

ON THE DIELECTRIC PROPERTIES OF DUST AND ICE-DUST MIXTURES: EXPERIMENTAL CHARACTERIZATION OF THE MARTIAN POLAR LAYERED DEPOSITS ANALOG MATERIALS. E. Heggy¹, S. M. Clifford¹, A. Younsi², J.L. Miane², R. Carley³, R.V. Morris⁴, ¹Lunar and Planetary Institute, Houston, Texas, USA (heggy@lpi.usra.edu and clifford@lpi.usra.edu), ²Laboratoire PIOM-ENSCP, Pessac, France; ³University of Cambridge, Cambridge, UK; ⁴NASA Johnson Space Center, Houston, Texas, USA.

Recent data from the MARSIS orbital radar sounder on Mars Express has provided the first insights into the electromagnetic properties of the Martian polar layered deposits (PLD). Among the most important information that can be derived from the MARSIS polar data are the thickness, depth and geometry of internal layers. A necessary requirement for the accurate interpretation of these data is knowledge of the appropriate dielectric properties of the polar ice as a function of dust concentration, composition, temperature, and radar sounding frequency. To address this need, we have conducted laboratory measurements of the electromagnetic properties of several dry Mars analog soils that match the surface compositions inferred from the TES [1] and OMEGA [2] IR spectral data. To investigate how the presence of such material affects the dielectric properties of the polar ice materials, we have also conducted measurements of ice-dust mixtures, covering the frequency range from 1 MHz to 3 GHz. Measurements were performed as a function of density, temperature, dust content and dust composition. Measurements were performed on two types of samples: (1) dry soils -- both natural and synthetic -- consisting of ground basalts and various mixtures that included components consisting of hematite, magnetite and maghemite to pure silica sand; and (2) ice-dust mixtures with various concentration of the dry soil analogs prepared in (1). These measurements are being compiled to construct more realistic geo-electrical models of the PLD and better interpret the MARSIS data.

Introduction: The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS), which operates in the frequency band of ~1 to 5 MHz, represents the first attempt to explore the Martian deep subsurface, with a particular emphasis on the detection of subsurface water [4]. MARSIS radargrams of the PLD have revealed significant internal layering, but whose relationship to the visible layering observed in the polar scarps and troughs is unknown. Early analysis of these data suggests that their accurate interpretation is strongly dependent on our understanding of the electromagnetic properties of the deposits [5]. On Earth, this type of knowledge is often acquired with the aid of complementary electromagnetic sounding techniques -- such as Transient Electromagnetic Methods (TEM) and resistivity measurements. These techniques provide an independent assessment of soil electrical conductivity which, in turn, affects radar signal

attenuation and penetration depth. While this knowledge can significantly reduce the ambiguities in radar data interpretation, such an approach is not yet possible for Mars. Instead, we must rely on laboratory measurements of analog materials to help constrain the plausible range of dielectric properties that define the propagation and reflection characteristics of the PLD. The measurements presented here span the range (1 MHz - 3 GHz) covered by MARSIS (1 - 5 MHz), the SHARAD (20 MHz) sounder onboard the Mars Reconnaissance Orbiter, and the WISDOM GPR (0.5 - 3 GHz) that will fly on ESA's 2011 ExoMars Rover [6].

Experimental setup: The soil/dust samples were prepared by grinding each of the mineral components into a fine (50 μm grain) homogenous powder, which were then mixed in various amounts to form the simulants. Sample density and porosity were controlled using a hydraulic press to compact the powders into pellets having equal masses. Samples were then dried in a vacuum-oven for 48 hours in order to remove residual moisture that can affect the measured complex dielectric constant. To prepare the ice-dust samples, dust was mixed with different amounts of distilled water to form a homogenous liquid, which was then poured into the dielectric cell and frozen (while being agitated to maintain mixture uniformity). Two cells were used that were specially designed for measuring the dielectric properties of low loss materials (e.g. teflon and ice). The first is an open coaxial cell used to measure the dielectric constant of loose powder materials. The second is a reflection cell that is used to measure ice-dust mixtures. Both measurements cells are connected to an impedance analyzer that swept the frequency and conducted measurements over the range of 1 MHz - 3 GHz. The two cells were placed in an environmental chamber which permitted control and variation of both temperature and pressure conditions after the samples achieved thermal equilibrium. The analyzer is connected to a central command unit to extract data and calculate in real-time the real and imaginary parts of the complex dielectric constant. Measurements were then made over the full frequency range for each sample as a function of temperature, density, dust content and composition.

Measurement results: Figure 1 shows the real and imaginary parts of the dielectric constant, as a function of the samples density, for a typical loose, dry basaltic soil sample, containing ~14% of magnetite [7],

that was collected near Craters of the Moon National Monument (Idaho, USA).

