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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Refer to NPO-41822, volume and number of this NASA Tech Briefs *issue, and the page number.*

The Mars Science Laboratory Touchdown Test Facility

NASA's Jet Propulsion Laboratory, Pasadena, California

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.

John H. Glenn Research Center, Cleveland, Ohio

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, and uses echoes off of the reflector plate with (*BS*) and without the sample present (*M*"), as well as using the echo off of the sample front surface (*FS*). (The FS echo may require specialized signal processing to "de-noise" and amplify it if it is received off of a foam front surface.)

This work was done by Ron Roth for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18262-1/3-1.

Compact Microwave Fourier Spectrum Analyzer

Large delays needed for time-domain autocorrelations would be realized photonically.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact photonic microwave Fourier spectrum analyzer [a Fourier-transform microwave spectrometer, (FTMWS)] with no moving parts has been proposed for use in remote sensing of weak, natural microwave emissions from the surfaces and atmospheres of planets to enable remote analysis and determination of chemical composition and abundances of critical molecular constituents in space.

The instrument is based on a Bessel beam (light modes with non-zero angular momenta) fiber-optic elements (see figure). It features low power consumption, low mass, and high resolution, without a need for any cryogenics, beyond what is achievable by the current state-of-the-art in space instruments. The instrument can also be used in a wide-band scatterometer mode in active radar systems.

The basic advantage of the proposed instrument is its wide bandwidth along with high resolution, enabling microwave hyperimaging of the planetary atmospheres and surfaces. For example, the analyzer will have similar resolution to the Cassini Titan Radar Mapper operating in the scatterometer mode, and will have at least two orders of magnitude wider bandwidth, compared with the same instrument operating in the radiometer mode. This will allow collecting a hundred times more data during the same observation period.

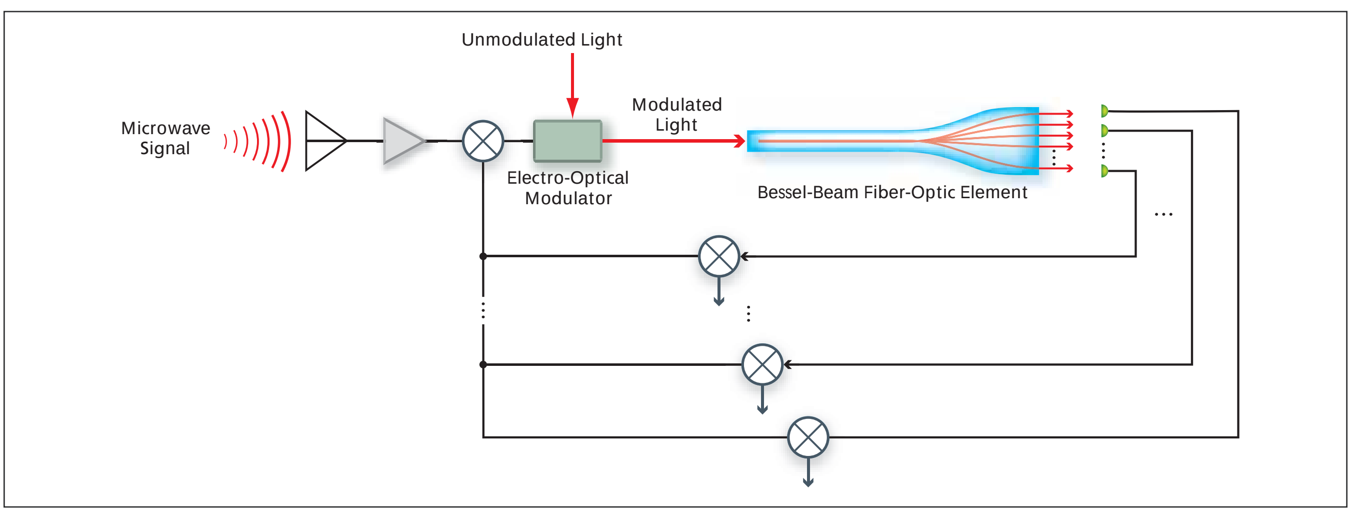
The analyzer has significant advantages for remote detection of chemical components from space. It uses microwave radiation to record the rotational spectrum of a molecule in the microwave spectral region, i.e., between approximately 6 GHz and 40 GHz. For instance, FTMWS can be used for the accurate remote detection of water vapor as well as for the study of hydrogen isotopic ratio.

The analyzer has a very long, mile-range, maximum delay realized with photonics techniques. This capability is ultimately crucial for achieving a high resolution with the Fourier transform spectrum analyzer. To obtain the 1-MHz spectral resolution necessary for resolving the microwave emission spectrum of water in remote sensing, it would ordinarily be necessary to use microwave delay lines having lengths up to 300 m. Such long microwave delay lines would not be practical. However, the instrument would exploit the fact that compact delay lines can be realized photonically.

It has Fellgett (multiplex) advantage taken from Fourier spectroscopy. A typical microwave spectrum analyzer sequentially measures the microwave power within each of a number of narrow spectral bands. The new instrument would simultaneously measure the time-domain autocorrelations of the microwave emission signal of interest using a number of different delays, then calculate the spectrum of that signal by use of a fast Fourier transform. Hence, the instrument would constantly and simultaneously provide data on all the bands of the spectrum.

It has all the advantages of a static Fourier transform spectrometer. There are no moving parts, which eliminates many potential mechanical problems onboard the spacecraft. The instrument has no need for a reference laser since the detector array samples the interferogram always at the same points. The analyzer obtains full interferogram at once so it is insensitive to the flicker noise or fluctuations of the input signal. This is critical, e.g., for spectroscopy of a constantly changing planetary environment.

As shown in the figure, the incoming



The **Microwave Spectrum Would Be Translated** to the optical spectrum, wherein compact delay lines can be realized by use of highly dispersive optical elements.