

**AFOSR Grant F49620-02-1-0353
Final Performance Report**

June 1, 2002 – December 31, 2004

Principal Investigators

Dr. Fioralba Cakoni
University of Delaware
Newark, Delaware 19716
Phone: 302-831-0592
FAX: 302-831-4511
Email: cakoni@math.udel.edu

Objectives

The main concern of this grant is the detection of hostile targets such as perfect conductors partially coated by a dielectric material or anisotropic dielectrics partially coated by a thin layer of highly conductivity material with both the shape and the material properties being unknown. From the multistatic far field data measured in a sector of limited aperture it is desired to detect both the shape of the object as well as whether or not it is coated. Since it has previously been shown that the scattering due to the background can be subtracted off in a rigorous manner, for theoretical purposes it suffices to consider these problems for obstacles in a homogeneous background medium. The proposed research includes theoretical and numerical investigation of these questions.

Status of Effort

We began by considering the inverse scattering problem in the important practical case of limited aperture far field data [1] and then turned our attention to target identification problems for partially coated objects. We first considered the case of a perfect conductor that is partially coated by a thin dielectric layer and showed how both the shape and the surface impedance of the layer can be determined from far field data [9], [11]. Here the basic mathematical difficulty is to successfully treat mixed boundary value problems in inverse electromagnetic scattering theory where it is not known a priori whether or not the unknown object is partially coated and, if so, what are the material properties and extent of the coating. This work has led to an investigation of an analogous approach for determining the shape [3], [4], [10], and surface conductivity [14] of a partially coated dielectric by a very thin layer of metallic paint as explained below. This problem is of particular interest in the detection of decoys, e.g. wooden "scuds" or "missiles" coated by a thin metallic sheet constant surface impedance. Although the shape of the scattering object, whether a weapon or a decoy, can be determined by the linear sampling method,

20050520 008

in order to successfully identify the target one must obviously know more about the scatterer than its shape. In particular, one must determine information on the refractive index near the boundary of the scatterer which we refer to as the surface conductivity. A variational method for determining the essential supremum of the surface conductivity was given in [14] with numerical examples being presented for the case of the scattering of TE polarized electromagnetic waves by an orthotropic infinite cylinder.

We have also investigated the inverse scattering problem for thin perfectly conducting obstacles whose width is very small in comparison to the other dimensions and the wave length [5], [6], [13]. We model this object by an open bounded surface. Furthermore we allow one side of the thin object to be coated with an unknown dielectric material. The main result here is the extension of the linear sampling method, which was originally developed for the case of scattering obstacles with nonempty interior, to include the above case of obstacles with empty interior. An important outcome of this investigation is that the target visualization tool is the solution of the same equation for both obstacles with nonempty interior and obstacles with empty interior. This means that it is not necessary to know a priori the geometry of the target

Accomplishments/ New Findings

The main accomplishments during the period of this report were

- 1) The successful use of the linear sampling method to determine the shape of:
 - an anisotropic dielectric (possibly) partially coated by a thin layer of highly conductive material
 - a (possibly) partially coated perfect conductor
 - a very thin object (screens)
- 2) The derivation of an explicit formula giving the surface impedance of a partially coated perfect conductor from a knowledge of the far field pattern of the scattered electromagnetic wave and an analogous formula giving a lower bound for the surface conductivity of a partially coated dielectric.

Personnel Supported

F. Cakoni (Principal Investigator)

Publications

1. F. Cakoni and D. Colton, Combined far field operators in electromagnetic inverse scattering theory, *Math. Methods Applied Science* **26** (2003), 413-429.
2. F. Cakoni and D. Colton, On the mathematical basis of the linear sampling method, *Georgian Math. Journal* **10** (2003), 411-425.

3. F. Cakoni and D. Colton, A uniqueness theorem for an inverse electromagnetic scattering problem in inhomogeneous anisotropic media, *Proc. Edinburgh Math. Soc.* **46** (2003), 293-314.
4. F. Cakoni, D. Colton and H. Haddar, The linear sampling method for anisotropic media, *J. Comp. Applied Math.* **146** (2002), 285-299.
5. F. Cakoni and D. Colton. The linear sampling method for cracks, *Inverse Problems* **19** (2003), 279-295.
6. F. Cakoni, D. Colton and E. Darrigrand, The inverse electromagnetic scattering problem for screens, *Inverse Problems* **19** (2003), 627-642.
7. F.Cakoni and H.Haddar, Interior transmission problem for anisotropic media, in *Mathematical and Numerical Aspects of Wave Propagation, WAVE 2003*, (Cohen et al. Eds.) Springer Verlag, (2003), 613-618.
8. F.Cakoni and G.Hsiao, Mathematical model of the interaction problem between electromagnetic field and an elastic body, in *Acoustics, Mechanics, and Related Topics of Mathematical Analysis; Armand Wirgin ed.*, (2003), 48-54.
9. F. Cakoni, D. Colton and P. Monk, The electromagnetic inverse scattering problem for partially coated Lipschitz domains, *Proc. Royal Soc. Edinburgh* **134A** (2004), 661-682.
10. F. Cakoni and D. Colton, A target signature for distinguishing perfect conductors from anisotropic media of finite conductivity, *Journal Math. Computers in Simulation* **66** (2004), 325-335.
11. F. Cakoni and D. Colton, The determination of the surface impedance of a partially coated obstacle from far field data, *SIAM J. Appl. Math.* **64** (2004), 709-723.
12. F. Cakoni and D. Colton, Mixed boundary value problems in inverse electromagnetic scattering, *Advances in Scattering Theory and Biomedical Engineering*, World Scientific Publishing, 2004, 60-70.
13. F.Cakoni and E. Darrigrand, The inverse electromagnetic scattering problem for a mixed boundary value problem for screens, *Journal Comp. Appl. Math.* **174** (2005), 251-269.
14. F. Cakoni, D. Colton and P. Monk, The determination of the surface conductivity of a partially coated dielectric, *SIAM J. Appl. Math.*, to appear.
15. F.Cakoni, G.Hsiao and W. Wendland, On the boundary integral equation method for a mixed boundary value problem of a biharmonic equation, *Complex Variables*, to appear.

Interactions/Transitions

Professors Cakoni has visit many scientific institutions and attended numerous conferences and seminars as invited speakers both in this country and in Europe.

REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-05-

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the collection of information, to Washington Headquarters Service, Room 1224, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0707-0188), Washington, DC 20503.

0160

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE	3. REPORT TYPE AND PERIODICITY	
4. TITLE AND SUBTITLE Electromagnetic Inverse Scattering By Partially Coated Targets			5. FUNDING NUMBERS F49620-02-1-0353	
6. AUTHOR(S) Dr. Fioralba Cakoni				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Delaware 210 Hullihen Hall Newark, DE 19716			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Office of Scientific Research 875 North Randolph Street Suite 325, Room 3112 Arlington, VA 22203 <i>nm</i>			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT <i>Approved for public release, distribution unlimited</i>			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The successful use of the linear sampling method to determine the shape of an anisotropic dielectric (possibly) partially coated by a thin layer of highly conductive material. A (possibly) partially coated perfect conductor and a very thin object (screen). The derivation of an explicit formula giving the surface impedance of a partially coated perfect conductor from knowledge of the far field pattern of the scattered electromagnetic wave and an analogous formula giving a lower bound for the surface conductivity of a partially coated dielectric.				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT		20. LIMITATION OF ABSTRACT