UNIVERSITY
OF TRENTO

DIPARTIMENTO DI INGEGNERIA E SCIENZA DELL'INFORMAZIONE

38123 Povo – Trento (Italy), Via Sommarive 14
http://www.disi.unitn.it

INVERSION OF LARGE-SCALE ELECTROMAGNETIC DATA THROUGH THE ITERATIVE MULTIZOOMING RECONSTRUCTION OF NONMEASURABLE EQUIVALENT CURRENT DENSITIES

M. Donelli, D. Franceschini, M. Benedetti, A. Massa, and G. L. Gragnani

January 2011

Technical Report # DISI-11-264

Inversion of Large-Scale Electromagnetic Data through the Iterative Multizooming Reconstruction of Nonmeasurable Equivalent Current Densities

M. Donelli, D. Franceschini, M. Benedetti, A. Massa
ELEDIA Research Group at DIT, University of Trento, Via Sommarive 14, I-38050 Trento, Italy
Phone: +39 0461 882057, Fax: +39 0461 882093, E-mail: andrea.massa@ing.unitn.it

G. L. Gragnani
DIBE, University of Genoa, Via Opera Pia 11A, I-27100 Genova, Italy
Phone: +39 010 3532243, Fax: +39 010 3532245, E-mail: gragnani@dibe.unige.it

In the framework of the inversion of electromagnetic data, several methodologies consider the introduction of an equivalent current density defined into the dielectric domain to be reconstructed. However, one of the main drawbacks of these approaches is their "difficulty" to reconstruct the so-called "nonradiating" (or "nonmeasurable" when the electromagnetic data are measured only in a limited domain or positions outside the investigation domain) components of the equivalent current density. Hence the obtained solution may be too inaccurate and, in many realistic cases, it suffers from a strong low-pass effect.

In order to overcome this drawback, *Habashy et al.* [1] presented a reconstruction method where the problem of nonmeasurable currents was properly and directly addressed through a successive steps process. Taking into account the guidelines suggested in [1], *Gragnani et al.* [2] proposed a nonlinear procedure based on the reconstruction of the measurable components of the equivalent current density by means of the singular value decomposition of the discretized Green's operator. Such components are then inserted into a nonlinear equation whose unknowns are the nonmeasurable components as well as the dielectric properties of the investigation domain. In order to solve this equation, a nonlinear (multiminimum) functional is defined and minimized by means of a standard steepest-descent procedure.

Even though the results obtained by taking into account the nonmeasurable current density were better than the ones of the minimum-norm solution, the method demonstrated some inaccuracies or faults due to the presence of the local minima, which correspond to false solutions of the inversion problem. Moreover, the choice of a suitable representation for the nonradiating currents represented an open problem partially addressed.

In this paper, these problems are faced through an integrated strategy based on an innovative stochastic method and on an iterative multizooming procedure. As far as the representation of the nonradiating currents is concerned, the problem is twofold since there is the need of a suitable choice of the basis functions as well as of their number. Since the existence of nonradiating components is equivalent to the Green's integral operator having a null-space and one way to decrease the size of the null space is to let the equivalent current density have fewer degrees of freedom, it is convenient to approximate this density with a smaller number of basis or unknowns, e.g. by using a coarse grid in the domain under test [3]. This generally yields a more faithful reconstruction than when a large number of grid points are used. However, the reconstructed profile presents a poor spatial resolution because of the inappropriate sampling step. In order to fully exploit the reduction of the null-space enhancing the achievable spatial resolution, an iterative multizooming process is thus considered. Starting from a coarse representation, the method iteratively defines a subgridding of the support of the equivalent current density successively improving the representation (in terms of spatial accuracy) of the current as well as the scatterer profile by minimizing the nonlinear cost function defined in [2]. Towards this end, it is well known that in order to avoid local minima problems it is profitable to consider global optimizers especially when the number of dimensions of the solution space is not-so-large. As a matter of fact, the multistep process allows a significant reduction of the number of unknowns. Consequently, an innovative minimization technique based on the particle swarm optimizer (PSO) [4] is used.

REFERENCES

[1] T. M. Habashy, M. L. Oristaglio, and A. T. de Hoop, "Simultaneous nonlinear reconstruction of two-dimensional permittivity and conductivity," *Radio Sci.*, vol. 29, pp. 1101-1118, 1994.

[2] G. L. Gragnani and S. Caorsi, "Inverse-scattering method for dielectric objects based on the reconstruction of nonmeasurable equivalent current density," *Radio Sci.*, vol. 34, pp. 1-8, 1999.

[3] W. C. Chew, Y. M. Wang, G. P. Otto, D. Lesselier, and J. Ch. Bolomey, "On the inverse source method of solving inverse scattering problems," *Inverse Probl.*, vol. 10, pp. 547-553, 1994.

[4] M Donelli and A. Massa, "A computational approach based on a particle swarm optimizer for microwave imaging of two-dimensional dielectric scatterers," *IEEE Trans. Microwave Theory Techn.*, vol. 53, pp. 1761-1776, 2005.