A Sparse Electromagnetic Imaging Scheme Using Nonlinear Landweber Iterations

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Development and use of electromagnetic inverse scattering techniques for imagining sparse domains have been on the rise following the recent advancements in solving sparse optimization problems. Existing techniques rely on iteratively converting the nonlinear forward scattering operator into a sequence of linear ill-posed operations (for example using the Born iterative method) and applying sparsity constraints to the linear minimization problem of each iteration through the use of L_0/L_1-norm penalty term (A. Desmal and H. Bagci, IEEE Trans. Antennas Propag, 7, 3878-3884, 2014, and IEEE Trans. Geosci. Remote Sens., 3, 532-536, 2015). It has been shown that these techniques produce more accurate and sharper images than their counterparts which solve a minimization problem constrained with smoothness promoting L_2-norm penalty term. But these existing techniques are only applicable to investigation domains involving weak scatterers because the linearization process breaks down for high values of dielectric permittivity.

To overcome this limitation, in this work, a nonlinear optimization scheme for electromagnetic imaging of sparse domains is proposed. The proposed method, unlike previously developed schemes, does not rely on an implicitly- or explicitly-enforced linearization of the nonlinear optimization problem but directly uses a Tikhonov-based approach (M. Fornasier, Walter de Gruyter, 9, 2010). This approach constructs the nonlinear least-squares problem for the data misfit between measured scattered fields and those formulated as a nonlinear function of domain's (complex) permittivity. The resulting minimization problem in unknown permittivity is solved using nonlinear Landweber iterations. The sparsity constraint is enforced by applying a thresholding function at every iteration. Additionally, a frequency hopping technique is proposed to account for multiple frequency measurements within the thresholded nonlinear Landweber iterations. This technique allows for efficient and more convergent reconstruction of investigation domains with frequency dependent complex permittivity, for example when the loss in the scatterers is represented using conductivity.

Numerical experiments, which make use of synthetically and experimentally generated data, demonstrate the accuracy and efficiency of the proposed inversion algorithm.