Multiphysics Uncertainty Quantification with FDTD

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Significant research activity has been dedicated over the past few years to the area of uncertainty quantification in computational electromagnetics (C. Chauviere, J. S. Hesthaven, L. Lurati, *SIAM J. Sci. Comput.*, vol. 28, No. 2, pp. 751 - 775, May 2004). This is not surprising: electromagnetic analysis and design is often subject to a variety of fabrication and material tolerances, which need to be properly accounted for to ensure that any design optimization is robust. Moreover, many applications of interest, including biomedical hyperthermia, involve multiphysics interactions of electromagnetic waves. This motivates the extension of sensitivity analysis and uncertainty quantifcation methods to multiphysics problems.

The present paper extends our recent work on FDTD-based high-order sensitivity analysis and parametric modeling (K.A. Liu and C.D. Sarris, *2018 Int. Microwave Symp. Digest*), as well as previous work on an FDTD-based polynomial chaos expansion (PCE) method (A.C.M. Austin and C.D. Sarris, *IEEE Trans. Microwave Theory Tech.*, Nov. 2013), to FDTD -based electromagnetic-thermal simulations, both uncoupled (i.e. the standard approach where fields computed at the electromagnetic steady-state are used to compute the source terms of the thermal problem) and coupled. We focus on how uncertainties in the electromagnetic domain, including numerical errors, propagate into the thermal domain in the coupled and uncoupled case. Along with a multiphysics PCE-FDTD method, we present efficient multiphysics sensitivity computation techniques, which run in parallel with the FDTD simulation and can be readily extended to compute high-order sensitivities. In turn, these can be used to build multiphysics parametric models, with respect to material and geometric parameters of the problem at hand.