Measuring Low Concentrations of Liquid Water in Soil

Electrical-impedance measurements serve as sensitive indications of moisture content.

NASA's Jet Propulsion Laboratory, Pasadena, California

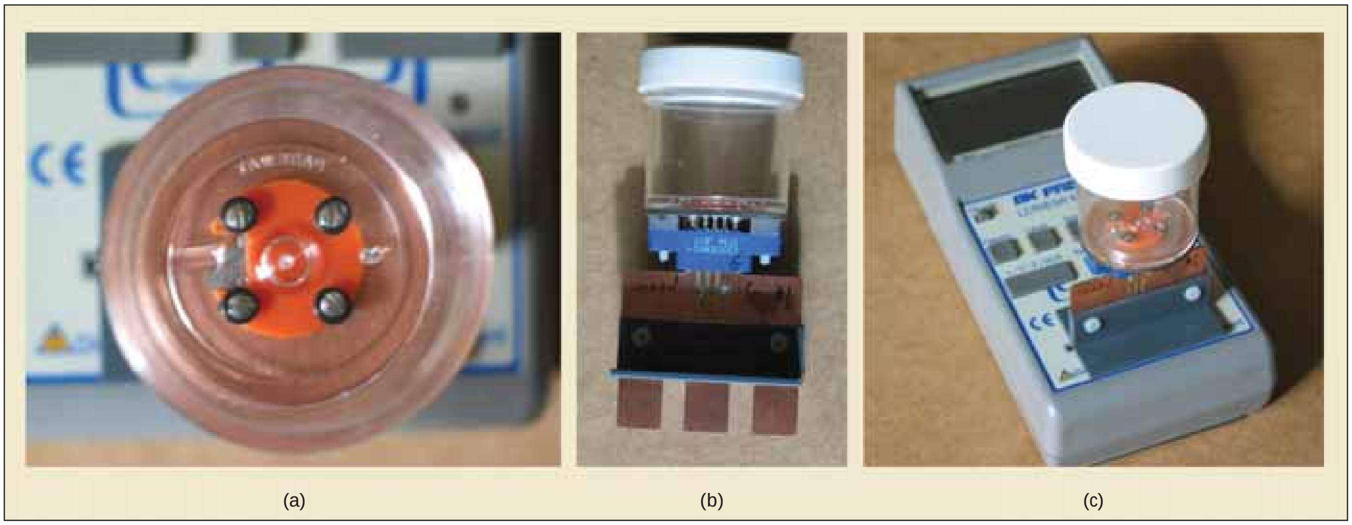

Figure 1. A **Sample Chamber Containing a Four-Electrode Probe** is mounted on a printed-circuit board that is plugged into a commercial impedance spectrometer: (a) top view of the soil moisture cup showing the four probes that are spaced 11.18 mm apart; (b) side view of soil moisture chamber inserted into printed wiring board that inserts into the LCR meter, and (c) LCR meter with soil-measuring cup.

An apparatus has been developed for measuring the low concentrations of liquid water and ice in relatively dry soil samples. Designed as a prototype of instruments for measuring the liquid-water and ice contents of Lunar and Martian soils, the apparatus could also be applied similarly to terrestrial desert soils and sands. The high sensitivity of this apparatus is best appreciated via a comparison: Whereas soil moisture contents of agricultural interest range between 3 and 30 weight percent, this apparatus is capable of measuring moisture contents from 0.01 to 10 weight percent (at room temperature). Moreover, it has been estimated that optimization of the design of the apparatus could enable measurement of moisture contents as low as 1 part per million by weight.

The apparatus is a special-purpose impedance spectrometer: Its design is based on the fact that the electrical behavior of a typical soil sample is well approximated by a network of resistors and capacitors in which resistances decrease and capacitances increase (and, hence, the magnitude of impedance decreases) with increasing water content. The apparatus includes a commercial impedance

