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A study of Mars' rotation measurements using four-way Doppler and inverse VLBI methods

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Abstract

We plan to observe the multi-landers on the Mars using the four-way Doppler measurements relayed by an orbiter to observe Mars' rotation as a mission candidate of MELOS (Mars Exploration with Lander-Orbiter Synergy). We also introduce the new technology called inverse VLBI.

1. Introduction

Variation of planetary rotation provides us information concerning both the interior structure and the surface mass redistribution. Such information is valuable for elucidating not only present condition but also evolution of a planet as a system. Precession and nutation of Mars reflect the present status of the core-mantle sub-system, besides length-of-day variation and polar motion of Mars are induced by variation of the atmosphere-cryosphere sub-system.

Two-way tracking of orbiters on Mars were executed to elucidate the physics of Mars. Precession and length-of-day variation have been measured by means of tracking data of Viking 1 and 2 [1], and Mars Pathfinder [2]. To achieve the accuracies in the order of 1 mas (milli-arc second) to detect Mars' rotation variation, orbiter-to-lander tracking were proposed for NetLander [3] and ExoMars [4].

A Japanese research group has recently started to plan a new Martian explorer; MELOS (Mars Exploration with Lander-Orbiter Synergy). As one of the missions of MELOS, we are proposing areodetic observations using space geodetic techniques such as four-way Doppler measurements and inverse VLBI. By measuring Mars' rotation with higher accuracy, we will be able to determine the state of the core (liquid or solid) more clearly, estimate its radius if it is liquid, and figure out the quantities of seasonal surface mass redistribution.

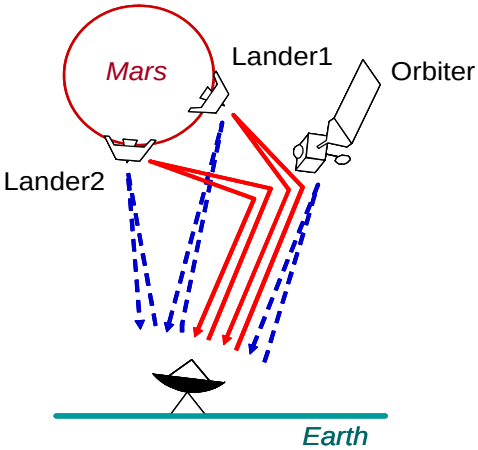

Figure 1: A mission concept of Mars' rotation observations by four-way Doppler measurements proposed for MELOS. Solid (red) and dashed (blue) lines indicate the links for 4-way Doppler measurements, and 2-way ranging and ranging rate, respectively.

2. Four-way Doppler measurements

Four-way Doppler measurements (FWDP) are ranging rate measurements of target spacecraft via relay spacecraft. Utilizing the heritage of RSAT by SELENE, we plan to track the multi-landers of MELOS relayed by the MELOS Orbiter. Figure 1 shows a configuration of Mars' rotation observations by four-way Doppler measurements proposed for MELOS. The number and the distributions of landers are tentative. The carrier links of the four-way communication are relayed as solid (red) lines; starting from a ground station to the orbiter, to the landers, back to the orbiter, and finally back to the ground station. Two-way ranging and ranging rate (RARR) measurements for each spacecraft are

executed simultaneously with the links indicated as dashed (blue) lines in Figure 1. The expected accuracies for these observations are almost in the same order as that in the case of orbiter-to-lander tracking [5].

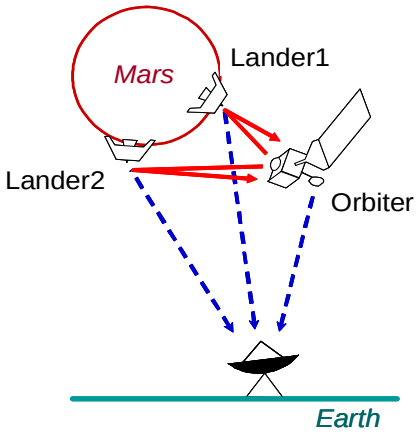

Figure 2: A mission concept of Mars rotation observations by inverse VLBI proposed for MELOS. Solid (red), and dashed (blue) lines indicate the links for the phase-shift measurements from Orbiter to Landers, and spacecraft to the ground station, respectively.

3. Inverse VLBI

We also introduce a new technology called inverse VLBI [5]. One ground radio telescope, not a VLBI network, observes both the orbiter and the landers with same-beam or switching of the antenna. Figure 2 indicates the configuration of Mars' rotation observations by inverse VLBI proposed for MELOS. Solid (red), and dashed (blue) lines indicate the links for the phase-shift measurements from Orbiter to Landers, and spacecraft to the ground station, respectively. In the case shown here, the signals from the landers are coherently locked with those of the orbiter, and phase differences between the two spacecraft are also measured at the orbiter. The functions of the orbiter and the landers may be exchanged depending on the limits of resources including mass and electric power of each spacecraft, although, the precisions of the measurements are independent of such configuration changes.

4. Summary

We propose the precise observations of Mars' rotation by using the four-way Doppler measurements and inverse VLBI for the Japanese future exploration for Mars; MELOS (Mars Exploration with Lander-Orbiter Synergy). Tracking of the mars landers by four-way Doppler measurements (FWDP) are executed by the carrier links starting from a ground station to an orbiter, to one lander, back to the orbiter, and finally to the ground station. Inverse VLBI (IVLBI) will measure the difference in the two ranges between the landers and the ground station, from which information of Mars' rotation will be extract. The expected accuracy for the rotation is estimated as less than 1 mas including the systematic phase noise.

References

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