

Project ID: 60162

Enhancements to and Characterization of the Very Early Time Electromagnetic (VETEM) Prototype Instrument and Applications to Shallow Subsurface Imaging at Sites in the DOE Complex

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Lead Principal Investigator: David L. Wright, U.S. Geological Survey, MS 973, Box 25046, Federal Center, Denver, CO 80225 (303)236-1381, dwright@usgs.gov

Co-Principal Investigator: Weng Cho Chew, University of Illinois at Urbana-Champaign, Department of Electrical and Computer Engineering, 1406 W. Green St., Urbana, IL 61801 (217)333-7309, chew@espark.ece.uiuc.edu

Number of Graduate Students and Post-Docs: 2 grad students and 1 post-doc.

DOE Problems Addressed

The problems being addressed are those that require imaging of the shallow subsurface and include:

- Detection and Characterization of large metal and concrete structures.
- Improvement in the ability to characterize contaminant geological settings and predict the movement of contaminants in the vadose zone whether the dominant flow is matrix flow or fracture dominated.
- Improvements in the ability to image shallow subsurface leaks from waste pits or tanks.
- Improvements in the ability to detect and characterize buried objects in waste pits and delineate the boundaries of such pits.

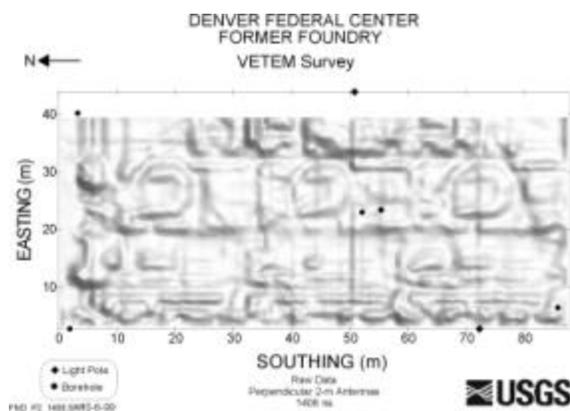
The ability to more rapidly and accurately image the shallow subsurface in electrically conductive earth can result in considerable savings in time and money in environmental restoration or deactivation and decommissioning activities.

Research Objective

The objective of this research is to enhance the state-of-the-art in electromagnetic imaging of the shallow subsurface in electrically conductive media where ground-penetrating radar (GPR) provides insufficient penetration and time domain electromagnetic (TDEM) systems provide insufficient resolution. This objective is being pursued by instrumentation enhancements to the existing very early time electromagnetic (VETEM) system coupled with physical and numerical modeling. Success in this endeavor will improve the speed and accuracy of waste pit and trench location and characterization, and could have additional applications to shallow DNAPL and LNAPL spill and cleanup monitoring, clay barrier integrity assessment, and landfill stabilization monitoring. This could result in significant savings in time and money during characterization, remediation, and decommissioning of facilities.

Research Progress and Implications

This report summarizes work after 2.4 years of a 3-year project. We have made substantial progress on both the instrumentation and modeling and have done one demonstration at the INEEL Cold Test Pit, another at Pit 9, also at INEEL, and at the Denver Federal Center (DFC) over a buried WWII former munitions foundry. Accurate and rapid methods for modeling our antennas over conductive earth have been developed, and methods for calculating fields from buried conducting and dielectric objects have been obtained. 2D and 3D inverse methods have been investigated, and a fast 1D Distorted Born Iterative Method (DBIM) inversion algorithm has been successfully applied to VETEM field data from Pit 9 at INEEL and the DFC foundry site. The figure below is from the DFC foundry site.



VETEM images were better than any that have been produced by GPR or any of the commercial EM systems that have been used there to date.

Planned Activities

In the remaining months we plan to try a gradiometer configuration, begin moving to an All-Terrain-Vehicle towed version

and finish documentation of the system. We also plan some additional calibration experiments.

Other Access to Information

1. W.C. Chew, "Imaging and inverse problems in electromagnetics," *Advances in Computational Electrodynamics*, Ed. A. Taflove, Artech House, Boston, pp. 653-702, 1998.
2. S.Y. Chen and W.C. Chew, "Electromagnetic subsurface remote sensing," in *Wiley's Encyclopedia of Electrical and Electronics Engineering*, editor, J.G. Webster, vol.6, pp.474-487, 1999.
3. T.J. Cui, W.C. Chew, A.A. Aydinler, S.Y. Chen, D.L. Wright, D.V. Smith, J.D. Abraham and R.T. Smith, "Nonlinear Inverse scattering of two-dimensional dielectric objects buried under a lossy earth," *Research Report, Electromagnetics Laboratory, University of Illinois at Urbana-Champaign*, No. CCEM-12-99, May 1999; also submitted to *IEEE Trans. on Geoscience and Remote Sensing*.
4. D. L. Wright, D. V. Smith and J. D. Abraham, "A VETEM survey of a former munitions foundry site at the Denver Federal Center", *Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP2000)*, Arlington, VA, pp. 459-468, February 20-24, 2000.

Many additional papers in journals and conference proceedings such as GPR'98, SAGEEP'99. Also see the site <http://empc22.ece.uiuc.edu>.