PERFORMANCES OF THE WISDOM GPR DESIGNED FOR THE SHALLOW SOUNDING OF MARS.

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Introduction: WISDOM (Water Ice and Subsurface Deposit Observations on Mars) is a Ground Penetrating Radar (GPR) that is one of the panoramic instruments selected to be part of the Pasteur payload onboard the Rover of the ExoMars mission. These Pasteur Panoramic Instruments (the wide angle camera PANCAM, the infrared spectrometer MIMA and WISDOM) will perform large-scale scientific investigations at the sites the Rover will visit. Among these instruments, WISDOM is the only one that can provide information about the subsurface structure prior to drilling.

WISDOM has been designed to characterize the shallow subsurface structure of Mars. It will give access to the geological structure, electromagnetic nature, and, possi-bly, to the hydrological state of the shallow subsurface by retrieving the layering and properties of the buried reflectors. In addition, the data it will provide will be used to determine the most promising locations at which to obtain underground samples with the drilling system mounted on board the rover.

This paper describes the WISDOM instrument particular attention is paid on its antennas design as well as on its operations during the mission. Eventually the first measurements performed with a WISDOM prototype on Earth are presented. They show very promising results to well below 2-meter depth.

The instrument: The instrument objective for WISDOM is to provide information on the sub-surface structure down to a depth of 2 or 3 meters (commensurate to the drill capacities) with a vertical resolution of a few centimetres. The actual penetration depth and resolution will depend on the properties of the subsurface.

Principle of the Radar. WISDOM is a step frequency Ground Penetrating Radar (GPR) operating over a broad frequency range (from 500 MHz to 3 GHz). It is a polarimetric GPR and will provide co-polar as cross polar data that will allow to better characterize oriented structures like faults. The instrument operates in the frequency domain which is a way to obtain a better matching of the receiver to the signal and thus to have a better efficiency. An inverse Fourier Transform is then performed to obtain the impulse response of the subsurface. Hard gating is also implemented that allows to cancelled any direct coupling between transmitting and receiving antennas and also to lessen if desired the amplitude of the surface echo that could otherwise make detection of close weaker echoes difficult.

The antennas. GPR operating from the surface usually take advantage of antennas placed directly on the ground or accommodated in a close-by ground configuration with respect to the wavelength. Considering the requirements for the design of the ExoMars rover a ground clearance of about 30 cm was necessary, the radiation pattern of each single WISDOM antenna element must be directed towards the ground. The WISDOM antennas must also guarantee transmission and reception of the whole signal band width without noticeable distorsion. In addition, since WISDOM is a full polarimetric two-channel GPR, it needs an antenna design with two perpendiculars linear polarized transmitting antennas and two co- and cross-polar oriented antennas for reception. All the requirements together with the radiation coupling effects with the rover structure led to a design based on Vivaldi structures for each single element. To realize the full polarimetric antenna system two perpendicular oriented Vivaldi elements are combined in each of the two dual polarized antennas. The antennas will be covered by a thin dielectric foil to protect the sensitive parts from Martian dust particles. The mass for the whole antenna system is around 400 g. The antennas will be mounted on the back of the Rover pointing downward

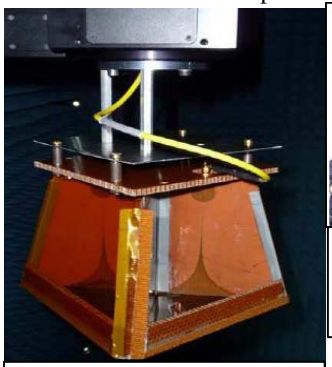

Figure 1: Prototype of one WISDOM polarimetric antenna

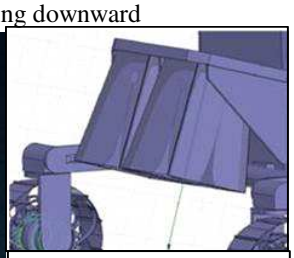

Figure 2:The two antennas accommodated on the Rover

The operating modes. WISDOM objectives during the mission on Mars define the measurement strategy schematically described as follows:

During the Rover traverse between two successive experiment cycles, (drilling and sample analysis) radar soundings are performed along the rover path to provide a survey of the structure and nature of the underground and their variations at a large scale. This information is required to

understand the overall geological context and the properties of the subsurface. Soundings should be performed approximately every 20 m

When a particular location has been selected to eventually drill, WISDOM will be operated on a 2D network in order to obtain a 3D map of the soil characteristics and of their variability (alluvial or eolian layering, shallow ice, etc…) and to improve the characterization (shape, nature, …) of the elements (rocks, boulders, etc…) that are embedded in the soil and might be of interest or pose a problem to the drill. Full polarimetric soundings are performed every 10cm along lines separated by 100cm; the typical exploration grid size is 5m x 5m.

