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Observation of the lunar ionosphere by the dual-spacecraft technique in SELENE and theoretical considerations

Hiroki Ando[1*], Takeshi Imamura[2], Takahiro Iwata[2], Koji Matsumoto[3], Hirotomo Noda[3], Hideo Hanada[3], Koichiro Oyama[4], Akinori Saito[5]

[1]The university of Tokyo, [2]ISAS/JAXA, [3]NAOJ, [4]National Cheng Kung University, [5]Kyoto University

Observations of the bending near the moon of radio waves emitted from the radio star in the 1960s and radio occultation experiments performed in the Luna missions of Russia in the 1970s indicated the existence of the lunar ionosphere on the sunlit side with electron densities of the order of 100 cm^{-3}. On the other hand, theoretically the lunar ionosphere is thought to have densities on the order of 1 $cm^{-3}$when we consider that the solar wind electric field sweeps ions and electrons away and that the density of the lunar neutral atmosphere is as low as 10^4-$10^5 cm^{-3}$. The radio science (RS) experiments in the SELENE (KAGUYA) mission aims at solving this problem.
In the SELENE RS, we have conducted more than 300 observations of the lunar ionosphere by using two radio frequencies of 2218 MHz and 8456.125 MHz transmitted from a single spacecraft (Vstar). The purpose of using two radio frequencies is to extract the contribution from the electrons density along the ray path by removing the effects of the frequency variations of the onboard frequency source via a linear combination of the phase variations in the two frequency bands. In addition to this single spacecraft method, we have conducted a new occultation method using two satellites, which is the theme of this thesis. In this method, one of the two sub-satellites, Rstar, is used to measure the terrestrial ionosphere contribution while another sub-satellite, Vstar, is occulted by the moon; the difference between the two measurements gives the lunar ionosphere component without being disturbed by the terrestrial ionosphere. A difficulty in this method was that we were forced to use two S-bands whose frequencies are close to each other (2218 MHz and 2287 MHz) because of the specification of the Rstar's transponder. This results in a relatively large uncertainty in the derived electron density. Another difficulty was that the two sub-satellites must be present within the beam diameter of the ground antenna, and consequently, the number of observation opportunities was limited.
The 21 observations by this method covered the solar zenith angles (SZA) ranging from 71.5 to 1 23.2 degree. Within this SZA range we do not see a steady increase of the electron density even on the sunlit side of the lunar surface; this result is not in harmony with the result from the Luna missions, in which the enhanced electron density is a stable feature on the sunlit surface even near the terminator. There are two exceptional cases, in which enhancements of the electron column density were observed below 30 km altitude with magnitudes similar to those observed in the Luna missions. This implies that the lunar ionosphere has a sporadic or localized feature in this SZA range.

Keywords: lunar ionosphere, radio occultation, SELENE