Mini-symposium A5
Numerical Methods for Inverse Scattering Problems

Organizers
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A05-01 Keynote
Testing 3D Inversion Algorithms using Optimized FETI-FDP2 method against experimental data
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Often, inverse problems are solved thanks to optimization schemes which are based on iterative techniques requiring a call to a forward solver at each iteration. This forward solver must simulate an efficient way the scattered field associated to the predicted permittivity map. It must also take into account the environment in the vicinity of the object (rough surface, medias with complex shape...) Moreover, this forward solver is also exploited to estimate efficiently the various gradients which are necessary to compute the descent direction updates. Indeed, due to the reciprocity properties of the wave equations, it is possible to directly provide close-form expressions of these gradients by means of a point-by-point complex multiplication of the electromagnetic field and of a so-called a joint field.

We have developed a finite-element modelling tool associated to a domain decomposition technique where the computational problem is divided into non overlapping subdomains in order to construct and solve an equivalent reduced-order interface problem. The solution inside each subdomain can then be evaluated independently by imposing known mixed boundary conditions at the internal interfaces between subdomain. Such a tool enables to handle large-scale electromagnetic problems.

We will present in this talk the combination of the optimization of this direct solver with a Newton-type minimization scheme. Inversion results obtained from 3D experimental data will also be displayed.

A05-02 Invited
Fast Inverse Scattering Method for 3D Magnetodielectric Objects
Qing Huo Liu, Wenji Zhang, Zhiru Yu, Yanyun Hu, Yuan Fang, Jianyang Zho
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In this presentation we present a fast inverse scattering method for magnetodielectric objects having both permittivity and permeability values different from those in the vacuum. Magnetodielectric materials have many emerging applications, including metamaterials, but their forward and inverse scattering problems are challenging to solve with the integral equation formalism because of the complexity. In this work, the forward problem is formulated by the coupled electric and magnetic field volume integral equations, and is solved by the stabilized bi-conjugate gradient FFT (BCGS-FFT) method for magnetodielectric objects. The volumetric root-top functions are used as both basis and testing functions for the electric and magnetic flux densities (D, B), while the second order curl conforming basis functions are used for these electric and magnetic vector potentials to make the solver efficient and accurate, with only O(N) complexity in memory and O(NlogN) complexity in CPU time for a problem with N unknowns. The inverse scattering problem of inhomogeneous magnetodielectric materials is solved by using the Born iterative method and distorted Born iterative method, and variational Born iterative method. Applications in microwave frequency and low-frequency bands will be presented.

A05-03 Invited
A model-based inversion algorithm for electromagnetic data
Maokun Li, Aria Abubakar, Tarek M. Habashy
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We will present a model-based inversion algorithm for electromagnetic data inversion. In this algorithm, the inversion domain is described by the so-called regional conductivity model and both geometry and material parameters associated with this model are reconstructed in the inversion process. This method has the advantage of using a priori information such as structural information extracted from seismic measurements, and/or inversion results a priori derived from a pixel-based inversion method. By incorporating this a priori information, the number of unknown parameters to be retrieved becomes significantly reduced.

In the 3D model-based inversion algorithm, the models are described by points in the 3D space and the so-called radial basis functions are used as the interpolation functions for connecting these points. The use of the radial basis functions renders the surface of the target intrinsically smooth. The L2-norm and weighted L2-norm regularization schemes are employed to constrain the curvature and to further smooth the surface of the target. Numerical tests using both synthetic and experimental data demonstrate that both the shapes and material properties of the targets are well reconstructed. As a complementary algorithm to the pixel-based inversion algorithms, the model-based inversion algorithm helps to reduce the non-uniqueness in the data interpretation.

A05-04
Effective PDE-based and IE-based inversion methods with no forward solver for highly nonlinear inverse scattering problems
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We first present a new partial differential equation (PDE) based method to solve the inverse scattering problems (ISP) where forward solver is not needed. In such a new method, by properly extracting known information, electric fields and contrast are both considered as unknowns and alternatively optimized. Regularization upon the induced current is employed to stabilize the inversion. Subsequently, the connection between the aforementioned PDE-based inversion method, using the Helmholtz equation, and the conventional integral equation (IE) based inversion method, using the Lippmann-Schwinger equation, is discussed. On the other hand, in a recent work [1] we have proposed a new IE, using which in the IE-based inversion method one is able to solve the highly nonlinear ISP with strong scatterers. With such a new IE and the connection between the PDE- and IE-based inversion methods, we propose a new PDE, using which the PDE-based inversion method can also solve the highly nonlinear ISP. Pros and cons of both PDE- and IE-based inversion methods will be discussed.


