GEOELECTRICAL MODELS AND RADAR ECHO SIMULATION FOR SOUNDING THE MARTIAN SUBSURFACE:

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Introduction: Recent high resolution images from the Mars Orbital Camera (MOC) on board the Mars Global Surveyor (MGS) orbiter reveals the possibility of the presence of water in the near subsurface at a depth of a few hundred meters [1], that could outgo from an underground ice rich-saturated layer covered locally by volcanic altered materials. Thus the fractured ground ice might contain some pockets where local conditions of pressure, temperature and fluid impurities led to the presence of liquid water lenses (this phenomena was observed in the radar sounding of temperate ice grounds on Earth). Three space missions to Mars will use the low frequency sounding radar technique: the first one is the MARSIS experiment on board of the Mars Express orbiter scheduled for 2003, and the second one is the Ground Penetrating Radar (GPR) experiment within the NetLander mission planed for 2007. Both systems will operate at frequencies around 2 MHz, searching mainly for deep subsurface water and mapping the subsurface-layered structures. The third radar experiment is planed for 2005 on board the Mars Reconnaissance Orbiter (MRO), operating at higher frequency near 20 MHz. Its objective is mainly to detect shallow subsurface water lenses with a lower penetration depth and a better resolution. To evaluate experimentally the performances in terms of penetration depth and signal to noise ratio of such radar systems for Martian subsurface exploration, we conducted series of measurements of the electromagnetic properties of volcanic and sedimentary materials, in order to construct representative geoelectrical models of the Martian subsurface for the 1-20 MHz frequency range, for terrains where young fluvial-like features raise the possibility that liquid water may exist at shallow depths (100 to 500 m in deep). We used expected subsurface petrophysical and geophysical conditions such as temperature gradient, rocks porosity and granulation that may exist along the first few hundreds of meters of the Martian crust. We then use the Finite Difference Time Domain (FDTD) technique to simulate the radar wave interaction with those specific subsurface models. Those results help us to consider possible optimal sites for each of the planed radar experiment, in order to derive an unambiguous detection of water in the Martian subsurface.

Geoelectrical modeling: Radar subsurface exploration requires a minimum knowledge of the geoelectrical property of the investigated media in order to reduce ambiguities about the identified object. If we assume that major part of the Martian crust is close to the geological description of Clifford in 1993 with a general context of volcanic iron oxide-rich materials, covering a thick ice ground layer, then the electrical and magnetic losses in the first layers could strongly decrease the depth of investigation on a large part of the planet [2]. Such a global model for the Martian subsurface has to be refined for local water investigation. Thus we present here four geoelectrical models of local sites on Mars where water could be searched for using sounding radar. Those models are also representative of potential landing sites of the Netlander experiment.

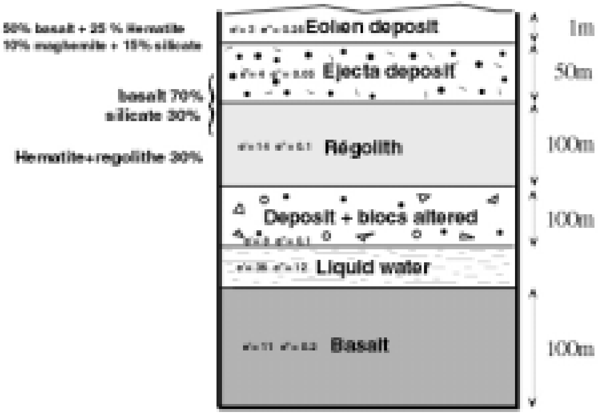

Figure 1: The geological model corresponding to the northern Tartarus Montes region (27.2°N latitude, 184.7°W longitude).

Our approach consists in generating a geological model for each site (cf. Fig. 1), then deriving experimentally the permittivity and permeability of well-defined mixtures of volcanic and sedimentary materials used as analogues of each subsurface layer. We characterized volcanic materials such as basalt, hematite, maghemite and some other minerals that may be presents on Mars such as montmorillonite, halite, gypsum, dolomite and calcite. We also elaborated mixture of basalt, iron oxides and evaporites with representative amounts, to synthesize samples some subsurface layers of our geological models. Samples have all been reduced to the same granulation (to avoid changes in magnetic losses due to this parameter) and we studied different porosities corresponding to various locations in the geological profiles. Table 1 shows an example of the geoelectrical profile corresponding to the geological model in Figure 1, for the two frequencies 2 MHz (left) and 20

MHz (right). We evaluated the permittivity ε, the absorption coefficient α and permeability μ for each layer. We then integrated those measurements to build three-dimensional dielectric profile using the Yee algorithm in the FDTD simulation space [3]. We can note that absorption coefficient is more important at 20 MHz but we have a better resolution to identify the presence small water lenses with a satisfying penetration depth ranging from few tenths of meters to few hundreds depending on site mineralogy and geophysical conditions.

