Particle-In-Cell Simulations on Electric Field Antenna Characteristics in Space Plasma

Youhei Miyake[1]; Hideyuki Usui[1]; Hirotsugu Kojima[1]; Hiroshi Matsumoto[2]

[1] RISH, Kyoto Univ.; [2] RASC, Kyoto Univ.

The properties of an electric field antenna immersed in space plasma are affected by complex interactions among antenna, plasma waves, and plasma particles. Such effects must be investigated quantitatively for the calibration of wave data obtained by spacecraft observations. However, the analysis of the antenna properties in space plasma is very complex because the plasma is a dispersive and anisotropic medium. In the previous theories, only simple dipole or monopole antenna model could be treated and approximations were hired in the current distribution along the antenna or the sheath structure around the antenna. Meanwhile, many scientists have investigated the antenna properties in vacuum numerically with the FDTD (Finite Difference Time Domain) method which solves the Maxwell equations with spatial and temporal grid points. However, the FDTD method with a dielectric tensor obtained under the cold plasma approximation can not treat plasma kinetic effects on antenna properties. In the present study, we utilize the method of three-dimensional electromagnetic PIC (Particle-In-Cell) simulations which can treat the electrodynamic phenomena in plasma in time and space. In PIC simulations, we put a conducting antenna immersed in plasma and examine the electric field antenna properties in space plasma. PIC simulations enables us to examine the antenna properties including plasma kinetic effects such as sheath around the antenna in a self-consistent manner.

Using this method with the dipole antenna model, we first investigate the dependence of antenna impedance resonance on the plasma temperature, magnitude of static magnetic field and sheath size around the antenna. We compare the results of computer experiments with the previous theories. It is found that the resonance at the plasma frequency become weaker and resonance frequency become higher as the thermal velocity of the background plasma is larger.

Secondly, we introduce the new antenna model including a spacecraft body for the design of electric field antennas onboard future mission called SCOPE. In order to include the effects of realistic photoelectron sheath structure, we perform the electrostatic PIC simulations and create the photoelectron sheath environment in a self-consistent manner. The obtained photoelectron sheath structure differs from simple cylindrical sheath models which are used in previous sheath impedance theories. This is considered due to the photoelectron emission from the spacecraft body surfaces and the potential difference between electric field antennas and spacecraft body.

Finally, we examine the photoelectron sheath effects on antenna impedance properties. We perform the electromagnetic simulations to analyze the impedance properties by using the photoelectron sheath environment constructed in the electrostatic simulation. We use the delta-gap feeding method for the impedance analyses. Preliminary results show that photoelectron sheath affects the antenna impedance properties at the frequency range approximately corresponding to the density of local photoelectrons. We will able to examine the antenna characteristics including the more realistic antenna configurations and plasma environments, which is left as a future work.