Measuring Low Concentrations of Liquid Water in Soil
Electrical-impedance measurements serve as sensitive indications of moisture content.

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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 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.

Figure 1. A Sample Chamber Containing a Four-Electrode Probe

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.)
A building to house the Touchdown Test Program for the Mars Science Laboratory (MSL) mission was designed and built to be temporary and reusable. The building was taller, larger, and more complex than expected due to the need to support the load of a rover vehicle and related equipment. A cantilevered frame was used to allow for quick deployment followed by reassembly and storage of the facility for an extended period of time. The building was designed to accommodate a crane landing event and was constructed to be able to be disassembled and reassembled in a matter of weeks, be stored for a period of about a year, and then be reassembled again quickly for validation and verification (V&V) testing.

The building was designed to be a 50-ft-tall (15-m) 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.

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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/reflective 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,