Project Title: High-Frequency Electromagnetic Impedance Measurements for Characterization, Monitoring and Verification Efforts
Project ID: #73776
Publication Date: 10 June 2001

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RESEARCH OBJECTIVE

Non-invasive, high-resolution imaging of the shallow subsurface is needed for delineation of buried waste, detection of unexploded ordinance, verification and monitoring of containment structures, and other environmental applications. Electromagnetic (EM) measurements at frequencies between 1 and 100 MHz are important for such applications, because the induction number of many targets is small and the ability to determine the dielectric permittivity in addition to electrical conductivity of the subsurface is possible. Earlier workers were successful in developing systems for detecting anomalous areas, but no quantifiable information was accurately determined. For high-resolution imaging, accurate measurements are necessary so the field data can be mapped into the space of the subsurface parameters. We are developing a non-invasive method for accurately mapping the electrical conductivity and dielectric permittivity of the shallow subsurface using the EM impedance approach (Frangos, 2001; Lee and Becker, 2001). Electric and magnetic sensors are being tested in a known area against theoretical predictions, thereby insuring that the data collected with the high-frequency impedance (HFI) system will support high-resolution, multi-dimensional imaging techniques.

RESEARCH PROGRESS AND IMPLICATIONS

We are in the first year of a three-year renewed project with the same project objectives of the previous one (Project ID; #60328). During the previous 3-year project, a prototype 0.1 to 30 MHz system was assembled using off-the-shelf components including a magnetic dipole transmitter, electric and magnetic antennae. The system was tested at sites of different electrical properties and an interim report (Lee and Becker, 2001) was prepared demonstrating the proof-of-concept.

This annual report summarizes work performed over the past six months of the renewed three-year project. The report consists of progresses in two subjects; improvement in electric field measurement and use of magnetic fields for an independent ground truth. The success in achieving the overall objective of the HFI system depends on the accurate field measurements, especially the electric field. Our experience indicates that the electric field is often contaminated with stray pick-ups caused by the wiring attached to the antenna. Over the past few months we have been testing various system layouts and wiring around the antenna. So far, we have been able to improve the data quality to within a 2% repeatability, but it is still not as good when antenna orientation is reversed.

The other subject investigated involves an independent way of achieving the ground truth. The ground truth is important in calibrating sensors and verifying measured data. Electrical resistivity can be easily estimated using DC resistivity method. An independent resistivity estimate can also be obtained using the ellipticity and tilt angle of the magnetic field (Smith and Ward, 1974), which will be routinely measured as part of the HFI survey. Figure 1 shows comparisons in ellipiticity and tilt angle between those numerically simulated (using EM1D) and those obtained from field data collected at the Richmond Field Station. Numerical model used consists of a thin (0.37 m) overburden of 120 ohm-m resistivity over a 45 ohm-m half space. A DC resistivity sounding at this location, as well as the impedance data, shows good agreement with the model. The permittivity is not well resolved due to the low resistivity (Lee and Becker, 2001).

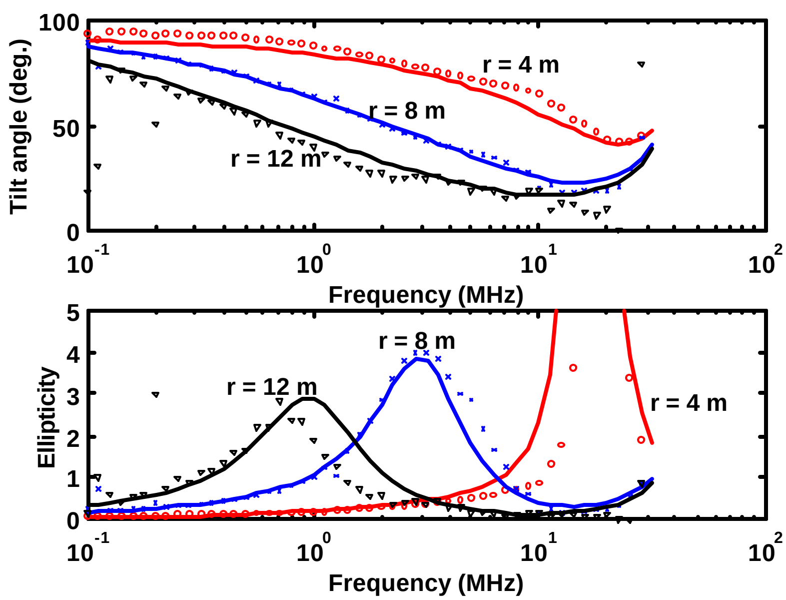

Figure 1. The tilt angle and ellipticity for a vertical magnetic dipole source derived from model simulations and field measurements. The red, blue, and black symbols and lines are for source-receiver separation of 4, 8, and 12 m, respectively. The solid lines are calculated results with EM1D while the circles, crosses, and triangles represent field data for various separations.

PLANNED ACTIVITIES

For the remainder of the first year (FY2001) improvement in the accuracy of the electric field measurement will be continued. At the beginning of the second year (FY2002), individual components will be assembled and the assembled system will be field tested at a site to be chosen (SRS, Idaho, or Hanford). The field test will be thoroughly evaluated in terms of performance of individual components and overall HFI objectives. In FY2003 a prototype HFI system will be finally assembled for field demonstration. Upon completion of the project, the system may be field deployed to monitor moisture contents of clay caps at SRS, and to monitor and predict vadose zone contaminant movement in the Hanford and other DOE sites.

INFORMATION ACCESS

Frangos, W., 2001, High Frequency Impedance Measurements for Non-invasive Permittivity Determination, PhD Thesis, University of California, Berkeley.

Lee, K.H., and Becker, A., 2001, High frequency electromagnetic impedance measurements for characterization, monitoring and verification efforts, Interim Report, Project #60328, U.S. DOE.

Smith, B.D., and Ward, S.H., 1974, On the computation of polarization ellipse parameters, Geophysics, 39, 867-869.