Nested Equivalent Source Approximation for EM Scattering by Penetrable Bodies

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The Boundary Element Method (BEM) discretization (also known as Method of Moments – MoM – in computational electromagnetics) is particularly well suited for solving time harmonic electromagnetic problems, for a large class of practical problems: typical examples are metallic scatterers, or scatterers composed by only a few different homogeneous materials (as opposed to, e.g., the human body). However, the efficient solution of large BEM problems is still very challenging, due to the dense matrix it yields. Fast solvers, i.e. proper factorizations of the system matrix reducing storage and CPU requirements, are usually necessary to handle large meshes.

The authors recently proposed a Nested Equivalent Source Approximation (M. Li, M. A. Francavilla, F. Vipiana, G. Vecchi, and R. S. Chen, IEEE Trans on Antennas and Prop, 62(7), 3664-3678, 2014) for the scattering by metallic structures, in which the low rank approximation at each level is expressed recursively in terms of its child levels, and eventually in terms of the low rank approximation at leaf level. This yields an $O(N)$ algorithm for statics to moderate frequencies, and an $O(N\log N)$ scheme for fully dynamic problems (with proper and significant modifications with respect to the static algorithm).

Here we extend NESA to non-metallic scatterers. Assuming the scatterer is piecewise homogeneous, the problem is usually formulated by applying the equivalence theorem onto the interfaces between different materials. By properly combining the different boundary conditions on the fields on the two sides of the interface, different equations can be derived, e.g. Poggio-Miller-Chang-Harrington-Wu-Tsai or Muller formulations. The above mentioned formulations require evaluating different integro-differential kernels; here we exploit NESA to efficiently approximate the different integral kernels arising from dielectric formulations. NESA provides the flexibility of kernel-independent schemes, still with the same asymptotic computational complexity of state of the art kernel-based fast factorizations. Numerical examples will be shown to prove accuracy and favorable computational cost of NESA when applied to dielectric bodies.