Compressive Sensing and Finite-Difference Methods in Electromagnetics

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Recent developments in compressive sensing [D.L. Donoho, *IEEE Trans. Information Theory, vol. 52, no. 4, Apr. 2006*] have inspired several applications in remote sensing and communications. Moreover, [Carin *et al.*, *J. Computat. Phys.*, vol. 228, no. 9, May 2009] indicated the potential applications of compressive sensing to numerical electromagnetics, using multi-static scattering analysis via the fast multipole method, as an example. This effort is reminiscent of the extensive investigation of wavelet-based methods in the time and frequency domain that led to a generation of sparse frequency-domain solvers [B.Z. Steinberg and Y. Leviatan, *IEEE Trans. Antennas and Propagat.*, May 1993] and the class of Multi-resolution Time-Domain methods [M. Krumpholz, L.P.B. Katehi, *IEEE Trans. Microwave Theory Tech.*, Apr. 1996].

This paper is aimed at exploring the implications of compressive sensing techniques for finite-difference methods in the time and frequency domain (FDTD and FDFD). In particular, the number of time-steps needed to characterize a problem in the frequency-domain via FDTD, as well as the number of frequencies needed to characterize a problem in the time-domain via FDTD is typically reduced by using extrapolation and asymptotic waveform evaluation techniques, respectively. Compressive sensing offers an alternative framework to consider these problems, and a fresh perspective that can lead to substantial computational savings. Similarly, any numerical process that involves sampling of potentially sparse signals, be it in the context of the FDTD/FDFD analysis of radiating structures or Brillouin diagram calculations of periodic structures, can benefit from compressive sensing concepts.

Finally, FDTD-based wireless channel modeling is discussed from a compressive sensing perspective. In particular, the extraction of system-level indoor channel models necessitates the study of multiple scenarios involving transmitter-receiver pairs that are distributed within the channel. Since each simulation is computationally intensive, the ability to extract such models from a reduced number of samples is important. To that end, compressive sensing ideas can be exploited.