THE DIELECTRIC PROPERTIES OF MARTIAN SOIL SIMULANT *JSC MARS-1* IN THE FREQUENCY RANGE FROM 20Hz TO 10kHz.

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Introduction: The concentration of water in the Martian regolith is an important parameter in many scientific domains. Water possesses an electrical signature that allows the identification of its presence among other materials, even in low quantities. A laboratory facility has been setup to measure the complex permittivity of soil mixtures as a function of porosity, humidity, and temperature in the frequency range 20 Hz – 10 kHz. The influence of porosity and temperature are discussed, and a measurable gravimetric water content threshold is evaluated.

Measurement Setup: The dielectric properties of materials can be measured in many ways, depending upon the frequency range. In this work we apply the parallel plate capacitor technique between 20 Hz and 10 kHz, and use a circuit with an RC configuration [1]. A spectrum analyzer is used to measure the amplitude and phase shift of the signal injected in the material that fills the space between the capacitor plates. In order to minimize the impact of spurious capacitances of the circuitry associated to cables and connectors, two measurements are required. First, a calibration measurement is performed involving only the equipment in order to allow the elimination of errors caused by parasitic effects. A second measurement performed on a sample of the material under investigation provides data for the calculation of its conductivity and permittivity. In order to provide an accurate calibration for the experimental setup, several standard tests for conductivity and permittivity have been performed, namely with dielectric oil, pure water, acetone, and a KCl solution (0.01 mol dm^{-3}). The whole experiment was conducted under a steady nitrogen flow in a thermal chamber. The temperature was varied in steps of 15°C from -55°C to 20°C.

Properties of JSC Mars-1 simulant: Estimates of the structure and composition of the Martian surface and interior have been derived from various sources, and have allowed the development of soil analogues. One of the most common Mars soil simulants is known as *JSC Mars-1* [2], and was used in the experiments described here. The water content of *JSC Mars-1* has been modified for the purpose of this work, but the chemical composition of this simulant has not been altered otherwise. *JSC Mars-1* is highly hygroscopic, and the gravimetric water content at the saturation point is about 0.6 for a porosity of ϕ=0.54. Thermal gravimetry was utilized to measure the water content of the samples. Despite the fact that hydroxides are fully removed only above 700°C, free water can be eliminated below 200°C [3]. The sample has been heated to 180°C, thus interlayer water is fully removed. In order to prevent the absorption of atmospheric humidity, the dried soil container remained sealed during the experiments.

Results and Discussion: The measurements were performed using *JSC Mars-1* simulants with different porosity and gravimetric water contents. Figure 1 and Figure 2 show how the permittivity of the *JSC Mars-1* simulant varies in the frequency range from 20 Hz up to 10 kHz, with a porosity of ϕ=0.54, for different combinations of temperature (T) and gravimetric water content (θ).

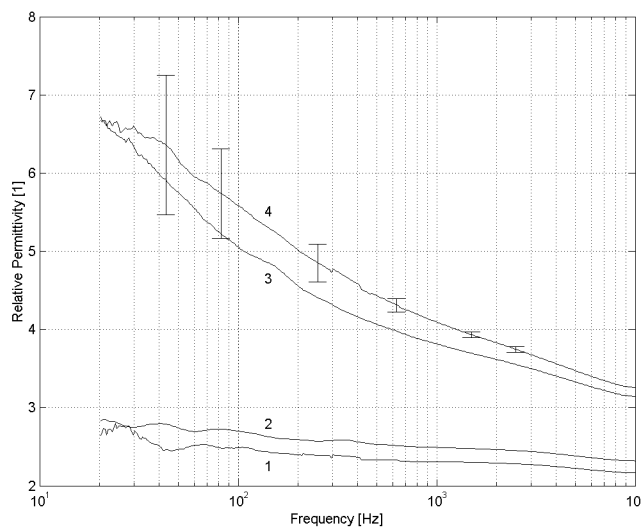

Figure 1. Relative dielectric constant of the *JSC Mars-1* simulant as function of frequency, at ϕ=0.54, with diferent gravimetric water contents: θ<0.005 (1), θ=0.01 (2), θ=0.05 (3), and θ=0.1 (4) for T=-55°C.