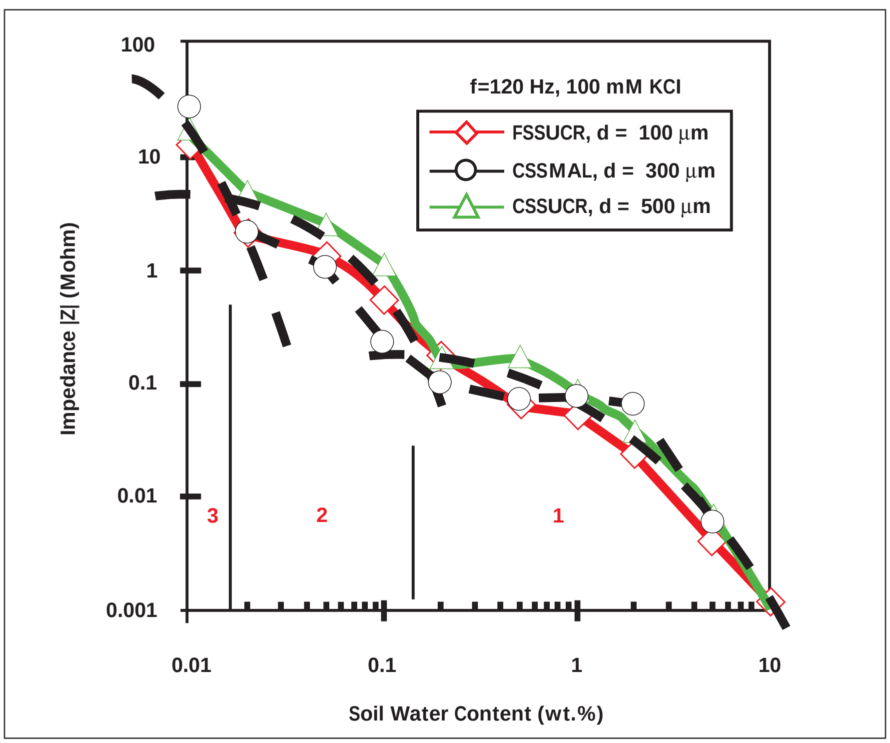

Figure 2. **Three Regions** measured by the impedance spectrometer that are explained by the soil moisture model. Measurements were obtained from fine silica sand and two samples of coarse silica sand with a diameter "d". The soil water was doped with 100 mM KCl and measured at a frequency of 100 Hz. (Note: FSSUCR is fine silica sand from the University of California, Riverside; CSSMAL is coarse silica sand from Mallinckrodt Chemicals; and CSSUCR is coarse silica sand from the University of California, Riverside.)

spectrometer and a custom sample chamber. Four stainless-steel screws at the bottom of the jar are used as electrodes of a four-point impedance probe. The leads from the electrodes are routed to a 10-pin connector that is plugged into a printed-circuit board that, in turn, is plugged into the impedance spectrometer (see Figure 1). Special precautions were taken in constructing the printed-circuit board to shield the signal conductors to enable measurement of impedances as high as 3 GΩ, thereby enabling measurement of very low levels of moisture. The lower limit of impedance measurable by this apparatus is 100 Ω.

For a typical measurement run, a sample of soil is placed in the jar and the magnitude and phase angle of impedance are measured at fixed frequencies of 100 Hz, 120 Hz, 1 kHz, 10 kHz, and 100 kHz, using applied AC potentials of 50 mV, 250 mV, and 1 V. The measurement data can then be plotted and analyzed to estimate water content, as illustrated by the example of Figure 2.

This work was done by Martin Buehler of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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The Mars Science Laboratory Touchdown Test Facility

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In the Touchdown Test Program for the Mars Science Laboratory (MSL) mission, a facility was developed to use a full-scale rover vehicle and an overhead winch system to replicate the Skycrane landing event. A driving requirement for the testing facility was the need to support a load of 5,000 lb (2,268 kg) at a minimum height of 13 m. Few facilities at JPL qualify with enough height, leaving the Building 280 Static Test Tower as the logical choice. However, this facility is popular, so an additional requirement was that the MSL test facility be temporary, and be able to be disassembled in a matter of a week or two, be stored for a period of time, and then be reassembled again quickly for V&V (verification and validation) testing.

The Building 280 Test Tower is a 50-ft-tall (15-m) steel tower structure measuring approximately 15 by 15 ft (4 by 4 m). Overhead pulleys were mounted on a new cantilevered frame so that testing could be conducted on the south face of the tower. Landing surfaces consisted of flat and sloped granular media, and rigid, planar surfaces. Various combinations of rocks and slopes were studied. Information gathered in these tests was vital for validating the rover analytical model, validating design and system behavior assumptions, and for exploring events and phenomena that are either very difficult or too costly to model in a credible way.

This work was done by Christopher White; John Frankovich; Phillip Yates; George H. Wells, Jr.; and Robert Losey of Caltech for NASA's Jet Propulsion Laboratory. NPO-45847

Non-Contact Measurement of Density and Thickness Variation in Dielectric Materials

An improved nondestructive inspection method uses terahertz energy for density and thickness mapping in dielectric, ceramic, and composite materials.

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This non-contact, single-sided terahertz electromagnetic measurement and imaging method characterizes microstructural (e.g., spatially-lateral density) and thickness variation in dielectric (insulating) materials. This method was demonstrated for space shuttle external tank sprayed-on foam insulation and has been designed for use as an inspection method for current and future NASA thermal protection systems and other dielectric material inspection applications where no contact can be made with the sample due to fragility and it is impractical to use ultrasonic methods (the latter methods require the sample under test to be immersed in liquid).

To provide some background, a basic pulse-echo terahertz thickness measurement for a dielectric (insulating) material is made by sending terahertz energy via a transceiver into and through the material backed by a metallic (electrically conducting) plate that reflects the terahertz energy back to the transceiver. The terahertz transceiver is separated from the dielectric sample by an air path. Thickness values are calculated using the time delay between the first front surface (*FS*) and the first substrate/reflector plate echo (*BS*) and knowledge of velocity according to distance = velocity × time delay. In a similar fashion, the velocity through the material can be determined by knowing thickness. Velocity is an important parameter because density can be derived from velocity using established velocity-density relationships for the dielectric material.

The new method allows characterization of thickness without prior knowledge of velocity and characterization of velocity without prior knowledge of thickness, and it does so using the same set of measurements. The method is still based on pulse-echo measurements,