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Efficient Adaptive Algorithms for an Electromagnetic Coefficient Inverse Problem

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Thesis for degree of Doctor of Philosophy to be defended in public on
September 1, 2017 at 13.15 in Pascal,
Department of Mathematical Sciences, Chalmers Tvärgata 3, Gothenburg.
The defence will be conducted in English.

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ABSTRACT

This thesis comprises five scientific papers, all of which are focusing on the inverse problem of reconstructing a dielectric permittivity which may vary in space inside a given domain. The data for the reconstruction consist of time-domain observations of the electric field, resulting from a single incident wave, on a part of the boundary of the domain under consideration. The medium is assumed to be isotropic, non-magnetic, and non-conductive. We model the permittivity as a continuous function, and identify distinct objects by means of iso-surfaces at threshold values of the permittivity.

Our reconstruction method is centred around the minimization of a Tikhonov functional, well known from the theory of ill-posed problems, where the minimization is performed in a Lagrangian framework inspired by optimal control theory for partial differential equations. Initial approximations for the regularization and minimization are obtained either by a so-called approximately globally convergent method, or by a (simpler but less rigorous) homogeneous background guess.

The functions involved in the minimization are approximated with finite elements, or with a domain decomposition method with finite elements and finite differences. The computational meshes are refined adaptively with regard to the accuracy of the reconstructed permittivity, by means of an a posteriori error estimate derived in detail in the fourth paper.

The method is tested with success on simulated as well as laboratory measured data.

Keywords: coefficient inverse problem, inverse scattering, Maxwell's equations, approximate global convergence, finite element method, adaptivity, a posteriori error analysis