Ultrawideband Inverse Scattering in Continuous Media based on Bayesian Compressive Sensing

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The goal of inverse scattering is to estimate unknown parameters of target(s) of interest from noisy (cluttered) measurements. These parameters may include the target's location, orientation and/or material properties. In Bayesian-based inversion, both the target's parameters and the clutter are modeled as random variables with certain probability density functions (PDFs). The inversion algorithm combines (any) a priori information on the target's parameters with physics-based forward-problem PDFs and array acquisitions to produce a posteriori PDFs of the unknowns. This approach provides a means for measuring the confidence interval of the inversion and for adaptively optimizing subsequent measurements. Bayesian inference applied to compressive sensing was introduced in [S. Ji, Y. Xue, and L. Carin, *IEEE Trans. Signal Process.*, vol. 56, pp. 2346-2356, 2008] where sparsity priors were imposed on a compressible (sparse) set of unknowns. This problem was solved efficiently using a technique known as the 'relevance vector machine' (RVM) [M. E. Tipping, *J. Machine Learning Res.*, vol. 1, pp. 211-244, 2001]. Recently, Bayesian compressive sensing has been applied in microwave imaging of sparse, discrete scatterers using single frequency data [G. Oliveri, P. Rocca, and A. Massa, *IEEE Trans. Geosci. Remote Sens.*, vol. 49, pp. 3993-4006, 2011].

In this work, we develop ultrawideband (UWB) inverse scattering techniques for extended targets embedded in continuous random media, based on Bayesian compressive sensing. This scenario arises in many applications such as medical imaging, ground penetrating radar, and controlled-source electromagnetics (CSEM) for hydrocarbon exploration. We exploit frequency diversity of the UWB interrogating signal to produce a statistically stable inversion; that is, an inversion that does not depend on the particular realization of the clutter but only on its statistics. We apply time-reversal-based focusing techniques to increase the efficiency of the inversion. In addition, we propose a technique for determining the optimal data acquisition features (location, polarization, and frequency band) so as to maximize the differential information gain. This work is supported by NSF under grant ECCS-0925272.