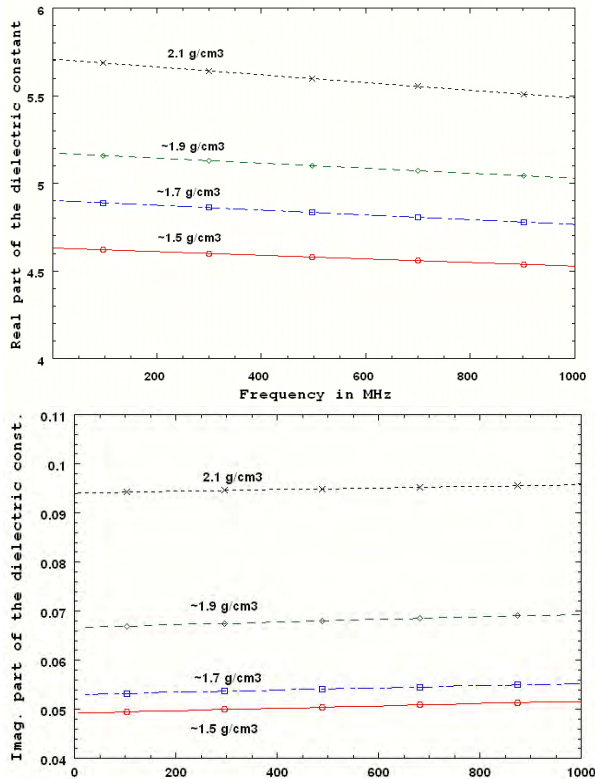


Figure 1: The real (top) and imaginary (bottom) part of the dielectric constant for a loose, dry basaltic soil as a function of density and frequency, at room temperature.

The lab measurements show a clear increase in both the real and imaginary parts of the dielectric constant with increased density. However, their spectral behavior is different: the real part tends to decrease with the frequency, while the imaginary part shows a very slight increase. This spectral behaviour is consistent as a function of density but varies with composition. As for temperature, our current equipment has been calibrated to operate at a minimum of -80°C with errors in the complex permittivity below 5%. In Table 1, dielectric measurements of the same loose, dry basaltic soil as in Fig. 1 are shown over the temperature range of -20°C to -70°C at a density of 1.9 g/cm^3 . Over this 50°C temperature range, the measurements indicate that the influence of temperature is not as significant as density on the real and complex parts of the dielectric constant.

Table 1: The real and imaginary parts of the dielectric constant for a loose, dry basaltic soil as a function of the temperature and at a density of 1.9 g/cm^3

	$\epsilon'(-20^{\circ}\text{C})$	$\epsilon''(-20^{\circ}\text{C})$	$\epsilon'(-70^{\circ}\text{C})$	$\epsilon''(-70^{\circ}\text{C})$
2 MHz	5.08	0.061	4.91	0.057
20 MHz	5.06	0.061	4.88	0.057

500 MHz	4.81	0.063	4.66	0.058
1000 MHz	4.63	0.066	4.48	0.063

Figure 2 shows preliminary data on the real part of the dielectric constant for an ice-basalt mixture with a dust content (mass fraction) of 25%, 50% and 75%. These measurements were made at -30°C and over a frequency range of 0.01 - 1 GHz. They clearly show an increase in the dielectric constant as a function of dust content. The spectral behavior also appears to be nearly linear considering the 5% measurement error for the reflection cell.

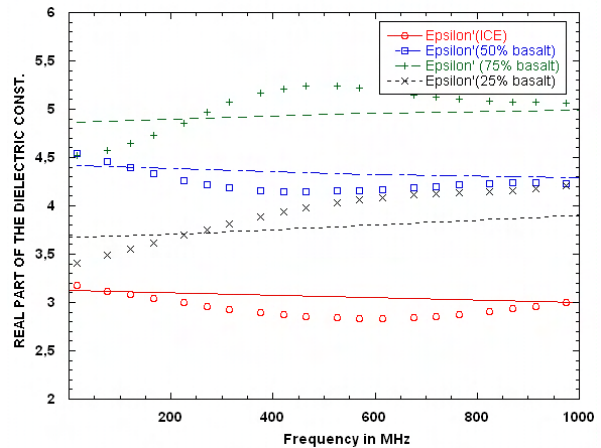


Figure 2: the real part of the dielectric constant for an ice-basalt mixture.

At 2-20 MHz, the real part of the dielectric constant ranges from 3.1 for pure ice to 4.8 for an ice sample with a 75% basaltic dust content. Measurement of the imaginary part of the dielectric constant, for this and other ice-dust mixtures, will be present at the conference. These measurements are expected to greatly assist in assessing the attenuation and maximum sounding depth of MARSIS, as well as the surface and internal layer reflection coefficient for the polar deposit materials.

References: [1] Banfield, J. L., (2002) *JGR*, Vol. 107, E6, pp 9-2. [2] Bonello, G. et al (2004) *PSS*, pp 133-140. [3] Picardi et al (2004), *PSS* [4] Clifford, S.M. (1993), *JGR*, vol. 98, pp. 10,973-11,016 [5] Picardi et al (2005), *Science*, pp 1925 ; [6] Berthelier et. (2005), *LPSC 36* [7] Leeman et al., 1976, *Contrib. Mineral. Petrol.*, 56, 35–60.