

**A Hybrid PMCHWT and VIE Formulation  
For the Calculation of EM Scattering from Electric and Magnetic Materials**

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We found out from our previous study [1] that, to solve the problem of electromagnetic scattering from objects with thin dielectric coating, the hybrid volume and surface integral equation (VSIE) [2] approach resulted in a matrix equation system that converges much faster than the matrix system obtained by using the surface integral equation (SIE) with PMCHWT [3] formulation. This conclusion is true only when the material is of layered structure and the thickness is small. For thick material or bulk material that are homogeneous, the VSIE needs much more unknowns, and hence it is not efficient to model the homogeneous portion of the material using the volume integral equation, even though it may create a matrix system that is well conditioned. In this case, the PMCHWT formulation is one of the most efficient methods.

However, the surface integral equation formulation is applicable to homogeneous material only. If there is a slight change of dielectric contrast within the volume, or there is a small portion of the material region that has inhomogeneous permittivity, the SIE will no longer be valid. It has been proposed that an additional volume integral equation be introduced [4] to model the inhomogeneous part of the material region. The idea is to use the induced volume current for the region that has dielectric contrast which is different from the majority of the dielectric region. This is called the hybrid PMCHWT and VIE formulation. In this presentation, we apply this method to calculate the scattering by three-dimensional material scatterers. Our formulation uses the quadrilateral mesh for the surface modeling and hexahedron mesh for the volume modeling. Methods to treat the singular integrals for various integral operators are discussed, and validation numerical results will be shown in the presentation.

- [1] C. C. Lu and C. Luo, "Comparison of SIE and VSIE for Computation of EM Scattering with Large and Complex Structures", *The 2002 IEEE Antennas and Propagation Symposium*, vol. 3, pp. 184-187, June, 2002.
- [2] C. C. Lu and W. C. Chew, "A coupled surface-volume integral equation approach for the calculation of electromagnetic scattering from composite metallic and material targets," *IEEE Trans. Antennas Propagat.*, vol. 48, no. 12, pp. 1866-1868, Dec, 2000.
- [3] T. K. Wu, and L. L. Tsai, "Scattering from arbitrarily-shape lossy dielectric bodies of revolution," *Radio Sci.*, vol. 12, no. 5, p. 709-718, 1977.
- [4] S. Gedney and C. C. Lu, "High-Order Integral Equation Solution for Scattering by Composite Material", *The 2003 IEEE Antennas and Propagation Symposium*, submitted for publication, January, 2003.