EPSC Abstracts
Vol. 11, EPSC2017-933, 2017
European Planetary Science Congress 2017

Radio science electron density profiles of lunar ionosphere based on the service module of circumlunar return and re-entry spacecraft

M. Wang (1), S. Han (2), J. Ping (1), G. Tang (2) and Q. Zhang (2)
(1) National Astronomical Observatories, Chinese Academy of Sciences, Beijng, China, (2) National Key Laboratory of Science and Technology on Aerospace Flight Dynamics, Beijng, China (wangmy@nao.cas.cn)

Abstract

The existence of lunar ionosphere has been under debate for a long time. Radio occultation experiments had been performed by both Luna 19/22 and SELENE missions and electron column density of lunar ionosphere was provided. The Apollo 14 mission also acquired the electron density with in situ measurements. But the results of these missions don't well-matched. In order to explore the lunar ionosphere, radio occultation with the service module of Chinese circumlunar return and reentry spacecraft has been performing. One coherent S-band and X-band radio signals were recorded by China deep space stations, and local correlation was adopted to compute carrier phases of both signals. Based on the above work, the electron density profiles of lunar ionosphere was obtained and analyzed.

1. Introduction

Since 1960s, radio occultation has been used in planet exploration to detect vertical changing of temperature, pressure and electron density of atmosphere and ionosphere. In 1966, the radio occultation experiment of Pioneer-7 proved the existence of Lunar ionosphere which is very thin (electron density is about $4*10^4$ el/cm^3)[8]. In Apollo 14 mission, the electron density detected by the Charged Particle Lunar Environment Experiment (CPLEE) was 10^4 el/cm^3 at several hundred meters high during lunar day time. In Luna-19 & 22 mission, the electron density profiles were detect and the peak densities were about 10^3 el/cm^3 [10]. In the last decade, European mission SMART-1 and Japanese mission SELENE also performed radio occultation experiment for Lunar ionosphere[1,6,7].

The circumlunar return and reentry spacecraft is a Chinese precursor mission for the Chinese lunar sample return mission. After the status analysis of the spaceborne microwave communication system, we confirmed that the frequency source of the VLBI beacon in X-band and the signal in S-band is provided by the same frequency source onboard the satellite and its short-term stability is n*10-9. Compared to the frequency source onboard SELENE whose short-term stability is n*10-7 [6], the service module provides a stable and reliable signal source for dual frequency radio occultation.

China deep space network measurement center has organized a series of radio occultation experiments which performed by Jiamusi and Kashi deep space station.

2. Radio experiment of the service module of the circumlunar return and reentry spacecraft

With the radio occultation technique, electromagnetic waves are transmitted from the spacecrafts to the Earth, passing through the atmosphere (either during a rise event or a set event as seen from the receiver), are refracted at an angle that is determined by the refractivity gradients along the path. The refractivity variation depends on the gradients of air density, water vapour and electron density (in this case, only electron density counts).

As seen in Fig. 1, the signal transmitted from the spacecraft in S and X band passed through Luanr ionosphere, interplanetary plasma, Earth ionosphere and atmosphere, finally received by the station. A hydrogen maser in the receiving station is used as the frequency reference source for open-loop radio experiments.

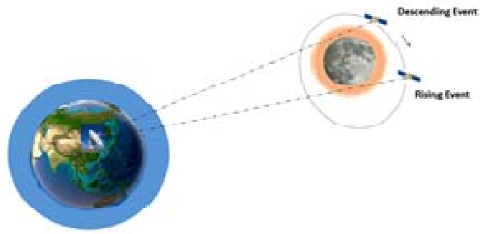

Fig. 1. The illustration of the service module of the circumlunar return and reentry spacecraft radio occultation experiment.

The signals transmitted from the spacecraft in S and X band passed through lunar ionosphere, interplanetary plasma, Earth ionosphere and atmosphere, finally received by the ground tracking stations. According to the coherent ratio of the S/X signal, we convert the phase information of S-band signal to the frequency of X-band signal and calculate the difference of these two signal. Then, the extrapolation algorithm was used here to deduct the interference error of the earth ionosphere and the interplanetary plasma. Based on the above work, the electron density profiles of lunar ionosphere was explored.

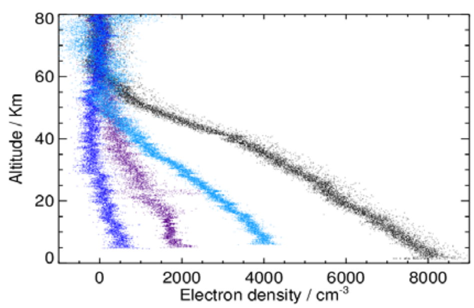

Fig2. The electron density profiles based on Radio experiment of the service module of the circumlunar return and reentry spacecraft.

The maximums of electron column concentrations are between 0.4~0.5×10^{16} el/m^2, are two times of the maximum result from Luna 19/22, are 1~2 orders higher than the SELENE result, but well-matched with the result from CPLEE. These results show that the lunar ionosphere is clearly exist and much stronger than we expected. The result here gives a positive support and some dynamical constrains for the scientific objective of the very low frequency radio astronomical payload onboard the Chang'E-4 lander mission. But it also raises a new question that the characteristics and formation mechanism of a stronger lunar ionosphere is remain unknown. More observations will be performed for further scientific targets.

Acknowledgements

This work was supported in by the NSFC No.41590851.

References

[1] Y. Goto, T. Fujimoto, Y. Kasahara, A. Kumamoto, T. Ono, "Lunar ionosphere exploration method using auroral kilometric radiation," Earth Planets & Space, vol 63, pp. 47-56, 2011.

[2] T.J. Stubbs, D.A. Glenar, W.M. Farrell, et al., "On the role of dust in the lunar ionosphere," Planetary & Space Science, vol. 59, pp. 1659-1664, 2011.

[3] W.D. Daily, W.A. Barker, M. Clark, et al., "Ionosphere and atmosphere of the moon in the geomagnetic tail," Journal of Geophysical Research, vol. 82, pp. 5441-5451, 1977.

[4] J.S. Ping, Y.D. Huang, M.Y. Wang, et al., "The possibility of detection of Mars ionosphere by radio occultation (in Chinese)," Deep Space Exploration, vol. 2, pp. 18-25, 2007.

[5] M.J. Wu, P. Guo, X.G. Hu, et al., "Research on error analysis of ionosphere detection by radio occultation (in Chinese)". Annual publication of Shanghai Astronomical Observatory, Chinese Academy of Sciences, vol. 1, pp. 99-111, 2014.

[6] T. Imamura, K.I. Oyama, T. Iwata, Y. Kono, K. Matsumoto, Q. Liu, et al., "The possibility of studying the lunar ionosphere with the SELENE radio science experiment," Earth Planets Space, vol. 60, pp. 387-390, 2008.

[7] T. Imamura, T. Iwata, Z.I. Yamamoto, N. Mochizuki, Y. Kono, K. Matsumoto, et al., "Studying the lunar ionosphere with selene radio science experiment," Space Science Reviews, vol. 154, pp. 305-316, 2010.

[8] S. Pluchino, F. Schillirò, E. Salerno, G. Pupillo, G. Maccaferri, P. Cassaro, "Radio occultation measurements of the lunar ionosphere," Memorie Della Società Astronomica Italiana Supplement, vol. 12, pp. 53, 2008.

[9] A.S. Vyshlov, "Preliminary results of circumlunar plasma research by the Luna 22 spacecraft," Space Res, vol. 01, pp. 945-949, 1976.