GUEST EDITORS' INTRODUCTION

Testing inversion algorithms against experimental data: inhomogeneous targets

This special section deals with the reconstruction of scattering objects from experimental data. A few years ago, inspired by the Ipswich database [1–4], we started to build an experimental database in order to validate and test inversion algorithms against experimental data. In the special section entitled 'Testing inversion algorithms against experimental data' [5], preliminary results were reported through 11 contributions from several research teams. (The experimental data are free for scientific use and can be downloaded from the web site.) The success of this previous section has encouraged us to go further and to design new challenges for the inverse scattering community. Taking into account the remarks formulated by several colleagues, the new data sets deal with inhomogeneous cylindrical targets and transverse electric (TE) polarized incident fields have also been used. Among the four inhomogeneous targets, three are purely dielectric, while the last one is a 'hybrid' target mixing dielectric and metallic cylinders. Data have been collected in the anechoic chamber of the *Centre Commun de Ressources Microondes* in Marseille. The experimental setup as well as the layout of the files containing the measurements are presented in the contribution by *J-M Geffrin, P Sabouroux and C Eyraud*. The antennas did not change from the ones used previously [5], namely wide-band horn antennas. However, improvements have been achieved by refining the mechanical positioning devices. In order to enlarge the scope of applications, both TE and transverse magnetic (TM) polarizations have been carried out for all targets. Special care has been taken not to move the target under test when switching from TE to TM measurements, ensuring that TE and TM data are available for the same configuration. All data correspond to electric field measurements. In TE polarization the measured component is orthogonal to the axis of invariance.

Contributions

- A Abubakar, P M van den Berg and T M Habashy, *Application of the multiplicative regularized contrast source inversion method TM- and TE-polarized experimental Fresnel data*, present results of profile inversions obtained using the contrast source inversion (CSI) method, in which a multiplicative regularization is plugged in. The authors successfully inverted both TM- and TE-polarized fields. Note that this paper is one of only two contributions which address the inversion of TE-polarized data.
- A Baussard, *Inversion of multi-frequency experimental data using an adaptive multiscale approach*, reports results of reconstructions using the modified gradient method (MGM). It suggests that a coarse-to-fine iterative strategy based on spline pyramids. In this iterative technique, the number of degrees of freedom is reduced, which improves robustness. The introduction, during the iterative process, of finer scales inside areas of interest leads to an accurate representation of the object under test. The efficiency of this technique is shown via comparisons between the results obtained with the standard MGM and those from an adaptive approach.
- L Crocco, M D'Urso and T Isernia, *Testing the contrast source extended Born inversion method against real data: the case of TM data*, assume that the main contribution in the domain integral formulation comes from the singularity of Green's function, even though

the media involved are lossless. A Fourier–Bessel analysis of the incident and scattered measured fields is used to derive a model of the incident field and an estimate of the location and size of the target. The iterative procedure lies on a conjugate gradient method associated with Tikhonov regularization, and the multi-frequency data are dealt with using a frequency-hopping approach. In many cases, it is difficult to reconstruct accurately both real and imaginary parts of the permittivity if no prior information is included.

