Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM29-06 Room:304 Time:May 22 16:15-16:30

Plasma wave turbulence induced by the wake of an ionospheric sounding rocket

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In the ionosphere, a rarefied plasma region called ‘plasma wake’ is formed behind a sounding rocket. For the past a few decades, many theoretical works, rocket experiments and numerical simulations have revealed the electron density depletion and the electron temperature enhancement in plasma wakes.

Several recent studies based on rocket observations have indicated that plasma waves are possibly excited in the rocket wake. They have discussed the observational results of the wave spectra in a frequency range around a few MHz based on the cold plasma theory and have suggested that the observed waves are the upper-hybrid resonance (UHR) mode waves. A wake turbulence model has been also proposed as a possible explanation for the waves where the two stream instability occurs in the wake center owing to the incident plasma flow from the both sides of the wake edges. However, there remains an issue that a part of the waves have not been explained by the dispersion relation of the UHR-mode waves calculated from the obtained electron density in the wake. In addition, these plasma waves have been investigated by using wave receivers with time resolutions worse than 500 msec, which is not enough for detailed investigations about their generations and propagations.

Plasma waves around the wake have been also reported in the region close to an artificial satellite and solar system bodies such as Moon. This suggests that the generation of plasma waves due to the rocket wake should be understood as a kind of universal phenomena in interactions between streaming plasma and a non-magnetic body.

To discuss the properties of the plasma waves caused around the rocket wake in more detail, we have measured the electron number density and electric fields of plasma waves in the mid-latitude ionosphere by an impedance probe and a plasma wave receiver, which were installed on the sounding rocket S-520-26. The time resolutions of the two instruments are about 260 msec, which corresponds to one fourth or one fifth of a spin period. The rocket was launched at Uchinoura in Kagoshima Prefecture, Japan, on January 12, 2012, and reached at an altitude of 298 km, approximately. We have observed plasma waves in the frequency range of 1.3-2.4 MHz (MF range) as well as in the frequency range below 0.9 MHz (LF range). The MF emissions are similar to the observed waves in the previous studies. Although the frequency range of the MF emissions is around the UHR frequency, we reveal that a component of the emissions are not explained by the dispersion relation of UHR-mode waves in the wake condition, which is deduced from the IGRF magnetic model and the data obtained by the impedance probe.

In this study, we discuss the mode of the observed plasma waves based the dispersion relation in a hot plasma. Assuming that the waves are generated around the wake near the rocket, we clarify that the MF emissions are explained by electrostatic cyclotron harmonics (ESCH) waves as well as the UHR-mode waves and that the LF emissions are electrostatic whistler-mode waves, because the wave length should be shorter than the size of the disturbed region. Besides, the analysis of the rocket attitude tells us that the both emissions are strongly observed only when the dipole antenna is in a certain direction. Moreover, we perform calculations of plasma dispersion relations numerically by assuming anisotropic velocity distribution functions including an electron beam or temperature anisotropy. As a result, positive linear growth rates are obtained in the wave number and frequency ranges of the electrostatic UHR-mode waves, ESCH waves and whistler-mode waves.

In this presentation, we compare the observational results with the obtained dispersion relations and discuss the properties of the observed plasma waves.

Keywords: wake, plasma wave, sounding rocket, ionosphere