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This project was concerned with the use and further development of the "linear sampling method" for determining the support of an anomaly in a piecewise constant background medium from measured electromagnetic scattering data. The main accomplishments were 1) the development of the mathematical theory of the linear sampling method for Maxwell's equations in the three-dimensional anisotropic media; 2) the numerical implementation of the linear sampling method for a three-dimensional scalar problem of locating buried orthotropic objects in the earth.

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Summary

This project was concerned with the use and further development of the "linear sampling method" for determining the support of an anomaly in a piecewise constant background medium from measured electromagnetic scattering data. The main accomplishments were 1) the development of the mathematical theory of the linear sampling method for Maxwell's equations in a three-dimensional anisotropic media; 2) the numerical implementation of the linear sampling method for a three-dimensional scalar problem and 3) the adaptation of the linear sampling method to the problem of locating buried orthotropic objects in the earth.

Professional Personnel

Dr. David Colton	Unidel Professor of Mathematics University of Delaware Co-Principal Investigator
Dr. Peter Monk	Professor of Mathematics University of Delaware Co-Principal Investigator

Report on Research

The first problem we considered was to determine if the linear sampling method could be used to find the location of a scattering object from data in an extremely limited aperture such as that gathered by the radar of an air-to-air missile. Unfortunately, it was shown by Colton and Piana that the answer is no [5]. On the other hand, it was shown that the sampling method could be used for apertures on the order of π in R^2 (or 2π in R^3), thus suggesting the applicability of this new method to the detection of buried objects in the earth from measurements on the earth's surface [5].

In order to use the linear sampling method for the inverse electromagnetic scattering problem, it was first necessary to extend this method from the scalar case to the case of Maxwell's equation in a three-dimensional anisotropic media. This has now been done by Colton and Potthast [6]. In the case of orthotropic media, it was further shown by Piana (an Italian post-doctoral student partially supported by this grant) that scattering data uniquely determines the support of anomalies, thus establishing that the linear sampling method gives unique results. This research is particularly important for the detection of hostile structures buried in the ground since such structures can be coated with anisotropic material in order to avoid detection. The above research shows that the shape and location of the structure is uniquely determined (at least for orthotropic media) and can potentially be numerically determined by using the linear sampling method.

This direction was pursued in Joe Coyle's Ph.D. thesis on the adaptation of the linear sampling method to the problem of locating buried orthotropic objects in the earth [7] and the numerical implementation of the linear sampling method for a three-dimensional (scalar) problem by Colton, Monk and Giebermann (a German postdoctoral student partially supported by this grant) [3]. This work suggests the possibility of using microwaves to locate (three-dimensional) buried objects by using a simple linear method but with no ad hoc approximations or a priori assumptions being made on the nature of the scattering objects whatsoever. As described in the final report of our previous grant, the linear sampling method (previously called the "simple method") mathematically places a grid on the material being probed, solves a linear integral equation of the first kind for each point on this grid (where the kernel of the integral equation is independent of the grid), and then determines the support of the aberrant inhomogeneity from a knowledge of the solution to this integral equation as a function of the grid point. As mentioned above, the extension of this method to the case of Maxwell's equations in a layered media would have potential application to a number of problems of interest to the Air Force, in particular the detection of underground structures buried in the earth. We plan to pursue this direction in the immediate future.

Survey papers describing the above work have been published [1], [2], as well as extensions to structures surrounded by a thin layer [4].

Personnel Supported

- Faculty

  D. Colton, P. Monk (Principal Investigators)

- Post-Doctoral Students

  M. Piana (partially supported by University of Genova)

K. Giebermann (partially supported by University of Bonn)

- Graduate Student

J. Coyle (supported by NSF GIG grant)

Publications

1. D. Colton, Recent progress on the linear electromagnetic scattering problem for anisotropic media, in *Mathematical and Numerical Aspects of Wave Propagation*, SIAM Publications, Philadelphia, 1998, 22-23.

2. D. Colton, A simple method for solving electromagnetic inverse scattering problems, in *Mathematical Methods in Scattering Theory and Biomedical Technology*, Pitman Research Notes, Vol. 390, Longman, 1998, 3-11.

3. D. Colton, K. Giebermann and P. Monk, A regularized sampling method for solving three-dimensional inverse scattering problems, submitted for publication.

4. D. Colton and P. Monk, A linear sampling method for the detection of leukemia using microwaves II, submitted for publication.

5. D. Colton and M. Piana, The simple method for solving the electromagnetic inverse scattering problem: the case of TE polarized waves, *Inverse Problems*, 14, 1998, 597-614.

6. D. Colton and R. Potthast, The inverse electromagnetic scattering problem for an anisotropic medium, *Quart. J. Mechanics and Applied Math.*, to appear.

7. J. Coyle, *Direct and Inverse Problems in Electromagnetic Scattering from Anisotropic Objects*, Ph.D. thesis, University of Delaware, 1998.

8. M. Piana, On uniqueness for anisotropic inhomogeneous inverse scattering problems, *Inverse Problems*, 14, 1998, 1565-1579.