Improvement of the MARSIS On-Board SW, on the Mars Express Mission. Preliminary scientific results on Phobos and Mars.

A. Cicchetti[1], C. Nenna[1], M. Cartacci[1], R. Noschese[1], R. Orosei[2]

[1] Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, Rome, Italy
[2] Istituto di Radioastronomia, Istituto Nazionale di Astrofisica, Bologna, Italy

Introduction

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) is a powerful instrument for subsurface remote sensing of the Mars planet. Since the beginning of operations, about fifteen year ago, many successful observations have been carried out, in particular for the study of Mars South and North Polar Layered Deposits (PLD).

At this point of this fruitful mission, having acquired a good knowledge of the Mars environment, it was decided to improve the instrument science performances, mitigating some instrument technical limitations, that were required at the beginning of the mission, but which were proven to be excessive and, above all, limiting.

The new on-board Software is now operative on the instrument and almost fully commissioned. Recently, it allowed to see beneath the surfaces of Mars and its moon Phobos in more detail than ever before.

Upgrade description

The new on-board SW includes a series of upgrades that improve signal reception and on-board data processing, to increase the amount and quality of science data sent to Earth.

Two new Operative Modes have been added to the ones already in use. The first one is **SSM**, it is related exclusively to the observation of Mars. It is similar to the existing main dual-channel subsurface mode SS3. The processing for the first operative channel will remain unchanged, while, on the second one, a dedicated new processing algorithms, have been developed in order to extract, from the received echoes just the samples containing with a relevant science information and discarding the remaining ones, that contain only noise.

The new second operative mode **SSP**, is designed mainly to optimize the observation of Phobos, however it can also be used on Mars, over small science targets of particular interest. Thanks to SSP, it is now possible to collect a large segment of raw unprocessed data, about 134 seconds, compared to the previous nominal segment of 24 seconds; SSP will also optimize adaptively the Receiver Gain during the flyby, thereby improving the dynamic range of the receiving channel used for recording the raw Science Data.

At the same time, data rate on the SC OBDH bus, will be strongly reduced, allowing MARSIS, PFS and SPICAM to operate simultaneously. This software upgrade is a major change, practically transforming MARSIS in a brand new instrument on board Mars Express, almost 20 years after its launch.

Improved Phobos Observations

The latest Phobos flyby (23/September/2022) offered the opportunity to test the performance of the MARIS SW upgrade.

The MARSIS instrument was originally designed to observe exclusively Mars. As a result, it was designed for use at the typical distance between the spacecraft and the planet's surface – more than 250 km.

The new SW upgrade allows MARSIS to be used at much closer distances (the minimum detectable range is now set at 40km). During this flyby, we used MARSIS to study Phobos from as close as 82 km. Being so close to Phobos allows to study its structure in more detail and identify important features that could not be detected from further away.

Thanks to the predicted Mars Express orbit geometry, in the next years [2023 : 2025], MARSIS will be able to observe Phobos even closer, at distances below 50km, providing new opportunities to study this unique celestial body, and contributing to solving the mystery surrounding Phobos' origin.

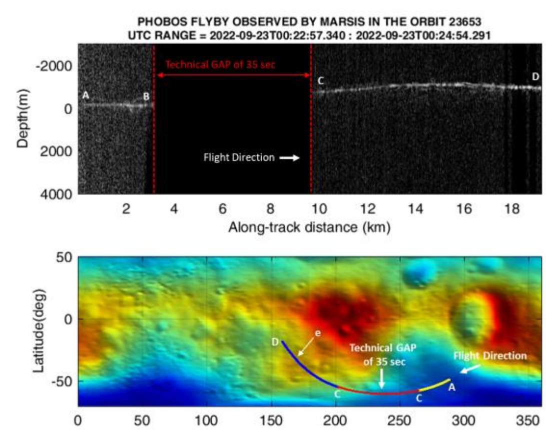

Fig. 1: Phobos observed by MARSIS with its new operative mode SSP

Figure 1 shows the 'radargram' acquired by MARSIS during the flyby. A radargram reveals the echoes produced when the radar signal emitted by MARSIS bounces off something and returns to the instrument. The brighter the signal, the more powerful the echo.

