DENSITY, TEMPERATURE AND FREQUENCY DEPENDENT MODEL OF THE DIELECTRIC MAP OF THE MARTIAN SURFACE. E. Heggy[1], R. A. Carley[2], A. Pommerol[3], S. M. Clifford[1], R.V. Morris[4]. [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., 77058-1113, Houston, TX, USA (heggy@lpi.usra.edu); [2]University of Cambridge, United Kingdom; [3]Ecole Normale Superieure de Lyon, France; [4]NASA, Johnson Space Center, Houston, TX, USA.

We report on laboratory electromagnetic characterization of several hyper-dry synthesized and field collected Mars analog soils that match the type of soils identified by the TES [1] and OMEGA [2] on the Martian surface in order to experimentally investigate the dielectric properties of the sediments covering the Martian surface at the frequency range from 1 to 1000 MHz. Measurements were performed as a function of the density and temperature, hence increasing the degree of complexity associated with the dependency of the surface dielectric properties on these surface environmental parameters. The density ranged from 0.8 to 2.4 gcm^{-3}, covering the density range of the Martian surface dust as deduced from TES thermal inertial data. Due to instrumentational constraint we were only able to vary the temperature range from 22 to –73 °C.

Measurements were performed on three types of samples: (1) synthetic mixtures of Mars-like soils that were prepared with the addition of varying amounts of hematite, magnetite and maghemite to pure silica sand; (2) field collected basaltic rocks with a well defined mineralogy and petrology from potential terrestrial Mars-analog sites; (3) dirty ice with different concentration of Martian dust. Those parametric measurements are integrated to form updated models of the surface dielectric map of Mars that consider the effect of variations in the surface density and temperature.

Introduction: The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) operating at the frequency band 1 to 5.5 MHz has provided the first attempt to explore the Martian deep subsurface [3], exploring the potential presence of subsurface water [4]. The returned radargram showed a variety of uncommon reflections and apparent geometries. The preliminary data analysis suggested that scientific return strongly depends on our understanding of the dielectric context of the sounded areas [5]. On Earth, low frequency radar sounding surveys are frequently associated with other electromagnetic sounding techniques, such as Transient Electromagnetic Methods (TEM) and resistivity measurements, to independently assess the soil conductivity, get an estimate of the radar signal attenuation, and constrain the penetration depth, therefore reducing the ambiguities in the radar data interpretations. Unfortunately, such an approach is not yet possible for Mars. Hence we have to rely on laboratory electromagnetic characterizations to constrain the dielectric parameters of the upper crust of the Martian surface and hence define the propagation and reflection matrices for the Martian upper crust layers. Our parametric measurements are performed in the frequency band 1 to 1000 MHz, covering the following ongoing and future sounding experiments: (1) MARSIS; (2) the SHAllow subsurface RADar (SHARAD) experiment on board the Mars Reconnaissance Orbiter, operating at a central frequency of 20 MHz; and (3) the GPR experiment on board the ESA ExoMars Rover scheduled for 2011, operating at a central frequency around 100 MHz [6].

Experimental setup: Samples were first grounded to form homogenous fine 50 μm grain powder that in a second step is mixed to form multiple phase mixtures of minerals. Sample density and porosity were controlled using a hydraulic press to compact those powders into pellets having equal masses. The study also included rock-machined pellets to allow comparison with results of the fine grain compacted ones. Samples were then dried in a vacuum-oven for 48 hours in order to remove residual moisture that can increase the measured complex dielectric constant values. Permittivity measurements were performed using guarded parallel plates capacitive cells specially designed in order to avoid the edge effect and resonance that occurs in classical capacitive cells when working with lossy soils. The first cell used both machined and compacted pellets. The second is an open coaxial cell used to measure the dielectric constant of loose powder-reduced material and dirty ice mixtures when cooled. Both measurement cells are connected to an impedance analyzer to perform a frequency sweeping over the band 1 to 1000 MHz. The two cells were placed in an environmental chamber with controlled degree of temperature and moisture to allow temperature variations. The analyzer is connected to a central command unit to extract data and calculate in real-time the real and imaginary part of the complex dielectric constant as a function of temperature variation, the density being constant for each sample. Frequency dependent model was established for each sample as a function of the temperature and density then assigned a soil type number. The results that will be discussed below are for a simple model of the dielectric map where the totality of the Martian surface is assumed to be covered with one soil type. At the time of the conference we will present more complex maps with multiple soil types derived mainly from recent THEMIS and OMEGA observations.

