EXPLOITING MARKOV RANDOM FIELDS IN MICROWAVE TOMOGRAPHY

(1)Roberta Autieri, (2)Michele D'Urso, (2)Tommaso Isernia, (1)Vito Pascazio

(1)Dipartimento per le Tecnologie - Università di Napoli "Parthenope"
Centro Direzionale di Napoli, Isola C4
80143 Napoli (Italy), ☎+39 081 5476712, Fax +39 081 5476777
email: {roberta.autieri, vito.pascazio}@uniparthenope.it

(2)DIMET – Università Mediterranea di Reggio Calabria
Loc. Feo di Vito, I-89060, Reggio Calabria, Italy
email: micdurso@unina.it, tommaso.isernia@unirc.it

1. SUMMARY

Microwave tomography is a non-invasive imaging technique which allows achieving accurate quantitative images of the internal dielectric properties of not accessible targets [1-3] by properly solving inverse scattering problems [1-3]. In particular, such images are obtained by illuminating the targets with known (or estimated) incident fields (primary fields) and by measuring the scattered fields in an external region located outside the investigated region. The contrast function (related to the complex equivalent permittivity of the object) is the unknown of these inverse problems. The (noise corrupted) scattered field samples (the data of the imaging problem) are related to the contrast function through a non-linear mapping.

The solution of these problems affect the feasibility and capabilities performances of many non invasive techniques adopted in medical imaging, detection of internal defeats in aircrafts and nuclear plants, in ground penetrating radar imaging for underground tunnels detection, and many others applications.

Traditionally, the solution of such a problem consists of minimizing (or maximizing), with respect to the unknowns, a proper defined cost functional involving the mismatching between the measured and expected scattered fields (see [1-3] for more details).

Since the information content of the measured scattered field data is bounded [4], and the unknown samples belong to functional spaces with infinite dimension, the inverse scattering problem to solve is an ill-posed problem, and the adoption of proper regularization strategies is mandatory. There are two main categories of regularization techniques: classic and Bayesian approaches. In the first one, the unknowns are modelled by means of deterministic functions while in the second case with random process. Classic regularization techniques are expressed in terms of quadratic or entropy-type penalty terms and the proper value of the tuning parameter adopted to weight the regularization term plays a key role. Its choice affects the accuracy of the global solution of the imaging problem. On the other hand, its estimate is generally very difficult and computationally heavy to be performed. In the non-linear inverse scattering problems this task can become prohibitive and supervised and empirical ad-hoc techniques are generally adopted for its choice.

Bayesian approaches have been recently adopted to overcome the above problems. These schemes allow estimating the regularization parameters starting from the (corrupted) scattered fields data without using any a priori information on the unknown targets to reconstruct.

In particular, we formulate the solution of the inverse problem in term of Maximum a Posteriori (MAP) estimation and we adopt a Gaussian Markov Random Fields (GMRF) as a priori model for the unknown image.

As each MRF is described by a Gibbs function depending on two parameters [2], we need to estimate such parameters before actually inversion. Starting from measured scattered fields, two different regularization parameters maps are estimated, for the real and imaginary part of the overall unknown of the imaging problem (the contrast function). Notably, the regularization parameters values are very high in presence of high discontinuities in the image to be retrieved, otherwise they are low. Accordingly, the estimated parameters maps return an estimation of the edge of the unknown contrast profile.

Once the parameters have been estimated, they are exploited in the inversion procedure to retrieve the unknown contrast profile, i.e. the permittivity and conductivity profiles of the system of obstacles located in the region under test. Note that the joint action of the ML estimation of the hyperparameters to be included in the MRF a priori model, and of the MAP estimation of the permittivity profiles allows the reconstruction of profiles that follow the actual shape of the permittivity profiles better that the ones that can be obtained without regularization. Moreover, the presented statistical regularization represents a valid approach to circumvent the problems of classic regularization techniques, especially regarding the ability of avoiding a manual and supervised setting of the regularization parameters.

The Bayesian approaches are characterized by a computational complexity which rapidly increases when the inverse scattering problem has to be solved in its full non-linearity. In such cases, the estimation step become very time consuming, thus enlarging the overall imaging time and the needed of hardware resources. On the other hand, the adoption of linear scattering models for developing accurate inversion approaches can allow to strongly reduce the computational time and to develop simple and effective imaging procedure which can be used also in the case of large scattering problems. Of course, in these case the adoption of a proper and accurate linear scattering model is a crucial point. Our choice focuses on the extended range linear approximation derived in the framework of the recent Contrast Source - Extended Born (CS-EB) model [3]. The linearity of this scattering model simplifies the estimation step of the regularization parameters with respect to the fully non-linear case and allows to enlarge the class of unknown contrast functions which can be accurately reconstructed without solving the inverse problems in its full non-linearity.

We tested the algorithm both on simulated and on real cases. The obtained results prove the effectiveness of the method and the accuracy of the reconstructed shapes of the objects and their permittivity values.

2. REFERENCES

[1] O. M. Bucci, L. Crocco, T. Isernia and V. Pascazio, "Inverse Scattering Problems with Multi-Frequency Data: Reconstruction Capabilities and Solution Strategies", *IEEE Trans. Geosci. Rem. Sensing*, vol. 38, pp. 1749-1756, Jul. 2000.

[2] Giancarlo Ferraiuolo, Vito Pascazio and Gilda Schirinzi, "Maximum a Postreriori estimation of height profiles in InSar Imaging", *IEEE Geoscience and Remote Sensing Letters,* vol.1, n. 2, pp. 66-70, April 2004.

[3] L. Crocco, M. D'Urso, T. Isernia, "New tools and series for forward and inverse scattering problems in lossy media", *IEEE Geoscience and Remote Sensing Letters*, vol.1, October 2000.

[4] O. M. Bucci, G. Franceschetti, "On the Spatial Bandwidth of Scattered Fields", *IEEE Transaction on Antennas and Propagation*, vol. 35, pp. 1445-1455, 1987.