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Particle-In-Cell simulation on the characteristics of a receiving antenna in space plasma environment

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Understanding of electric field antenna characteristics (e.g., effective length and impedance) in plasma environment is important because electric field measurement using electric field antennas is very common in plasma wave investigations with scientific spacecraft. However, due to complex behavior of the surrounding plasma, it is often difficult to apply theoretical approaches to the analysis of practical antenna characteristics including effects of the plasma kinetics and the inhomogeneity created in the vicinity of the antenna and the spacecraft.

In the current study, we applied the electromagnetic-PIC (Particle-In-Cell) plasma simulation to the complex antenna analysis in space plasma. By using the PIC modeling, we can self-consistently consider the plasma kinetics. This enables us to naturally include the effects of the inhomogeneous plasma environment such as a sheath created around the antenna. We particularly modeled situations of electrostatic/electromagnetic-wave reception by an antenna aboard scientific spacecraft and examined the effective length of the antenna.

In the present simulation model, we initially set up external waves that propagate in a simulation region. We also placed a wire antenna made of a perfect conductive body, in which the electric field values are set to zero. In the simulation, we observed the value of the wave electric field and the input voltage induced at a gap between two antenna-body elements. The effective length is obtained as the ratio of the input voltage to the wave electric field magnitude. In the current study, we examined the effective lengths in receiving the Langmuir and Whistler waves as electrostatic and electromagnetic modes, respectively. As a preliminary result, we confirmed that the effective length coincides with the half of the dipole physical length in absence of sheath and photoelectron effects. We next started the analysis on the influence of an ion sheath and a photoelectron cloud that are created in the vicinity of the antenna. For this aim, we treated the antenna as solid bodies, which absorb impinging particles and emit photoelectrons, and implemented the numerical model of the antenna charging. It was confirmed that an ion sheath and a photoelectron cloud are successfully created in the self-consistent manner for cases in absence and presence of photoelectron emission, respectively. The effects of such inhomogeneous plasma environment on the antenna characteristics will be reported. We will also report results for not only simple dipoles but also antennas with complex structure such as MEFISTO, which is an electric field instrument for BepiColombo/MMO.