STOCHASTIC COLLOCATION METHOD FOR FINITE ELEMENT WAVEGUIDE ANALYSIS AND STOCHASTIC GALERKIN METHOD FOR FINITE DIFFERENCE CIRCUIT ANALYSIS

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ABSTRACT. In this talk, we present on-going work in uncertainty quantification of computational electromagnetics and circuit simulation. The non-intrusive Stochastic Collocation Method is used to perform Finite Element analysis of a rectangular waveguide with geometric uncertainties. The intrusive Stochastic Galerkin Method is used to implement the Stochastic Latency Insertion Method (Stochastic LIM) which can efficiently perform transient circuit simulations with uncertainties in the circuit elements. The strengths and weaknesses of intrusive vs. non-intrusive techniques are discussed through these two applications.

The modal cutoff frequencies and dispersion characteristics of any waveguide geometry can be easily computed using the Finite Element Method. By leveraging coordinate transformation and the non-intrusive Stochastic Collocation Method, the statistics of the waveguide characteristics with geometric uncertainties can be quickly derived without the need to perform lengthy Monte Carlo simulations. Stochastic Collocation utilizes the Smolyak algorithm to construct a sparse grid interpolant that estimates the parameters of interest, which is then used to obtain the statistical moments and PDFs of the output. The number of nodes in the sparse grid grows favorably when compared with tensor product grid, although it still suffers from the "curse of dimensionality". Using Stochastic Collocation and Finite Element formulation for rectangular waveguide, we obtain the stochastic dispersion diagram for the structure, as well as the PDFs of each modal cutoff frequency. Results correlate very well with Monte Carlo.

Latency Insertion Method (LIM) is a transient circuit solver using the finite-difference numerical scheme. The method is fast and straight-forward to formulate, thus making it suitable for implementation using the intrusive Stochastic Galerkin Method. The new Stochastic LIM technique enables fast transient simulation of circuit with uncertain elements. When the mean and variance of the circuit elements are provided in the netlist, this method can calculate the statistics of the transient response to arbitrary sources using an augmented state space system. Due to the underlying leapfrogging finite-difference scheme, the computational complexity grows only linearly with the number of terms in the expansion. The formulation is verified using Monte Carlo on a random resistor network with inserted latencies. Like most other numerical techniques for uncertainty quantification, the Stochastic Galerkin Method also suffers from the "curse of dimensionality". We believe dimensionality reduction techniques such as Principle Component Analysis can be used to transform higher dimensional problems into ones with manageable dimensionality.

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