Experimental validation: A first field campaign has been conducted in 2008 on Svalbard . Figure3 shows an exposure of the sub-surface structure in the area where soundings with the prototype were performed.

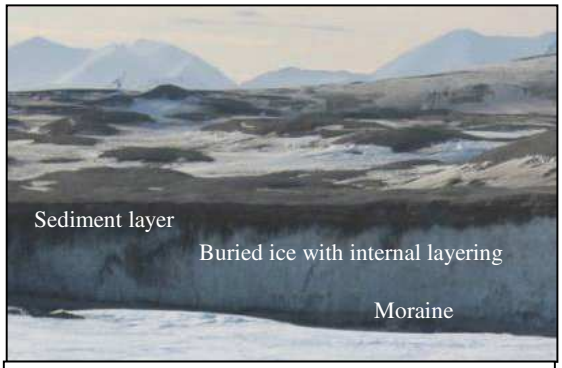

Figure3:Exposed sub-surface structure (a 2m thick sediment layer covering buried ice)

Figure4 shows a 40 meter long profile of raw data that was recorded on the area. The data were sampled every 10 cm along the track.

The interface detected at around 5 ns is the snow/sediment interface. We see that WISDOM can penetrate the first sediment layer and that the sediment/ice interface is clearly seen all along the profile length. Reflecting hyperbolas at the sediment/ice interface allow to retrieve the velocity value in this sediment layer. The estimated value is around 0,125 m/ns which gives a relative permittivity value of approximately 5.5. The thickness of this layer is around 2or3 meters.

At greater depths inside the ice layer, reflections from internal layers inside the sediments are noticeable.

Below the first sediment layer, buried ice with thickness going from almost zero at the begining of the profile to 3 meter at the end can be found. The bottom of the ice is seen all along the track too.

Further below, moraine material with higher conductivity is found. There is no layering inside the moraine and the radar signal is mainly scattered by rocks and other inhomogeneities inside the moraine. Scattering form these rock can be seen down to 1.5 meter into the moraine.

Conclusion: The ExoMars mission objective is to look for traces of past and present life on Mars and to characterise the shallow subsurface. To achieve this, an onboard drill will take up subsurface samples. WISDOM is the only instrument that can sound the sub-surface before drilling and will provide horizontal extrapolation of the characterization made on the samples collected by the drill. Experimental validation on permafrost has shown that the instrument performances are thoses expected.

References: :

[1] V. Ciarletti, et al, The performances of the WISDOM Radar on the ExoMars rover, Vol. 9, 08286, EGU 2007

[2] Hamran, S-E, T. Berger, L. Hanssen, M. J. Øyan, V. Ciarletti, C. Corbel and D. Plettemeier, 2007, "A prototype for the WISDOM GPR on the ExoMars mission" IWAGPR 2007, Naples, Italy.

Acknowledgment:

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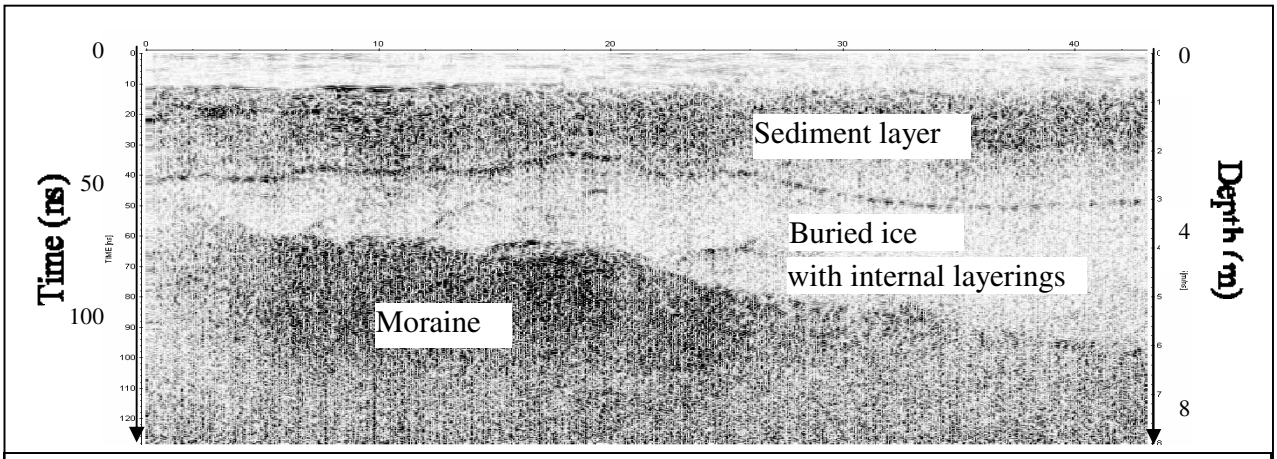

Figure 4 : A radar profile showing penetration through the upper sediment layer, through the glacier ice and down into the moraine materials underneath