application of higher order, hybrid BEM/FEM formulations to antenna modeling problems. Coaxial probe feeds are modeled both with a current filament and with a coaxial waveguide interface that includes detailed modeling of the probe. The latter work extends a previously published 0<sup>th</sup> order formulation (Zuffada, C., Cwik, T., and Jamnejad, V., *IEEE Trans. Antennas Propagat.*, Jan. 1997.)