UNIVERSITY
OF TRENTO

DIPARTIMENTO DI INGEGNERIA E SCIENZA DELL'INFORMAZIONE

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

TESTING THE ITERATIVE MULTISCALING METHOD AGAINST EXPERIMENTAL DATA - ON THE EFFECTS OF THE ELECTROMAGNETIC SOURCE MODELING IN THE RECONSTRUCTION PROCESS

D. Franceschini, M. Donelli, G. Franceschini, P. Rocca, and A. Massa

January 2011

Technical Report # DISI-11-238

Testing the Iterative Multiscaling Method against Experimental Data - On the Effects of the Electromagnetic Source Modeling in the Reconstruction Process

D. Franceschini, M. Donelli, G. Franceschini, P. Rocca, and 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

Within the framework of the medicine and biomedical engineering, without forgetting the industrial quality control in industrial processes and the subsurface sensing, many different applications require a non-invasive sensing of inaccessible areas. Towards this end, microwave imaging methodologies have gained a growing attention since they allow to retrieve information on the environment probed with electromagnetic fields by fully exploiting the scattering phenomena. Unfortunately, the inverse problem to be faced is intrinsically nonlinear, ill-posed, and non-unique. In particular, the ill-posedness and the non-uniqueness arise from the limited amount of information collectable during the acquisition of the scattered field. The number of independent scattering data is limited and they can only be used to retrieve a finite number of parameters of the unknown contrast function. To fully exploit such an information and to achieve a suitable resolution accuracy, several multi-resolution strategies have been proposed [*Miller et al.*, 1996a][*Miller et al.*, 1996b][*Bucci et al.*, 2000]. The Iterative Multi-Scaling Approach (IMSA) belongs to this class of algorithms [*Caorsi et al.*, 2003]. The unknown scatterers are iteratively reconstructed by initially considering a rough estimate of the dielectric distribution starting from the free space distribution. Successively, the initialization of the intermediate steps is obtained from the reconstruction at the previous step thorugh a simple mapping of the retrieved profile. Successively, the spatial resolution is enhanced in a limited portion of the investigation domain, that is in a set of regions-of-interest (RoIs) where the objects have been localized. Such a strategy is mathematically formulated by defining a suitable multi-resolution cost function whose global minimum is assumed as the estimated solution. The functional is iteratively minimized by using a conjugate-gradient-based procedure, but more sophisticated stochastic or hybrid algorithms can be suitably applied. In order to validate such an approach, the multi-resolution algorithm has been tested against experimental data [*Franceschini et al.*, 2005] collected in a controlled environment, since synthetically-generated data can give only limited indications and they model an ideal scenario. In dealing with real data, one of the key issue is the modeling of the electromagnetic source or of the related radiated field. In general, the electromagnetic field emitted by the probing system is measured only in the observation domain. However, iterative methods based on "Data" and "State" equations require the knowledge of the incident field (i.e., the field without the scatterers) generated from the source in the investigation domain. Towards this end, an accurate but simply model (i.e., requiring a reasonable computational burden) of the source should be developed. Complicated numerical models accurately reproduce real data, but they are difficult to be implemented starting from a limited number of samples of the radiated electromagnetic field collected in a portion of the observation domain. On the other hand, a rough model could introduce erroneous constraints to the reconstruction process. Nevertheless, whatever the source model, an effective inversion procedure should be able to reconstruct the scatterer under test with an acceptable accuracy according to its robustness to the noise. In this framework, to assess the effectiveness and the robustness of the IMSA, the results of a set of experiments, where different models for approximating the illuminating source are considered, will be shown.

References

E. L. Miller and A. S. Willsky (1996), "A multiscale, statistically based inversion scheme for linearized inverse scattering problems," IEEE Trans. Geosci. Remote Sensing, vol. 34, pp. 346-357.

E. L. Miller and A. S. Willsky (1996), "Wavelet-based methods for nonlinear inverse scattering problem using the extended Born approximation," Radio Sci., vol. 31, pp. 51-65.

O. M. Bucci, L. Crocco, and T. Isernia (2000), "An adaptive wavelet-based approach for non destructive evaluation applications," Proc. Antennas and Propagation Symp., APS-2000, vol. 3, pp. 1756-1759.

S. Caorsi, M. Donelli, D. Franceschini, and A. Massa (2003), "A new methodology based on an iterative multi-scaling for microwave imaging," IEEE Trans. Microwave Theory Tech., vol. 51, pp. 1162-1173.

D. Franceschini, A. Massa, M. Pastorino, and A. Zanetti (2005), "Multi-Resolution iterative retrieval of real inhomogeneous targets," Inverse Problems - Special Issue on 'Testing Inversion Algorithms against Experimental Data: Inhomogeneous Targets,' vol. 21, no. 6, pp. 51-63.