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Random Field Realization and Time Domain Stochastic Simulation of a Complex Electromagnetic Medium

R. Abedi[(1)], P. L. Clarke[(1)], S. Mudaliar* [(2)]
(1) University of Tennessee Space Institute, Tullahoma, TN, 37355, rabedi@utsi.edu
(2) Sensors Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Dayton, OH 45433-7318, USA, saba.mudaliar@us.af.mil

Field equations in continuum mechanics are based on the concept of Representative Volume Element (RVE), where material properties at each point of a continuum are based on the homogenized response of material within the RVE. Many conditions are stipulated on the existence and size of RVEs, including that its size must be sufficiently larger than microstructural inhomogeneities and smaller than macroscopic domain size. In many applications, however, using deterministic values based on RVE homogenization is not reasonable. In such conditions, constitutive equations take a stochastic form where material properties are random fields. This result in stochastic partial differential equations (SPDEs) with interesting physics in many wave propagation problems such as elastodynamics, acoustics, and electromagnetics.

We present a Time Domain Discontinuous Galerkin (TDDG) approach for the solution of SPDEs in electromagnetics that assume electric permittivity to be a random variable. Instead of using microscale homogenization techniques, e.g. homogenization based on statistical volume elements (SVEs), we assume a reasonable statistical form for permittivity. In addition, by assuming permittivity to be isotropic (a common assumption in many statistical analyses), there will be only one random field, permittivity, for the problem. We will use Karhunen-Loeve (KL) approach to generate random fields consistent with the underlying statistics, first and second statistical moments, of permittivity field. Subsequently, we simulate the realized random fields by the asynchronous Spacetime Discontinuous Galerkin (aSDG) method for a few scattering problems. By using a non-intrusive approach, e.g. collocation or Monte Carlo finite element methods, we propagate randomness from material properties to the signal measured at a receiver from a source point and discuss the uncertainty associated to material randomness.