Full-Vectorial 3D Microwave Inversion of Inhomogeneous Lossy Dielectric Objects

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This paper treats the three-dimensional (3D) full-wave quantitative inverse scattering problem. The goal is to reconstruct the complex permittivity of a 3D inhomogeneous (lossy) dielectric object within an investigation domain that is embedded in a homogeneous background medium. The object is illuminated with given time-harmonic incident fields and the scattered field vector is measured in a number of points surrounding the object, see Fig.1.

Due to the non-linearity of the inverse scattering problem, an iterative reconstruction algorithm, in which a cost function is minimized, is mandatory. The scattered field depends on two types of unknowns, the complex permittivity and the total field inside the object, which are related by a domain integral equation constraint. In this contribution the total field unknown is eliminated from the problem by means of solving a full forward problem, such that the cost function only depends on the complex permittivity. This is implemented with an efficient forward solver and an efficient Gauss-Newton optimization procedure that converges very rapidly. To handle the ill-posedness of the inverse scattering problem, a multiplicative-additive type of regularization is employed. This suppresses the effect of noise on the reconstructions and is believed to have its benefits in dealing with the non-linearity of the problem.

To calculate the value of the cost function and its derivatives with respect to the permittivity unknowns in a uniform cuboidal grid, a multiview full-vectorial 3D forward scattering problem has to be solved in every iteration of the optimization process. The vector fields are computed by discretizing a constrast-source integral equation with a Method of Moments. Since the solution of this problem is computationally demanding, two accelerating techniques are used: the FFT method, which exploits the convolution structure to accelerate the calculation of the scattered electric field in D, in conjunction with an iterative solver (X.M. Xu *et al.*, J. Appl. Comput. Electromag. Soc., 17(1), 97-103, 2002) and the Marching on in Angle method (A.G. Tijhuis *et al.*, IEEE Trans. Geosci. Remote Sens., 39 (6), 1316-1330, 2001).

The proposed regularized cost function penalizes strong local variations in the permittivity distribution. Expressions for the gradient vector and the hessian matrix of the regularized cost function are given. An update formula is derived and the update vector is used as a search direction along which a line search is performed to find the next iterate. Reconstructions from simulated data for some inhomogeneous biological objects are very promising.
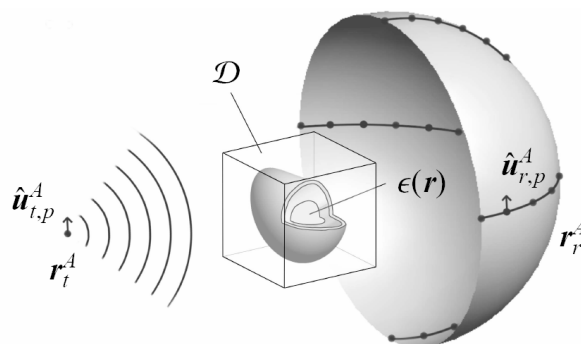

Fig. 1: Imaging configuration: dipole excitation in $\mathbf{r}_t$, receivers in $\mathbf{r}_r$, investigation domain D.

B-20:   Inverse Scattering
Monday, July 23, 2007   •   Renaaissance Room

Co-Chairs: *E. Marengo, Northeastern University, USA*
A. Franchois, Ghent University, Belgium

2:00 PM   URSI41: "Intensity-only localization and Inverse Scattering"
E.A. Marengo, R.D. Hernandez, Northeastern University, USA
Presenter: Edwin Marengo, Northeastern University, USA

2:20 PM   URSI60: "Full-Vectorial 3D Microwave Inversion of Inhomogeneous Lossy Dielectric Objects"
J. De Zaeytijd, A. Franchois, Ghent University, Belgium
Presenter: Ann Franchois, Ghent University, Belgium

2:40 PM   URSI225: "Inverse Source Reconstruction Using an -Exact-Discrete Inverse Method"
K.J. Kaczmarski[1], S.R. Laxpati[1], R.W. Stone[2],
[1]University of Illinois at Chicago, USA, [2]Stoneware Limited, USA
Presenter: Konrad Kaczmarski, University of Illinois at Chicago, USA

3:00 PM   URSI432: "Inverse Scattering of Inhomogeneous Dielectric Targets Using Genetic Programming"
R.A. Wildman, D.S. Weile, University of Delaware, USA
Presenter: Raymond Wildman, University of Delaware, USA

3:20 PM   URSI42: "Non-iterative Inverse Scattering Including Multiple Scattering"
E.A. Marengo, Northeastern University, USA
Presenter: Edwin Marengo, Northeastern University, USA

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