ANALYZING THE SHALLOW MARTIAN SUBSURFACE WITH THE WISDOM GPR V.Ciarletti[1], S. Clifford[2], D. Plettemeier[3], N. Mangold[4], E. Petinelli[5], A. Herique[6], W. Kofman[6], E. Heggy[7]
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Introduction: Missions involving a rover provide the opportunity for the detailled characterization of the subsurface by an onboard dedicated GPR. This insight into the environment's third dimension will logically complement the knowledge of the surface provided by the rover's camera.

The WISDOM (Water Ice Subsurface Deposit Observation on Mars) GPR has been designed and selected for the ExoMars rover mission. Its scope is to investigate the Martian near subsurface down to a depth of a few meters (commensurate with the capacity of the rover's 2-m drill) with a vertical resolution of a few centimeters. A prototype representative of the flight model (form/fit/ function) but with non qualified components is undergoing tests and validation. Here we describe the WISDOM instrument with a particular emphasis on the design that has been chosen to meet the challenging technical objectives and constraints of the 2018 ExoMars Rover mission to Mars. Results obtained in natural environments illustrate some of the instrument performance

Scientific objectives: The most fundamental and basic aspect of the geologic characterization of any environment is understanding its stratigraphy and structure – which provides invaluable insights into its origin, the processes and events by which it evolved, and (through the examination of superpositional and cross-cutting relationships) their relative timing. The WISDOM GPR is operated from the surface accommodated on a Rover and can provide an understanding of the 3D geological structure, electromagnetic nature of the subsurface. In this way, WISDOM will address some of the most important science questions about the nature of the landing site, such as its depositional and erosional history, deformational and structural development, and the potential role (and distribution) of liquid water and ice in the hydrologic and periglacial evolution of the local landscape. In addition to these objectives, the ExoMars mission will benefit from WISDOM hability to help identifying the most promising locations for drilling that combine targets of high scientific interest with minimum environmental risk to the drill.

The instrument: WISDOM has the ability to investigate and characterize the nature of the subsurface remotely, providing high-resolution (several cm-scale) data on subsurface stratigraphy, structure, and the magnitude and scale of spatial heterogeneity. To reach such a high spatial resolution, a broad frequency bandwidth is needed and, as a consequence, the instrument must operate at a central frequency which is approximately 100 times higher than the one used by the SHARAD radar (i.e. from 0.3 to 3 GHz). The downside of these higher frequency is the limited penetration that can be achieved into the subsurface. Nevertheless, measurements performed with WISDOM in natural environements have shown penetration down to 3 meters in pyroclatic deposits and in excess of 20 m in very favorable environnements such as ice and snow.

WISDOM is a step frequency radar operating over a wide frequency band between 0.3 and 3 GHz. Particular attention was paid to the design of the antenna system. The very broad frequency bandwidth necessary to achieve the expected vertical resolution was really challenging for the antennas design, especially given the constraints of the mission. Decision was made to have a fully polarimetric antenna system necessary to study depolarization effects. The EMC requirements, as well as pattern deformation due to radiation coupling effects with the Rover structure, led to an antenna design based on a Vivaldi element [2].

The instrument has been designed to comply with the stringent constraints of a mission to Mars in terms of mass, volume, power consumption allocation and planetary protection requirements. The mass allocation for the whole instrument electronics unit (DC/DC converters included), the antenna system and harnesses is less than 1.4 kg. The volume allocation for each polarimetric antenna system has been limited to approx. 20cmX20cmX20cm.(see Figure 1)

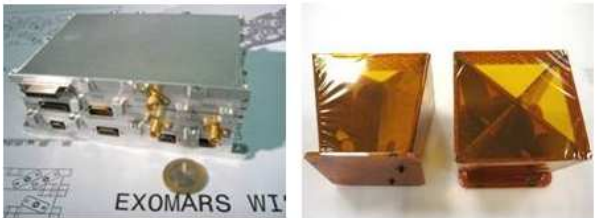

Figure 1 : WISDOM prototype : electronic unit on the left side and antennas on the right side

The fact that the instrument is designed to be mounted on a mars rover calls for antennas accommodated well above the surface (see figure 2).

