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Plasma wave turbulence due to the wake of an ionospheric sounding rocket

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A sounding rocket moving in the ionosphere generally interacts with surrounding plasma. Because this affects in-situ measurement data, it is very important to understand the physics of the interaction between the ionosphere and a moving vehicle. For instance, a rarefied plasma region called “plasma wake” is formed behind a sounding rocket. Several previous studies based on rocket experiments have suggested that upper-hybrid resonance (UHR) mode waves are excited in a rocket wake. A wake turbulence model has been proposed as a possible explanation for the waves where two stream instability occurs in the wake center owing to the incident plasma flow from the both sides of the wake edges. Thus, plasma waves are generated and have been observed by the wave receivers onboard the rockets. Plasma waves in a wake have been reported not only around sounding rockets but also around solar system bodies such as Moon. As for a rocket wake, the generation mechanism of the waves has been investigated by using wave receivers with time resolutions worse than 500 msec. They are, however, not enough for detailed investigations about the plasma wave generations and propagations.

To discuss the properties of the plasma waves caused around a rocket wake, we have analyzed the data of electric fields and electron number density in the S-520-26 sounding rocket experiment, which was performed at Uchinoura, Japan, on January 12, 2012. The rocket reached an altitude of 298 km, and the data has been obtained four or five times in one spin period of the rocket by using a newly developed digital plasma wave monitor and an impedance probe, whose time resolutions are about 260 msec.

In the observation, enhancement of plasma waves has been observed in two frequency ranges from 0.02 to 0.9 MHz (LF range), and from 1.3 to 2.4 MHz (MF range). The frequency range of the MF emissions is around the UHR frequency, which is determined based on the IGRF magnetic field model and electron number density measured by the impedance probe. However, the lowest frequency of the emissions is almost the same as the Z-mode cutoff frequency, particularly in higher altitude range than 280 km. The wave spectra are similar to those observed by the previous studies. The frequency range of the LF emissions is found to be that of whistler mode branch. Based on the rocket attitude, it is suggested that the electric fields of the LF and MF emissions are nearly perpendicular and parallel to the wake structure, respectively.

If we can assume that the observed waves are generated around the rocket, they have to be electrostatic waves because the wave length should be shorter than the size of the disturbed region. We have performed calculations of plasma dispersion relations with assuming some anisotropic velocity distribution functions of electrons expected around the wake, and deduced the linear growth rates, group velocities, etc. We compare the observational results with calculated ones, and discuss the generation mechanisms of the plasma waves.