Characteristics of electric field antennas in space plasmas

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In the plasma wave measurements, the accurate calibration of electric field sensors onboard spacecraft is always important and difficult problem. Long wire dipole antennas are typically used for electric field measurements. However, the complicated characteristics of wire antennas in plasmas make it difficult to conduct the accurate calibration. Especially, the characteristics of antennas in hot and dilute plasmas such as those in the geomagnetic tail region are much more different from those in the cold and dense plasmas in the ionosphere, since they are strongly affected by hot plasma dispersion, photoelectrons, and plasma sheath.

The characteristics of electric field antennas are represented by the antenna impedance and effective length. In order to conduct the precise calibration of antennas, we need to calculate or measure the accurate antenna impedance and effective length. Further, as the value added, the precise antenna impedance allows us to search for electron temperatures using the precise observations of electron thermal noise around the spacecraft. Since in the future mission such as the SCOPE mission, the precise measurements of electric fields are essential in order to perform the quantitative studies of wave-particle interactions, we need to establish the theoretical model of electric field antennas in hot and dilute plasmas and to develop the onboard measurement system of the antenna impedance and effective length.

Plasma Wave Instrument (PWI) onboard Geotail spacecraft has the capability of measuring antenna impedance using the very simple method in the limited frequency range. Theoretical attempts to calculate the antenna impedance and effective length in warm plasmas have been conducted for a past few decades mainly in Europe. On the other hand, the recent big progress of numerical studies by computer experiments allows us to examine the complicated characteristics of electric field antennas in the various model and various plasma parameters. In the present paper, we focus on the antenna impedance in hot and dilute plasmas. Geotail spacecraft already conducted the antenna impedance measurement in the various magnetosphere regions. The measurement is very limited in the frequency range from 10 Hz to 4 kHz. We compare the antenna impedance measured by Geotail spacecraft with those calculated by the antenna impedance theories in hot plasmas.The results show the interesting feature that the measured antenna impedance agree with those from theories in the frequency range between electron and ion plasma frequencies, however, in the other frequency range they do not coincide. We discuss this difference between the theories and spacecraft observations on the antenna impedance. We also summarize the specifications of the onboard antenna impedance measurement system in the future missions.