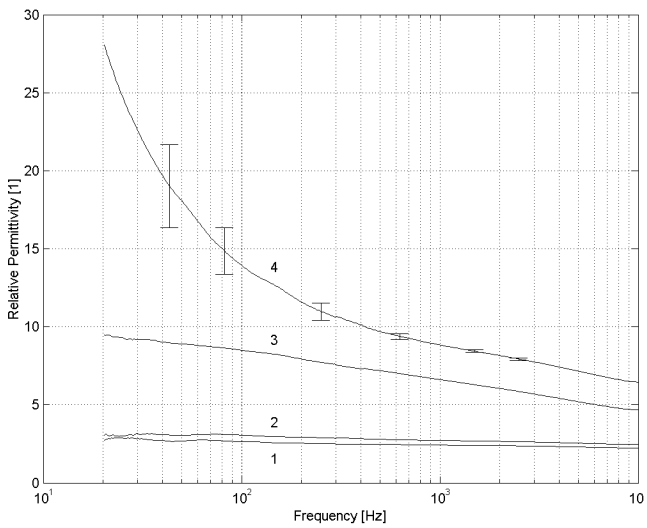

Figure 2. Relative dielectric constant of the *JSC Mars-1* simulant as function of frequency, at ϕ=0.54, with diferent gravimetric water contents: θ<0.005 (1), θ=0.01 (2), θ=0.05 (3), and θ=0.1 (4) for T=-25°C.

Additional results can be found elsewhere [1, 4]. At 20 Hz the conductivity of *JSC Mars-1* is the order of 5×10^{-10} Sm^{-1}, a value close to that expected for dry rocks without metallic components. For the sake of comparison, the conductivity in a *JSC Mars-1* saturated solution at 20 Hz and at room temperature is ~ 5 × 10^{-4} Sm^{-1}. An increase of dielectric constant and conductivity is observed when porosity decreases. The plots of loss tangent for the different porosities show two loss peaks, at 15 Hz and 6.5 kHz, reflecting the possibility that two different polarization mechanisms are involved [1]. The analysis of the *JSC Mars-1* loss tangent with varying temperature and water content shows an intricate behavior, proving that several concurrent polarization and conduction mechanisms are at work (peaks at ~100 Hz and above 100 kHz). A general increase of the loss tangent with water content is observed.

Conclusions: Water content and temperature both increase the conductivity and permittivity of the soil simulant. This effect is mostly conspicuous when the gravimetric water content is larger than 0.05; below this threshold, the dielectric properties of *JSC Mars-1* are not very sensitive to changes in moisture and temperature. A similar experiment has been performed to measure the dielectric properties of the *JSC Mars-1* simulant at room temperature and at low pressure [5], and those values are in qualitative agreement with our results at room temperature, but the lack of information about the porosity of the simulant used by those authors prevents any quantitative comparison. As expected from the theoretical results, this experiment confirms that both permittivity and conductivity increase when the water content increases and when the porosity is reduced.

There are no pronounced changes in conductivity or permittivity as long as the gravimetric water content remains below 0.01, but gravimetric water content of 0.05 gives rise to unmistakable effects. This finding quantifies the lowest possible water concentration that can significantly modify the electrical properties of a planetary surface and be possibly detected *in situ* by instruments carried by landers and rovers [6]. It can be anticipated that the large diurnal variation of the Martian surface temperature will induce changes, possibly minute, that will reveal water contents at a level of a few percent.

Although data analysis is very difficult at extreme low frequencies due to complex conductivity mechanisms and strong temperature dependence, these qualitative results indicate that water and ice can be detected among other materials, even at low contents, namely in the Martian regolith.

References: [1] Simões, F. et al. (2003) submitted to *JGR*. [2] Allen, C. C. et al. (1998), *LPS* XXIX, 160. [3] Yen, A. et al. (1998) *JGR* 103, 11125-11133. [4] Simões, F. et al. (2003) to be published in *ESLAB37*, ESA-SP. [5] Mantovani, J. G. and C. I. Calle (2003), Proc. *ESA-IEEE* Joint Meeting on Electrostatics, 688. [6] Trautner, R. et al. (2003) to be published in *ESLAB37*, ESA-SP.