Computer experiments on the characteristics of electric field antenna in the spacecraft environment

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The characteristics of electric field antennas installed on board the scientific satellites are studied by making use of the Particle-In-Cell (PIC) plasma simulations. The precise calibration of plasma wave data obtained by spacecraft observation requires the knowledge of antenna impedance in the space plasma environment. However, the plasma environment near the spacecraft, which becomes non-uniform due to the plasma kinetic effects such as sheath formation and photoelectron emission, is so complex that it is difficult to be treated by theoretical approaches.

To treat the antenna model including a spacecraft body and analyze the effects of photoelectron emission on antenna characteristics, we applied the PIC simulation method to the conventional FDTD method in the present study. Figure 1 shows the model of the present computer experiment. The present antenna model, which is immersed in background plasma, consists of perfect conducting antennas and spacecraft body. We also modeled the photoelectron emission from the sunlit surfaces of conducting body with an assumption of the arrival direction of sunlight.

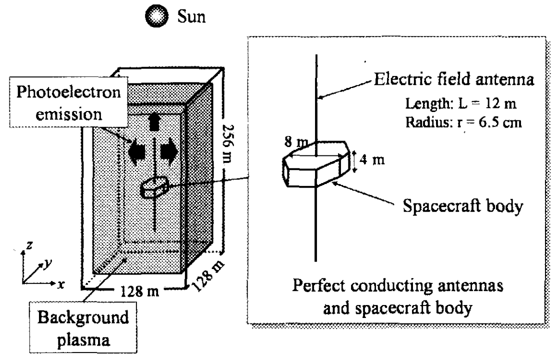

Figure 1: Simulation model.

Using these models, we first conducted the electrostatic simulations focused on photoelectron sheath formation around the spacecraft. The obtained electron density profile (Figure 2) shows that the electron dense region caused by photoelectrons is created around the sunlit antenna and spacecraft surface. Meanwhile, the sunless antenna is negatively charged with impinging background electrons and made the electron sparse region. It was also confirmed that the plasma environment depended sensitively on the incident angle of sunlight which determined the location and amount of photoemission.

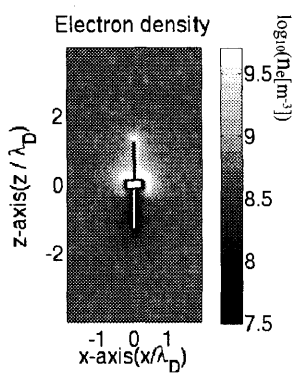

Figure 2. Contour map of electron density.

Next, the antenna impedance under the obtained plasma environment was examined by the electromagnetic simulations. Figure 3 shows the obtained results of imaginary part of impedance. Obtained results for both resistance and reactance were much different from those in vacuum below the characteristic frequency corresponding to the local density in photoelectron sheath. The difference of impedance characteristics between sunlit and sunless antennas was also found. This suggests that the impedance characteristics vary with the spin or attitude change of spacecraft. Now we start to consider the real plasma parameters of the Earth's magnetosphere and examine the antenna impedance. 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.

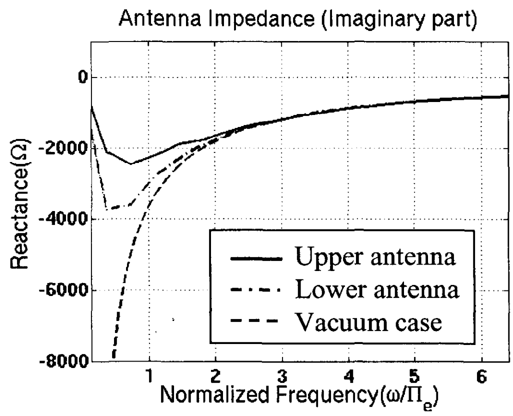

Figure 3: Imaginary part of impedance (reactance).

REFERENCES

[1] H. Usui, Y. Miyake, M. Okada, Y. Omura, and the GES project team, Development and Application of Geospace Environment Simulator for the Analysis of Spacecraft-Plasma Interactions, Submitted to IEEE Plasma Science, 2005.