A05-05 Invited
Electromagnetic MUSIC imaging and 3-D retrieval of defects in anisotropic, multi-layered composite materials
G. Rodeghiero, M. Lambert, D. Lesselier, P.-P. Ding
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To electromagnetically test damaged anisotropic multilayers like composite panels of aeronautical and automotive industry is a difficult
question: one needs fast and robust algorithms yielding images amenable to end-users’ decision about potential defects in both High-Frequency (HF) cases (dielectric materials) and Low-Frequency (LF) cases (conductive materials). Besides, it is important to get the results in close-to-real-time. Yet one also needs accurate responses of the multilayers, sound or damaged, to exterior sources at the forward modeling stage. The latter is considered via a Fourier-based Method of Moments applied onto an exact contrast-source integral equation involving the dyadic Green’s function of the layering, and via a first-order solution involving it as well as depolarization tensors of the assumed defects if small enough vis-à-vis the wavelength (HF) or skin depth (LF). The presentation will have two aims: to recapitulate most recent achievements, with emphasis on the fast calculation of the Green’s function when the dipole sources lie far away from the origin, yielding a fast-oscillating spectrum; to appraise most novel results obtained by standard and improved MUSIC (Multiple Signal Classification) algorithms for small multiple defects in weak interaction, while investigating MUSIC beyond its expected domain of application, for somewhat larger spherical defects.

A05-06 Invited
Quantitative Inverse Scattering with Sparseness Constraints - the Compressive Sensing paradigm
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Quantitative imaging techniques are aimed at evaluating the dielectric properties of targets located in inaccessible investigation domains by illuminating the scenario with a set of interrogating waves and by processing the resulting re-irradiated fields. These methodologies have important applications in biomedical diagnostics, non-destructive testing, remote sensing, and subsurface prospecting. Unfortunately, because of the theoretical properties of the associated inversion problems, the development of fast, and robust general-purpose numerical methods for quantitative imaging is still an open challenge. The introduction of a-priori information in terms of regularization terms within the inversion process has been proposed as an effective approach to handle quantitative imaging problems. More specifically, Compressive Sensing (CS) has emerged as one of the most promising paradigms for the development of effective inversion methodologies for quantitative imaging. CS techniques essentially exploit the fact that the data (e.g., the scattered field) is linearly related to the unknowns (e.g., the equivalent sources or the contrast), and that these unknowns have a (direct or indirect) sparse representation in a suitable domain. This contribution is aimed at reviewing some of the most advanced CS imaging methodologies, and at envisaging some of the ongoing research activities aimed at addressing current limitations and drawbacks.

A05-07
Imaging wave-penetrable objects in a finite depth ocean
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We extend the direct sampling method proposed in Ito et al. (2012) to image a wave-penetrable inhomogeneous medium in a 3D waveguide. Incidences and receivers are available only on part of the surface of a cylinder. The proposed method is basically direct and does not involve any matrix inversions or optimizations, thus computationally very cheap and efficient. Numerical simulations show that the method is feasibility and effectiveness for acoustic detection in a 3D waveguide. The method is applicable with a few scattered fields corresponding to only one or two incident waves, and is very robust against noise.

A05-08
Simultaneous reconstruction of the PEC and dielectric scatterers in through wall imaging application
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The study of through wall imaging problem is of great interest in the field of security check and the anti-terrorism. In most literatures, the wall and the unknown scatterers are both assumed to be dielectric implicitly, while the problem of mixture of PEC and dielectric is not often addressed yet, which is a more commonly encountered case. Therefore, in this article, we mainly discuss the reconstruction algorithm of PEC and dielectric scatterers together under the circumstance of through wall imaging. The T-matrix method is chosen as the modelling scheme. According to a recently published paper by the author, it is able to distinguish the PEC and dielectric scatterer simultaneously when the two kinds of scatterers coexist in the domain of interest. The optimization scheme is developed based on the subspace based optimization method, where the wall (obstacle) is considered as a known scatterer rather than part of the inhomogenous background. Numerical results are given to show the effectiveness of the proposed algorithm.