WISDOM/EXOMARS 2020: A CALIBRATED AND FULLY CHARACTERIZED GROUND PENETRATING RADAR READY TO SOUND THE MARTIAN SUBSURFACE.
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Introduction: In 2021, the second part of the ExoMars mission (Rover and surface platform) will land on Oxia Planum, which has been selected because it is an old Noachian terrain that shows evidence of aqueous episodes [1]. The mission's main objectives are to search for possible bio-signatures of past Martian life, to characterize the water and geochemical distribution as a function of depth in the shallow subsurface and to investigate the planet's subsurface in order to better understand the evolution and habitability of Mars. To reach these objectives, the ExoMars Rover is equipped with a drill able to collect samples at depth down to 2 m, that will be analyzed inside the Rover body.

WISDOM (Water Ice Subsurface Deposits Observation on Mars) is the polarimetric ground penetrating radar that will be accommodated on the Rover of the ExoMars mission [2],[3]. In accordance with the mission's objectives, the main goal of the instrument is to reveal the geological context and evolution of the landing site. WISDOM observations will be used to select the best places to collect samples in the subsurface. They will also guide the drill in order to avoid hazardous area.

In this paper, we will present a selection of the measurements that have been performed on the Flight Model (FM) of the instrument to check its performances and obtain reference data that will be used once on Mars to produce calibrated data.

Characterization of the Flight Model: WISDOM is a step-frequency radar, which operates from 500 MHz to 3 GHz. It is able to probe down to a depth of few meters with a vertical resolution of a few centimeters. WISDOM is composed of two elements, an Electronic Unit (EU) located inside the Rover body (Figure 1) and an Antenna Assembly (AA) accommodated at the rear of the Rover (Figure 2). The Flight Model (FM) of the instrument was delivered in January 2019 at Airbus premises in Stevenage for integration in the mission Rover.

In order to produce data calibrated both in time and amplitude, it is essential to characterize as much as possible the instrument that will land on Mars. Here we report a suite of measurements in controlled environments that have been performed before the instrument's delivery.

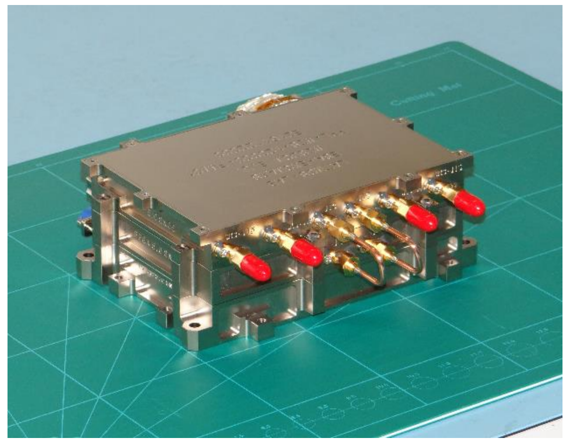

Figure 1 : WISDOM FM Electronic Unit

Figure 2 : WISDOM FM Antenna Assembly

Effect of temperature. The EU has to be able to operate at temperature ranging between -55°C and +55°C. The Thermal Vacuum environmental tests performed on the EU at the PIT (Plateforme d'Integration et Tests of OVSQ, Guyancourt, France) facilities provided the opportunity to quantify the effect of the temperature in low-pressure (~6 mbar) Martian conditions. The measurements show a linear decrease of the transmitted power with the temperature measured on the Radio Frequency board. We determine a power loss of about 0.05 dB per degree Celsius. The corresponding correction will be applied automatically in the WISDOM data processing pipeline in order to remove the effect of the temperature.

Antenna crosstalk and internal coupling. Measurements performed with both the EU and the AA in free space (i.e., without any obstacle closer than 3 m from the AA) have provided an accurate characterization of the direct coupling between the transmitting and receiving antennas (waveform), as well as of the internal coupling (i.e., inside the EU) ; these couplings will have to be removed from the data collected on Mars.

Amplitude calibration – link budget. Based on complementary measurements performed with a network analyzer, the transfer function necessary to convert WISDOM data into physical units (i.e., the received power in dBm) has been established. We also verify that, in case of a simple target (such as a large metallic plate) the received power is consistent with the characteristics of each element of the radar and settings (antennas' gain and radiation pattern, attenuations in the transmitting chain and in the cables). The achieved link budget enables us to validate the characterization of the instrument and to be confident that quantitative analysis of the data collected on Mars will be possible. In fact, we show in [4] that the calibrated amplitude of the surface echo can be used to estimate the subsurface permittivity value and thus to convert the time of arrival of the detected echoes into distance.

Impact of the rover structure Preliminary tests have been performed at Airbus, Stevenage (UK) with a rover named Charlie, which is also the rover used for the ExoFit trial [4]. This rover is not exactly similar to the Rosalind Franklin ExoMars rover but has the very same wheels. The impact of the rover's structure and in particular of its wheels on WISDOM data is not negligible and has been carefully analyzed. This analysis shows that the Rover impact must be taken into account when processing the data acquired on Mars which urges us to perform the same characterization with the actual Rosalind Franklin rover.

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References: [1] Vago et al. (2017), Astrobiology 17, 471–510. [2] Ciarletti et al. (2011), Proceedings of the IEEE, vol. 99, no. 99, 1-13. [3] Ciarletti et al. (2017), Astrobiogy 17 (6-7), 565-584. [4] Le Gall et al. (2019), this conference.