

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB NO. 0704-0188

Public Reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE 11/15/1999	3. REPORT TYPE AND DATES COVERED Final Progress Report 05/01/98-10/31/98	
4. TITLE AND SUBTITLE Wideband EMI modeling for buried unexploded ordnance			5. FUNDING NUMBERS DAAG55-98-1-0299	
6. AUTHOR(S) Lawrence Carin				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Duke University Department of Electrical and Computer Engineering Durham, NC 27708-0291			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  U. S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSORING / MONITORING AGENCY REPORT NUMBER  <i>ARO 38691.2-EL</i>	
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.				
12 a. DISTRIBUTION / AVAILABILITY STATEMENT  Approved for public release; distribution unlimited.			12 b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  A method-of-moments (MoM) model is developed for electromagnetic induction (EMI) signatures of conducting and possibly ferrous targets that are bodies of revolution (BoRs).				
<b>20001122 114</b>				
14. SUBJECT TERMS moment method, induction			15. NUMBER OF PAGES 3	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OR REPORT <b>UNCLASSIFIED</b>	18. SECURITY CLASSIFICATION ON THIS PAGE <b>UNCLASSIFIED</b>	19. SECURITY CLASSIFICATION OF ABSTRACT <b>UNCLASSIFIED</b>	20. LIMITATION OF ABSTRACT  <b>UL</b>	

## I. List of Manuscripts Submitted/Published under ARO Support

N. Geng, C. E. Baum and L. carin, "On the low-frequency natural response of conducting and permeable targets," IEEE Trans. Geoscience & Remote Sensing, vol. 37, pp. 347-359, Jan. 1999.

## II. Scientific Personnel

Faculty: Lawrence Carin (PI)

Post doc: Norbert Geng

## III. Invention Reports

None

## IV. Scientific Progress and Accomplishments

A circuit-based analysis of low-frequency, electromagnetic scattering from conducting targets has been presented, from which it was demonstrated that the late-time (natural) response from such targets is represented by an exponentially damped response. A rigorous, MoM analysis was then applied to the case of conducting, permeable BORs in free space, for which the damped natural response was demonstrated as still appropriate. Moreover, the MoM-computed decay constants were found to be in good agreement with measured data.

Several important relationships were derived and demonstrated: i) for a conducting, non-permeable target, the modal decay constants were shown to scale with conductivity, and therefore results need only be computed for a representative conductivity, assuming the target shape remains constant; ii) the decay constants (with  $m=0$ ) for highly permeable and conducting targets can be computed very accurately (<1% error) using a simple resonant-cavity analysis (particularly useful for simple shapes such as cylinders and discs); and iii) the Cramer-Rao lower bound for estimation of the decay parameters can often be simplified to a simple relationship which only depends on the SNR (computed from the noise variance and the decay coefficient). These relationships allow one to perform quick "back-of-the-envelope" computations of the system requirements for unambiguous target discrimination via decay-parameter estimation. In this context, for the examples considered here, we have found that an SNR of roughly 20dB is required.

The low-frequency, decay-constant discrimination of conducting, permeable targets has many applications. For example, one can use it for concealed-weapon *identification* [31] as well as for identification of buried metal mines (in which case discrimination mitigates the need to dig up each piece of anthropic metal clutter). With regard to the latter example, the effects of the lossy soil become important as the size of the metal target

diminishes (this is especially relevant for plastic mines which possess very small metal content). Therefore, in future work we will consider the BOR targets buried in a lossy half space. This problem constitutes a significant escalation in complexity, due to the need to compute the half-space dyadic Green's function.

## **V. Technology Transfer**

The research reported here has been undertaken in close collaboration with the Corps of Engineers (Vicksburg, MS) and the BoR code is now used by them routinely.