Analysis of Electrical Property Variations for Composite Medium Using a Stochastic Collocation Method

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In recent years, there has been a growing interest in the study electrical properties of artificially fabricated materials that exhibit unique properties (*Zouhdi, et al. , Dordrecht: Kluwer Academic Publishers, 2002*). Such engineered composite materials often consist of periodic arrangement of the unit elements whose dimensions are much smaller than the operating wavelength. To analyze arbitrary and complex mixtures, numerous analytical formulations have been proposed, e.g., Maxwell-Garnett formula (*Maxwell, Clarendon Press, Oxford, 1891*). However, since the conventional mixing theorems ignore the interaction between the conductive inclusions and can only consider limited shapes of inclusions, their accuracy degrades in the cases with complex structures (e.g., arbitrary inclusion shape, high volume fraction as well as large permittivity contrast between inclusion and host medium). To fully explore the heterogeneous electrical properties of composite materials, various numerical techniques have been proposed, such as finite difference method (FDM) (*kärkkäinen et al., IEEE Trans. Geosci. Remote Sen., May 2001*), finite element method (FEM) (*Myroshnychenko, et al., Physical Review, 2005*), finite-difference time-domain method (FDTD) (*Wu, Proceeding of 75th Ann. Internat. Mtg. Soc. Expl. Geophys., 2006*) and boundary integral equation method (BIEM) (*Sareni, J. Appl. Phys., 1997*).

In this talk, a three-dimensional finite-difference method (FDM) with periodic boundary condition is presented to analyze the complex effective permittivity of arbitrary composite materials with anisotropic inclusions. The numerical method is extended to combine with the stochastic collocation method based on high-order accurate interpolation of a general stochastic process (*Chauviere et al, SIAM J. SCI. COMPUT, Vol. 28, No. 2, pp. 751-775*), for modeling of problems with realistic complexity and uncertainty, e.g., a lack of knowledge in the model geometry or material parameters. Compared with the traditional Monte Carlo approach, which requires a large number of randomly sampled points, the new method leads to a much faster convergence, while maintain the same level of accuracy. In this talk, we use this method to analyze variations of the electrical property of the composite material having three-dimensional periodic structure. The corresponding variation resulting from the uncertainty in the structure geometry and material electrical parameters will be discussed.