Fast Probability Density Function Estimation for Statistical EMC/EMI Characterization

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The analysis of electromagnetic compatibility and interference (EMC/EMI) phenomena is often fraught by the uncertainty that characterizes a system's excitation (e.g., the amplitude, phase, and location of internal noise sources) or configuration (e.g., ambiguities in the routing of cables, the placement of electronic systems, component specifications, etc.). To bound the probability of system malfunction, fast techniques to accurately quantify observable uncertainty are called for.

The quantification of uncertainty in system observables is often achieved via Monte Carlo (MC) methods. MC methods call for the execution of a deterministic EMC/EMI simulator for many realizations of the random parameters, selected/sampled according to their (assumed known) underlying probability distribution. While MC methods are straightforward to implement and readily generate all required statistics, their convergence rates often are prohibitively slow.

Recently, a fast technique to estimate the statistical moments of system observables by computing multidimensional integrals over domains of random variables using Stroud integration rules was presented (H. Bağcı et al., in *Proc. IEEE Int. Symp. Electromagn. Compat.*, 18-22 Aug. 2008). The technique was shown to be much more efficient than MC methods because it only requires the execution of the deterministic EMC/EMI simulator for a small and "intelligently" chosen set of collocation points. Unfortunately, the technique does not produce probability density functions (pdfs) of observables.

Here, an extension of the scheme in the above referenced paper that yields full pdf information by leveraging generalized polynomial chaos expansion (D. Xiu, *Commun. Comput. Phys.*, 2(2), 2007, pp. 293-309) is presented. In the new technique, system observables are represented by polynomial expansions, the coefficients of which are determined by computing inner products on a sparse grid constructed using the Smolyak algorithm. Unlike classical polynomial chaos methods, the scheme can be implemented using existing electromagnetic simulators for characterizing statistical EMC/EMI phenomena on fully-loaded vehicle models; here we use a nonlinear time domain integral equation solver (H. Bağcı et al., *IEEE Trans. Electromagn. Compat.*, 49(2), 361-381,2007). Since the number of function evaluations required by the sparse-grid method is much less than that would be required by direct application of the MC method, the proposed pdf estimator is much more efficient than MC based ones.