RADAR PAYLOADS ONBOARD CHINESE LUNAR AND MARTIAN PROBES

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Introduction: China's lunar and deep space exploration is steadily being carried out. The lunar program incorporates lunar orbiters, landers, rovers and sample return spacecraft. China has proceeded Chang'e-1 (CE-1), Chang'e-2 (CE-2) and Chang'-3 (CE-3) successfully. Chang'e-4 (CE-4), which includes a lander, rover and a relay, will be launched in 2018 and Chang'e-5 (CE-5) is expected in 2019.

China is also planning Mars project to place an orbiter, lander and rover on Mars. The mission is scheduled in 2020.

Radar is an attractive and powerful technique. Radar mapping of the Moon's topography was firstly done by the Arecibo telescope at a wave- length of 70 cm in 1964 [1]. In 1972, the Apollo Lunar Sounder Experiment (ALSE) was the subsurface sounder experiment that flew on the Apollo 17 mission to study the Moon's surface and interior. The Lunar Radar Sounder (LRS) onboard the Japanese KAGUYA spacecraft (SELENE) found that most nearside Maria has subsurface stratifications [2]. Moreover, the Lunar Penetrating Radar (LPR) onboard the CE-3 Yutu Rover probed the lunar regolith layer and the underlying basalt units [3], which was the first ground penetrating radar mounted on the lunar surface. In the past 12 years, the Martian subsurface and Polar Caps have been probed by the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on Mars Express [4] and the Shallow Subsurface Radar (SHARAD) on Mars Reconnaissance Obiter [5].

Chang'e-4 LPR: CE-4 is composed of a lander, a rover and a relay. The lander will be soft-landed on the far side of the moon and the relay will be placed in an orbit around the Earth-Moon L2 point.

The LPR is a scientific payload on board the rover. It is completely same with CE-3 LPR instrument. CE-4 LPR works at two channels of dual frequencies of 60 MHz and 500 MHz. At these two frequencies, it can probe the structure and depth of lunar regolith within 30m, and investigate the structure of lunar crust to hundreds of meters deep. The free space range resolutions are ~ 50cm and ~ 25m for 60 MHz and 500 MHz respectively. The LPR uses one transmitting and one receiving dipole antenna for 60 MHz, which are installed at the back of the rover. For the 500 MHz system, one transmitting and two bow-tie receiving antennas are attached to the bottom of the rover, as shown in Fig. 1.

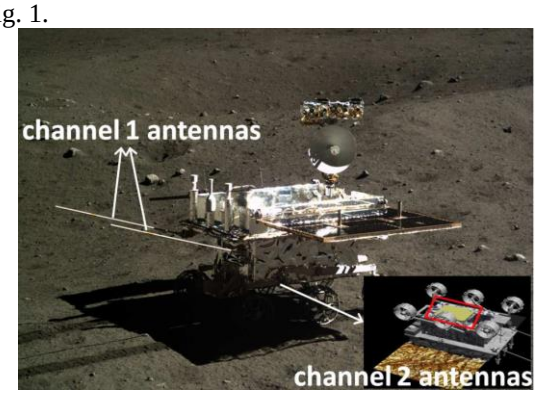

Fig.1 Illustration of the two radar channels on the LPR.

Chang'e-5 LRPR: The LRPR (Lunar Regolith Penetrating Radar) is a scientific payload on board CE-5 lander. The center frequency is 2GHz, and it is used to measure the structure of lunar regolith in the landing site around the drill. The LRPR consists of 12 bow-tie antennas. Ten antenna elements are in a line, while the other two are outside the line. The antenna element spacing is 12 cm. The mounting position arrangements of the antenna elements are shown in Fig. 2.

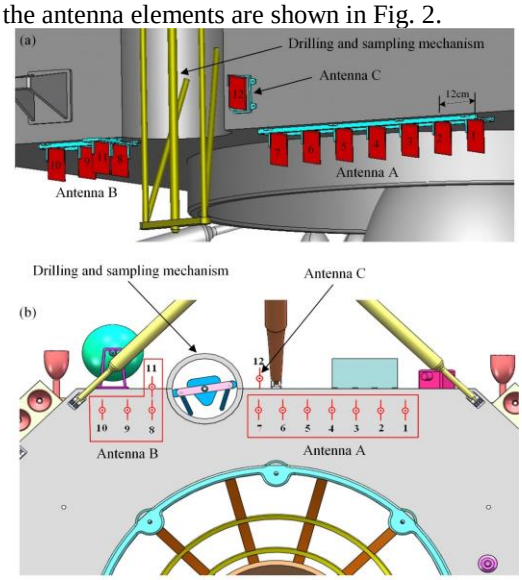

Fig.2 The arrangement of the LRPR antennas on the CE-5 lander.

The detection depth is assumed to be over 2 m and the range resolution better than 5cm. The ground tests have been done to evaluate the performance of the

LRPR, shown in Fig. 3. The interference caused by the metal bottom of the CE-5 lander is very serious. Some methods such as data processing and orbit calibration have been considered to reduce the impact.

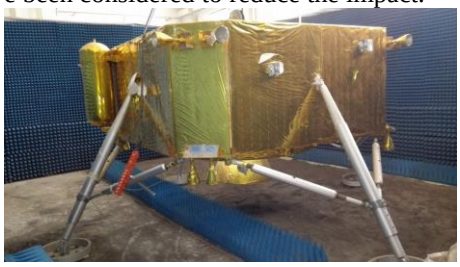

Fig.3 The ground tests of the LRPR.

Mars-1 MOSSR and RBMSPR: There are two radar scientific payloads onboard the Mars rover and the Mars orbiter respectively.

Mars orbiter subsurface sounder radar (MOSSR) works at dual frequencies of 15MHz and 40MHz. Two 10m tip to tip dipoles are designed to distinguish water ice and CO_2 ice by two crossed linear polarization. MOSSR will operate at highly elliptical orbit with the altitude from 250km to 800km that is very similar with MARSIS. The subsurface sounder can operate at one band or one linear polarization. Some digital processing could be done either on board to reduce the data rate or on ground to guarantee the data qualities.

Rover-Based Martian Subsurface Penetrating Radar (RBMSPR) works at the frequencies of 55MHz and 1300MHz. For the high frequency channel, the full polarizations including HH, HV, VH, VV are applied to determine the properties of targets and search for the existence of water ice underneath the surface. One polarization HH is used for the low frequency channel.

The calibrations and ground tests are in the process of design.

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