Layer	ε		α (dB m^{-1})		μ	
Dust	3	2.8	0.0045	0.0275	1.8	1.1
Ejecta	4	3.7	0.0031	0.0114	1.3	1.1
Regolith	9	7	0.0079	0.0474	1.3	1
Deposit	8	7.2	0.0022	0.0156	1	1
Wet basalt	36	32	0.0488	0.3657	1.4	1
Basalt	11	8.7	0.0018	0.0142	1	1

Table 1: The 2 MHz (left) and 20 MHz (right) geoelectrical model of the northern Tartarus Montes region.

Radar echo simulation: We defined for each simulation approximate wave emitter and receiver parameters for the radar instruments; to get a first order comparison of the performances for the three planed radars. We also established several sounding geometries in order to study the effect of subsurface interface slope on the backscattered radar signal. We mainly studied two cases for the presence of water: the first is its presence as a water saturated basalt layer as shown in Figure 1, and the second case is the one of water lenses inside a fractured ice ground layer. Simulations produce the radar echo for each model in terms of received power at the surface (y-axis expressed in W/m2) versus time (x-axis expressed in s) as shown in Figure 2 for the northern Tartarus Montes region. Figure 2 clearly shows the presence of four peaks corresponding to the first four electrical interfaces between the subsurface layers in Figure 1.

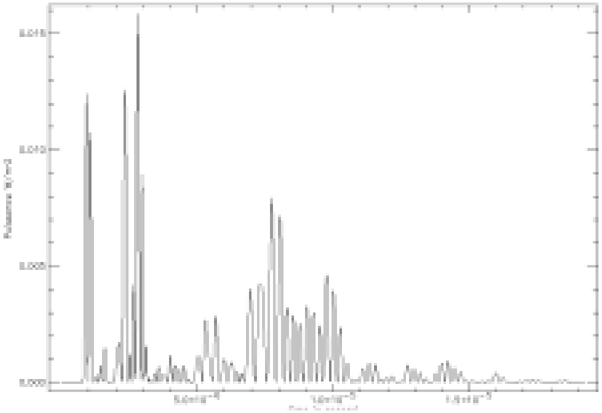

Figure 2: A 2 MHz radar echo for the northern Tartarus Montes region.

In order to reduce ambiguities on the presence of interfaces, we used a polarized incident wave and a H/V polarization on the receiving antenna. We correlated echo signals in each polarization to better identify the signature and the depth of each layer interface.

Radar echo in figure 2 show that it is possible to identify water at shallow depth at Tartarus Montes region site using a 2 MHz sounder, we can note the characteristic relatively broad signal arising from the deposit - liquid water interface due to the presence of moisture gradient.

Discussion: The geoelectrical models that we derived from laboratory measurements show considerable variations in the radar sounding performances according to the site location and the sounding frequency. Those performances are mainly controlled by the presence of subsurface inhomogeneities with dimensions comparable to the wavelength, magnetic losses and the abundance of iron oxides minerals and clays that produce considerable electric losses [4]. Unfortunely there is no direct observation at the present time that could inform us about the distribution and nature of those materials in the Martian subsurface. Thus the results from the MRO shallow subsurface sounder, coupled with laboratory measurements and numerical simulations, should be of great importance to prepare the Netlander experiment, as deep subsurface water reservoirs could be masked by the possible presence of near subsurface scatterers (voids, water lenses, inhomogeneities) [5]. Such results are crucial for the selection of future landing sites (Netlander, future rovers) and help to optimize the instruments performances and to invert the future radar data.

References: [1] Malin and K.S Edgett (2000), *Science*, 290, pp. 1927-1937. [2] E.Heggy et al. (2002), *ICARUS*, 154, in press. [3] K.Kunz and Luebbers R. J. (1993), *The Finite Difference Time Domaine Method for Electromagnetics*, CRC Press. [4] G.R.Olhoeft (1998), *GPR'98*, 387-392. [5] R.D. Watts and England A.W (1976), *Jour.of Glaciology*, 39-48.

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