Project ID: #60328
Project Title: High-Frequency Electromagnetic Impedance Measurements for Characterization, Monitoring, and Verification Efforts
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Lead Principal Investigator: Ki Ha Lee
Lawrence Berkeley National Laboratory, University of California
1 Cyclotron Road, MS 90-1116, Berkeley, CA 94720
Tel: (510) 486-7468; Fax: (510) 486-5686; e-mail: khlee@lbl.gov

Co-Investigator: Alex Becker
Material Sciences and Mineral Engineering,
University of California, Berkeley, CA 94720
Tel: (510) 643-9182; e-mail: alexb@socrates.berkeley.edu

Specific DOE Problems: 1) Maintaining physical integrity of clay caps to insure isolation of hazardous waste at the Savannah River Site (SRS). 2) Lack of advanced vadose zone characterization geophysical techniques for adequately predicting the movement of contaminants in the Hanford and other DOE sites.

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 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 imaging the electrical conductivity and dielectric permittivity of the shallow subsurface using the plane wave impedance approach (Song et al., 1997). 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

Following the initial sensor verification done last year for the frequency range of up to a few MHz, the project moved on to a wider portion of the radio spectrum up to 30 MHz to date. This step required development of a transmitter system in order to have signal at specified frequencies. Additionally, we have refined the behavior of the toroid sensor. On the data analysis part an inversion scheme for layered earth (1-D) has been developed, and the initial test using real data from Pt. Reyes appears successful.

Transmitter System: We acquired a function generator good to 30 MHz and an amplifier with a bandwidth of 250 kHz through 110 MHz. We also built and tested electric & magnetic transmitter antennae good through at least 30 MHz. To minimize spurious pickup and parasitic radiation, coaxial cables have been replaced by optical fibers. Additionally, we set up and tested a digital data acquisition system that operates under control of a notebook computer through a GPIB interface.

Field Measurements: In the initial development of the field system and its verification, measurements were made at the Richmond Field Station (RFS), University of California at Berkeley. The measured impedance showed good agreement with calculated values through 10 MHz. Conditions at the RFS are relatively conductive and, therefore, the electric field measurements are proportionately smaller and more difficult to make. Furthermore, the permittivity is relatively unimportant to the results. In a more resistive environment, such as the Savannah River Site clay caps, model studies show that the electric fields are greater and that the field ratio is more sensitive to the subsurface permittivity. Two attempts at securing high-frequency impedance data in a resistive environment have been made to date. The first attempt was made at Donner Summit in the Sierra Nevada Range using transverse and vertical magnetic dipole sources. Initial analyses show that the horizontal-mode impedance data agree well with a simple homogeneous earth model. The second attempt was made in a very highly resistive environment at Point Reyes National Seashore. Near-surface resistivities of 2,000 to 10,000 ohm-m have been measured. Data from the survey and simple 1-D inversion results are shown below (Figure 1).

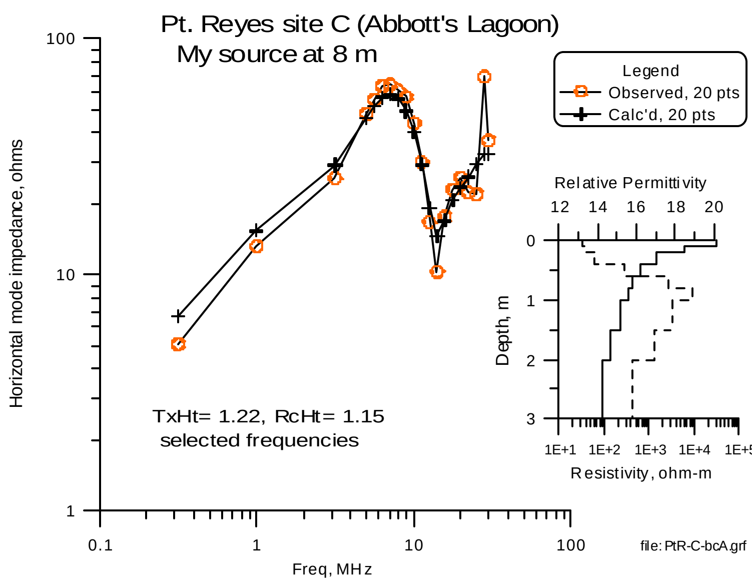

Figure 1. Impedance data (E_x/H_y) obtained at Pt. Reyes. 1-D inversion is shown on the right. Solid line is the resistivity, dotted line the relative permittivity.

Toroid Electric Field Sensor (Lee, 1997): Improvements in the shielding and extraneous pickup problems with the prototype toroid have lead to an improved response. However, the sensitivity of the device to the ambient electric field needs to be further improved for practical use. A ferrite core may be used to enhance the magnetic induction for improved sensitivity.

PLANNED ACTIVITIES

Future research will focus on cleaning up the signal measured by the stub dipoles and loop antenna through optical isolation and better signal conditioning. We will also investigate the phase calibration and stability of the system. We shall consider enhancing the toroid response amplitude through the use of a high-frequency ferrite core. The prototype field system will be further evaluated by conducting additional field tests, analyzing the data and comparing the results with other information. An overall evaluation of the feasibility of the high-frequency impedance methods will be made as part of the final project report to DOE and the end users.

INFORMATION ACCESS

Lee, K.H., 1997, High-frequency electric field measurement using a toroidal antenna, Lawrence Berkeley National Lab Report LBNL-39894, UC-2040.

Song, Y., Morrison, H.F., and Lee, K.H., 1997, High frequency electromagnetic impedance for subsurface imaging, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), 761-772.