The continuous bright line shows the echo from the moon's surface. The lower reflections are either 'clutter' caused by features on the moon's surface, or, more interestingly, signs of possible structural features below the surface.

Section A-B was recorded using the older configuration of the MARSIS software. The new configuration was prepared during the 'technical gap' and successfully used for the very first time from C-D.

The bottom panel shows the path of the observation, across the Phobos surface.

Simulation of the Phobos flyby

This Phobos flyby was also important, due to the presence of weak secondary echoes which could have been generated by discontinuities in the subsurface (cavities, layers of different materials, etc.) or by surface lateral clutter.

Isolating the echoes reflected by off-nadir surface, that could arrive at the radar antenna at the same time as subsurface nadir echoes and comparing them with the simulated echoes, from the surface return using Digital Terrain Model, it is possible to solve this ambiguity.

Figure 2 shows the comparison between the simulation results, with the real data acquired by the radar. The comparison is made difficult by the low power level of the echoes, often comparable with the noise power of the receiver, the study is still on-going.

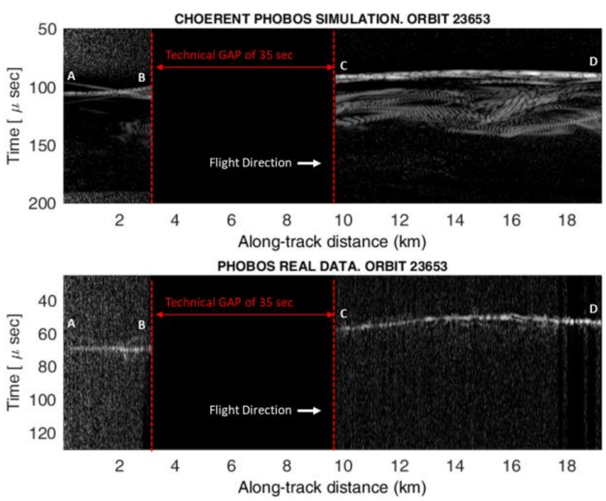

Fig. 2: Phobos Comparison between Simulated and Real Data

Improved Mars Observation in SSP mode

Several observations have been planned, on Mars areas of high scientific interest and when the spacecraft was on the night side of Mars, to minimize ionospheric distorsion of the signals. Figure 3 shows an example of a MARSIS radargram collected with the new Science Operative Mode (SSP), in the orbit 22795 (geen path across the surface). Figure 3 also shows an old fly-by on the same area, in the orbit 21886 (white path across the surface); the improvement with the new SW is evident.

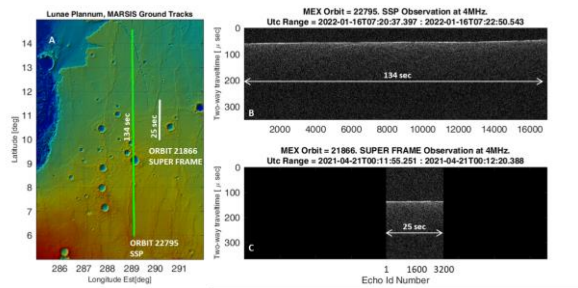

Fig. 3: Mars Data Comparison

References

[1] Safaeinili, A. et al (2007) First International Conference on the Exploration of Phobos and Deimos, LPI Contribution No. 1.

[2] Plettemeier, Dirk; Hahnel, Ronny; Hegler, Sebastian; Safaeinili, Ali; Plaut, Jeff; Gaskell, Bob; Orosei, Roberto; Cicchetti, Andrea; Picardi, Giovanni, Numerical computation of radar echoes measured by MARSIS during Phobos flybys, Radar Conference, 2009 IEEE , vol., no., pp.1-6, 4-8 May 2009.

[3] Cicchetti, A., Cartacci, M., Gim, Y. et al., 2011. MARSIS: Latest Phobos Flyby. Data Processing Results and Advanced Radar Configuration Design. EPSC-DPS Joint Meeting 2011 497.

[4]. A. Cicchetti, et al., Observations of Phobos by the Mars Express radar MARSIS: Description of the detection techniques and preliminary results. Adv. Space Res. 60, 2289-2302 (2017).

[5]. Orosei, R. et al. Radar evidence of subglacial liquid water on Mars. Science 361, 490–493 (2018).