- M Donelli, D Franceschini, A Massa, M Pastorino and A Zanetti, *Multi-resolution iterative inversion of real inhomogeneous targets*, adopt a multi-resolution strategy, which, at each step, adaptive discretization of the integral equation is performed over an irregular mesh, with a coarser grid outside the regions of interest and tighter sampling where better resolution is required. Here, this procedure is achieved while keeping the number of unknowns constant. The way such a strategy could be combined with multi-frequency data, edge preserving regularization, or any technique also devoted to improve resolution, remains to be studied. As done by some other contributors, the model of incident field is chosen to fit the Fourier–Bessel expansion of the measured one.
- A Dubois, K Belkebir and M Saillard, *Retrieval of inhomogeneous targets from experimental frequency diversity data*, present results of the reconstruction of targets using three different non-regularized techniques. It is suggested to minimize a frequency weighted cost function rather than a standard one. The different approaches are compared and discussed.
- C Estatico, G Bozza, A Massa, M Pastorino and A Randazzo, *A two-step iterative inexact-Newton method for electromagnetic imaging of dielectric structures from real data*, use a two nested iterative methods scheme, based on the second-order Born approximation, which is nonlinear in terms of contrast but does not involve the total field. At each step of the outer iteration, the problem is linearized and solved iteratively using the Landweber method. Better reconstructions than with the Born approximation are obtained at low numerical cost.
- O Feron, B Duchêne and A Mohammad-Djafari, *Microwave imaging of inhomogeneous objects made of a finite number of dielectric and conductive materials from experimental data*, adopt a Bayesian framework based on a hidden Markov model, built to take into account, as prior knowledge, that the target is composed of a finite number of homogeneous regions. It has been applied to diffraction tomography and to a rigorous formulation of the inverse problem. The latter can be viewed as a Bayesian adaptation of the contrast source method such that prior information about the contrast can be introduced in the prior law distribution, and it results in estimating the posterior mean instead of minimizing a cost functional. The accuracy of the result is thus closely linked to the prior knowledge of the contrast, making this approach well suited for non-destructive testing.
- J-M Geffrin, P Sabouroux and C Eyraud, *Free space experimental scattering database continuation: experimental set-up and measurement precision*, describe the experimental set-up used to carry out the data for the inversions. They report the modifications of the experimental system used previously in order to improve the precision of the measurements. Reliability of data is demonstrated through comparisons between measurements and computed scattered field with both fundamental polarizations. In addition, the reader interested in using the database will find the relevant information needed to perform inversions as well as the description of the targets under test.
- A Litman, *Reconstruction by level sets of n-ary scattering obstacles*, presents the reconstruction of targets using a level sets representation. It is assumed that the constitutive materials of the obstacles under test are known and the shape is retrieved. Two approaches are reported. In the first one the obstacles of different constitutive materials are represented in a single level set, while in the second approach several level sets are combined.

The approaches are applied to the experimental data and compared.

- U Shahid, M Testorf and M A Fiddy, *Minimum-phase-based inverse scattering algorithm applied to Institut Fresnel data*, suggest a way of extending the use of minimum phase functions to 2D problems. In the kind of inverse problems we are concerned with, it consists of separating the contributions from the field and from the contrast in the so-called contrast source term, through homomorphic filtering. Images of the targets are obtained by combination with diffraction tomography. Both pre-processing and imaging are thus based on the use of Fourier transforms, making the algorithm very fast compared to classical iterative approaches. It is also pointed out that the design of appropriate filters remains an open topic.
- C Yu, L-P Song and Q H Liu, *Inversion of multi-frequency experimental data for imaging complex objects by a DTA–CSI method*, use the contrast source inversion (CSI) method for the reconstruction of the targets, in which the initial guess is a solution deduced from another iterative technique based on the diagonal tensor approximation (DTA). In so doing, the authors combine the fast convergence of the DTA method for generating an accurate initial estimate for the CSI method. Note that this paper is one of only two contributions which address the inversion of TE-polarized data.

Conclusion

In this special section various inverse scattering techniques were used to successfully reconstruct inhomogeneous targets from multi-frequency multi-static measurements. This shows that the database is reliable and can be useful for researchers wanting to test and validate inversion algorithms. From the database, it is also possible to extract subsets to study particular inverse problems, for instance from phaseless data or from 'aspect-limited' configurations. Our future efforts will be directed towards extending the database in order to explore inversions from transient fields and the full three-dimensional problem.

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References

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[2] McGahan R V and Kleinman R E 1997 Second annual special session on image reconstruction using real data *IEEE Antennas Prop.* **39** 7–32

[3] McGahan R V and Kleinman R E 1999 Third annual special session on image reconstruction using real data: part 1 *IEEE Antennas Prop.* **41** 34–51

[4] McGahan R V and Kleinman R E 1999 Third annual special session on image reconstruction using real data: part 2 *IEEE Antennas Prop.* **41** 20–40

[5] Belkebir K and Saillard M 2001 Special section on testing inversion algorithms against experimental data *Inverse Problems* **17** 1565–71

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