Measurement and modeling results: Our measurement algorithm performed on 34 samples generated an important amount of data that allow performing both parametric and statistical studies at a satisfying level. Due to the limitation in space in the abstract, we show only a brief sample of the measurements output and the algorithm for its integration into the parametric model of the surface dielectric map of Mars. Figure 1; show the real and imaginary part of the dielectric constant for a typical dry basalt sample collected from the Crater of the Moon national monument (Idaho, USA) as a function of the samples density in g/cm^3.

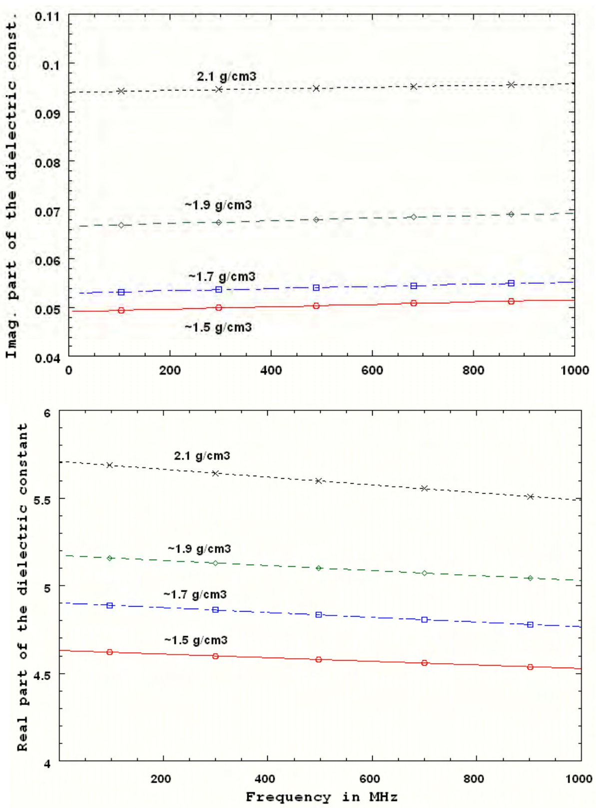

Figure 1: Real and imaginary part of the dielectric constant for a dry Basalt sample as a function of the density, measured at room temperature.

The measurements show a clear increase of the real and imaginary part of the dielectric constant as a function of the increase in density. In the other hand their spectral behaviour is different from each other: The real part tends to decrease with the frequency and the imaginary part show a very slight increase with the frequency. This spectral behaviour appears reproducible for the densities shown on figure 1 but varies with the sample changes in compositions. As for the temperature our experimental setting has been recently installed and calibrated to operate at the minimum lower temperature of –73 C° with errors bars for the complex permittivity below 8 %. Some preliminary results are shown in table 1, for the same basalt sample at a constant density of 1.9 g/cm^3.

	ε' (-20Cº)	ε'' (-20Cº)	ε' (-70Cº)	ε'' (-70Cº)
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

Table 1: *Real and imaginary part of the dielectric constant for a dry Basalt sample as a function of the temperature and at a density of 1.9 g/cm^3*

We can clearly note that the temperature dependency is not as well significant as the density for the dry basalt sample at this temperature range of –50Cº. Those two types of parametric measurements (i.e. as a functions of density and temperature) are then integrated in a frequency dependent model of the Martian surface dielectric map. The model displays the dielectric constant as a function of the variations in surface density as deduced from TES thermal inertia data [7] and an average surface temperature of –60 C°. We then generate a map for the areas between –60° South and 60° North, and separate maps for the Polar Regions (based on dirty ice measurements) that are still in progress. The map shows that 55 % of the surface sediments layer (1 to 10 meters deep) has a loss tangent around 0.07 and the average value is 0.05 at 2 MHz.

Implications: Our measurements and modeling shown an important and expected complexity in the Martian surface geoelectrical descriptions. This variation is accentuated in the low frequency range from 1 to 30 MHz, dielectric contrasts between different areas tend to minimize as we get to higher frequency range. This explains the quite homogeneous dielectric distribution observed from earth based radar observations [8] with exception of the polar caps. We will present in the conference attenuation and surface reflection coefficient maps in order to quantify, locate and visualize the effects of this dielectric heterogeneity on the potential of deep subsurface mapping.

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] Mellon, M.T. (2001), *JGR*. [8] Haldemann, A.F. et al., (2000) *Technical Report*, JPL.