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

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We study the characteristics of electric field antennas immersed in space plasma by performing computer simulations. The antenna characteristics are generally complex in space plasma because it is a dispersive and anisotropic medium. In the previous theories, antenna analysis was done for a dipole antenna immersed in uniform cold or hot plasma with assumed antenna current distribution [1][2]. In the present study, we apply the PIC simulation method to antenna analysis in which we can treat the antenna geometry including a spacecraft body and analyze the effects of photoelectron emission on antenna characteristics. These analyses will contribute to the calibration of plasma wave data obtained by spacecraft observations and the design of electric field antennas aboard the future mission.

Simulation model

In three-dimensional simulation region, we place a spacecraft and a set of conductive dipole antenna attached to the spacecraft body. The spacecraft and the antenna are assumed to be electrically insulated. Photoelectrons are emitted from sunlit surfaces of an antenna and a spacecraft. In the present analysis, we assumed that only one side of antenna and spacecraft surface is sunlit. The emitted electrons are assumed to have a Maxwellian spectrum in the velocity space.

Plasma environment with photoelectron emission

In order to analyze the plasma environment with the photoelectron emission, we performed the electrostatic simulation. The simulation results showed that the dense region of electron caused by photoelectrons was created around the sunlit antenna and spacecraft surface. Meanwhile, the sunless antenna was negatively charged with impinging background electrons and the electron sparse region was created around the antenna. In such a non-uniform plasma environment, it can be speculated that sunlit and sunless antennas have different impedance characteristics from each other.

Photoelectron effects on antenna impedance characteristics

We examined the antenna impedance in the created photoelectron environment by performing the electromagnetic simulations. We particularly focused on the reactance (imaginary part of impedance) characteristics of the sunlit antenna as a function of frequency. It was shown that the photoelectron dense region around the sunlit antenna decreases the absolute value of antenna reactance below the plasma frequency corresponding to the density of local photoelectrons. The variation of the reactance is caused by the increase of the effective electrical conductivity due to the dense photoelectrons around the sunless antenna. This effect was modified by the presence of static magnetic field. We will discuss the dependence of antenna impedance on the presence of static magnetic field and the arrival direction of sunlight which determines the area and amount of photoelectrons.

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REFERENCES

[1] K. G. Balmain, The Impedance of a Short Dipole Antenna in a Magnetoplasma, *IEEE. Trans. Antennas Propag.*, AP-12, 605–617, 1964.
[2] H. H. Kuehl, Resistance of a Short Antenna in a Warm Plasma, *Radio Science*, 1-8, 971–976, 1966.