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Initial Field and Calibration Tests of the WISDOM GPR for the 2018 ExoMars Mission

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Abstract

The WISDOM (Water Ice Subsurface Deposit Observation on Mars) Ground Penetrating Radar has been selected for inclusion in the payload of the rover for the ESA ExoMars mission (2018) [1]. WISDOM will remotely characterize the shallow subsurface of Mars, providing information essential to understanding the local geological context and the identification of the best locations for obtaining subsurface cores with the rover's onboard drill.

The requirements for the instrument's performance are driven by the objectives of the mission (a vertical resolution of a few cm and a nominal penetration depth of ~3 m). A series of initial field tests and calibrations have been initiated in simple environments to validate the performance of the instrument. Preliminary results show that WISDOM's calibrated data should provide reliable contextual and quantitative information about the nature of the Martian shallow subsurface. The instrument's depth of sounding, vertical resolution and accuracy are consistent with its expected performance.

1. Introduction

The main scientific objectives for the 2018 ExoMars mission are to search for potential traces of past and present life on Mars and to characterize the shallow subsurface. Samples of the subsurface down to a depth of approximately 1.5 meters will be collected by a drill and analyzed by the analytical instruments onboard the rover. Among the instruments that are part of the rover payload, only WISDOM has the ability to investigate and characterize the nature of the subsurface remotely (before drilling), providing high-resolution (a few cm-scale) data on subsurface stratigraphy, structure, and the magnitude and scale of spatial heterogeneity, to depths in excess of 3 m.

WISDOM's operational frequency range and bandwidth (between 0.5 and 3 GHz) were chosen to fulfill these challenging requirements [2]. Particular attention was paid to the design of the antenna system, which needs to transmit, receive and be able to conduct polarimetric measurements over the whole bandwidth without significant distortion [3].

A series of field tests and calibrations have recently been initiated in simple natural environments to validate the instrument's performance and the accuracy of the acquired data. This abstract reports on the first results obtained in the sand at Fontainebleau (located in the Seine-et-Marne, France) with a field instrument that has been constructed to be fully representative of the WISDOM flight model.

2. Field tests

The initial tests performed at Fontainebleau were designed to verify the instrument's performance and provide a better understanding of the experimental accuracy associated with the retrieved depth of a reflector and derived subsurface geoelectrical properties. This site was chosen because the sand here provides a reasonably homogeneous environment where calibration targets can easily be buried.

Figure 1: Experimental set up used for the tests in Fontainebleau.

In addition, the presence of several large (tens of meters) partially buried outcrops, embedded in the sand, provided well-defined interfaces between the sand and rock.

2.1 Measurements

WISDOM is a step frequency radar that operates in the frequency domain. The synthetic response in the time domain is obtained by Fourier transform performed on the raw data. In the time domain, the echoes are then detected and characterized by their propagation delay and amplitude. The measured delays depend on the distance of the reflecting interfaces and on the permittivity value of the subsurface materials (which are both unknown), while the received amplitudes depend on even more parameters: the radar characteristics, the geometrical properties of the reflecting interfaces (size, shape, orientation, roughness), the permittivity contrast with the surrounding medium and the propagation losses.

A series of specific measurements performed on appropriate configurations (for example, with a cable connecting the transmitter to the receiver or with the antennas looking upwards at the sky or downwards at a metallic plate) provide references that are then used to get calibrated data for both delays and amplitudes.

Profiles along the rover path are obtained by conducting a series of successive soundings, while 3D mapping of the subsurface can be achieved by having the rover follow a grid pattern.

2.2 Results

The simple environment in Fontainebleau allowed us to get some preliminary but interesting results whose accuracy has been verified by comparisons with simple theoretical calculations. The good agreement between experiment and theory is encouraging and provides some confidence in conducting field experiments in more complex environments.

The data show that, for a smooth and well defined interface, within an homogeneous medium having a permittivity of 4, a vertical resolution of ~3 cm is readily achievable, which is consistent with expectations.

Given the fact that the accuracy of a determination of a reflector's depth depends almost entirely on the accuracy of the permittivity value estimated for the soil, getting a reliable estimate of the subsurface permittivity value is essential. We have tested several different methods to get an estimate of this permittivity value which we have then applied to our analysis of the data. This comparison has shown that, to get the best estimate from these simple models, the method must be tailored to reflect the kind of environment the radar is operated in.

These initial tests have also confirmed the fact that the shape and amplitude of the returned surface echo can provide quantitative information regarding surface roughness.

The tests also showed that the direct coupling between the transmitting and receiving antennas is independent of the environment; this information will be used on Mars to monitor and correct any potential drift in either echo delay or amplitude during the mission.

3. Summary

The field tests conducted at Fontainebleau demonstrate that WISDOM's experimental performance meets or exceeds original estimates. This was the first in a seven year program of field tests that will investigate the performance of WISDOM in a series of progressively more complex and diverse Mars analogue terrains.

Acknowledgements

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References

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