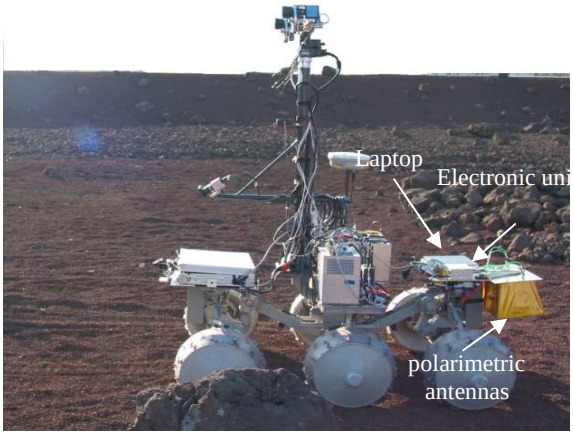

Figure 2 : The WISDOM prototype accommodated on the CNES rover IARES for operational tests performed in the frame of ESTEC-CNES Remote Experiment #2 for ExoMars (Toulouse Novembre 2011) [3].

Instrument performances:

Initial field tests have shown that the observed instrument performance is in agreement with the expected one. The vertical resolution achieved is, as expected, a few centimeters (depending on the actual subsurface properties).

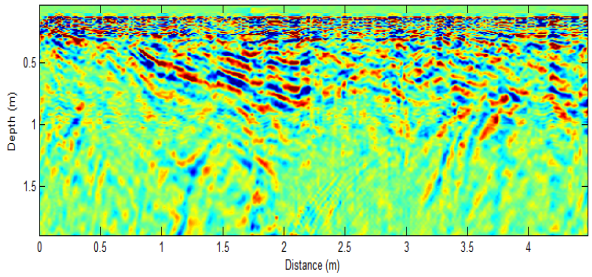

Figure 3 : Example of fine resolution obtained on Mount Etna. The profile shows some superimposed layers of pyroclastic deposits

When the soundings are performed according to a regular grid pattern, it is possible to eventually reconstruct a 3D subsurface structure. Figure 4 shows an example of 3D reconstruction of the very shallow layers detected on the CNES Mars yard in Toulouse [3]. For each profile, the soundings were performed every 10 cm and the profiles were 1 meter apart. The red interfaces correspond to interfaces where the deeper medium has a higher permittivity than the upper one value while the blue interfaces correspond to the reverse situation.

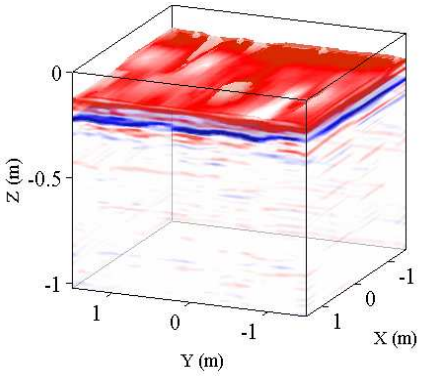

Figure 4 : Example of 3D reconstruction

Preliminary test measurements aiming at assessing the performances of the polarimetric capacities have been performed in an anechoic chamber at the University of Dresden, Germany. The results indicate that polarimetric measurements can provide an estimate of the orientation of cracks or other oriented structures inside the soil. Moreover, co-polar measurements performed on an individual reflector show a noticeable discrepancy (induced by the shape of the antenna's radiation pattern) that can be used to provide an indication of the location of off track reflectors.

Conclusion :

A prototype of a radar to perform polarimetric high resolution soundings of the shallow subsurface of Mars has been developed for the ExoMars mission. WISDOM will provide an understanding of the 3D structure and electromagnetic nature of the shallow subsurface and address the most important questions about the nature of the landing site. WISDOM is a versatile instrument that can readily be accommodated on any rover to be send on Mars

References:

[1] Ciarletti V. et al., (2010), PIEEE, 0023-SIP-2010-PIEEE [2] Plettemeier D. et al., (2009) Radar Conference, Pasadena 4-8 May 2009 [3] Joudrier L. et al, (2012) International Symposium on Artificial Intelligence, Robotics and Automation in Space.

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