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In-orbit Performance of Chang'e-4 Low Frequency Radio Spectrometer

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Abstract

The farside of the moon provides a unique radio-quite region for radio astronomy observations. It is shielded from terrestrial radio frequency interference and has a very thin ionosphere[1]. On 3 January 2019, Chinese Chang'e-4 (CE-4) lander touched down on the floor of Von Kármán crater, becoming the first spacecraft to land on the farside of the moon. A Low Frequency Radio Spectrometer (LFRS) is equipped on board the lander. It aims to observe the radio emission of solar and is regarded as a pathfinder mission for future space-based low frequency radio interferometer. A brief background noise mitigation method is introduced here.

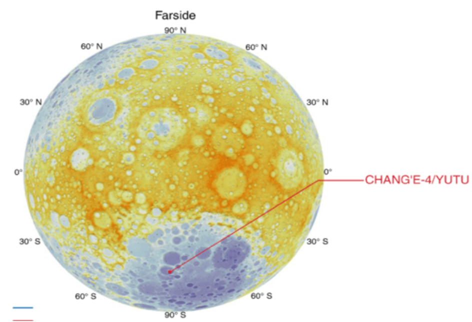

Figure 1: The Chang'e-4 landing location.

1. Introduction

Chinese Chang'e-4 (CE-4) mission is consist of a relay satellite placed at the Earth-Moon L2 point, a lander and a rover. CE-4 landed on the eastern floor of Von Kármán crater at 45.4446°S, 177.5991°E within South Pole-Aitken basin(Fig.1) [2]. On board the lander, a Low Frequency Radio Spectrometer (LFRS) will virtually unveiled low frequency domain below ~ 30MHz. Solar activities are expected to be observed, and emission from Jupiter and Saturn is possible. In addition, LFRS could provide the RFI and noise conditions at the farside location, a method for instrument calibration, and RFI/noise mitigation has been developed.

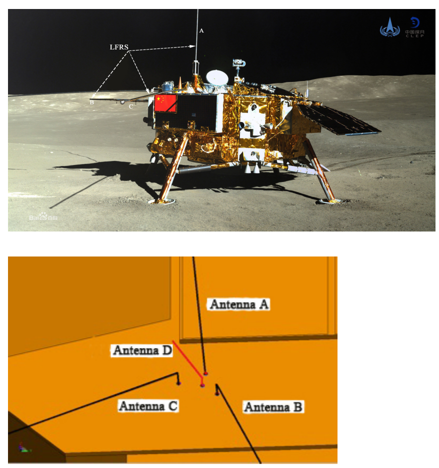

Figure 2: The lander image taken by panoramic camera on board the Yutu-2 rover (top) and diagram of Antenna A/B/C/D distribution(bottom).

2. Design of LFRS instrument

Three orthogonal 5m long dipole antennas are employed denoted as A, B and C.(Fig.2). During the EMC tests, the noise background of lander platform is extremely high. Thus it is a critical problem to migrate the background noise from received signals. A short antenna D was designed with a length of 20cm. The antenna D was mounted between the antenna A and the antenna C base, parallel to the lander wall, and the height was 40mm(Fig.2). As a result four channels receivers could receive signals simultaneously. The specifications are listed in the table 1.

Table 1: Specific parameters of LFRS

Items	Parameters
Working frequency	100kHz – 2MHz & 1MHz-40MHz
Receiver sensitivity	≤10 $\mathbf{nV/\sqrt{Hz}}$
Dynamic range	≥75dB
Frequency resolution	≤10KHz （100KHz~1.0MHz） ≤200KHz （1.0MHz~40MHz）
Maximum data rate	5Mbps
Power consumption	≤24 W
Clock precision	10^{-11}(S) and 10^{-9}(day)

3. Data processing

Because the short antenna D is close to the lander, it mainly receives the noise signal produced by the electronic equipment of the lander. The background noise is stable without working mode modification of the lander. The background noise could be reduced effectively by subtracting the signal of antenna D from signals of antenna A, B and C as followed equations.

$$V_{SA}(f) = V_A(f) - P_A(f) \cdot V_D(f) \quad (1)$$

$$V_{SB}(f) = V_B(f) - P_B(f) \cdot V_D(f) \quad (2)$$

$$V_{SC}(f) = V_C(f) - P_C(f) \cdot V_D(f) \quad (3)$$

$$P_A(f) = {U_A(f)}/{U_D(f)} \quad (4)$$

$$P_B(f) = {U_B(f)}/{U_D(f)} \quad (5)$$

$$P_C(f) = {U_C(f)}/{U_D(f)} \quad (6)$$

V_{SA}, V_{SB} and V_{SC} are the observed object signal by antenna A, B and C respectively, while V_A, V_B and V_C the received signal from both of the observed object and background noise of the lander. P_A, P_B and P_C dedicate the gain factors between antenna A/B/C and D. V_D is the background noise of the lander received by antenna D.

4. On orbit observations

LFRS started to observe on Jan 5, 2019. It has been working for the fourth lunar day. Because of interference, it has to work separately with the Lunar Penetrating Radar on board the rover. From Figure 3, the background noise could be reduced by ~15dB after mitigation.

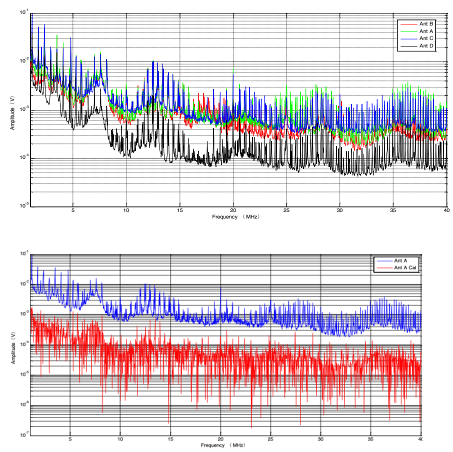

Figure3: Received signals by Antenna A/B/C/D (top) and Data processing after background noise mitigation (bottom).

Acknowledgements

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References

[1] David M.,Mark A. W., et al. Farside explorer: unique science from a mission to the farside of the moon, Exp Astron 33, pp. 529-585, 2012

[2] Wu, W.R., Li C.L., et al. Lunar farside to be explored by Chang'e-4. Nature Geoscience 12, pp. 222-223, 2019