Effect of photoelectrons on the impedance of the electric field antennas onboard spacecraft

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The quantitative understanding of the antenna characteristics in space plasma environment is required in the wave data calibration as well as in the antenna design for future missions. In many previous works, antenna is assumed to be an ideal thin conductive wire, totally transparent to the fluid plasma medium. However, antenna surface is a solid body and plasma particles which impinge the surface are absorbed at the surface and contribute to the charging. In the present paper, considering such particle impact effects, we focus on the effects of photoelectron emission on the characteristics of the antenna impedance. We present the three-dimensional electromagnetic PIC simulations which were performed to examine the photoelectron environment around the antenna and its effects on the antenna impedance.

We consider a situation that the spacecraft body and antennas, that are sunlit and then emit photoelectrons, are immersed in tenuous background plasma. In this situation, the conducting bodies are positively charged due to the dominant current of photoelectrons. We performed ES simulations focused on the creation of photoelectron environment and confirmed the positive charging of the sunlit spacecraft and antenna bodies. We also confirmed the formation of photoelectron cloud around the sunlit surfaces. For comparison, the sunless case, in which photoelectrons are never emitted, is also examined, and we confirmed the formation of electron sparse region around the spacecraft. After obtaining the plasma environments around the spacecraft and antenna, we move to EM simulations for antenna analysis. To obtain the input impedance of the antenna we adopted the Delta-gap feeding method which has been widely used in the antenna analysis in free space. Particularly, the impedance characteristics in the frequency range near the electron plasma frequency were focused. It is found that the electron conduction current flowing between conducing bodies influences the value of impedance below the characteristic frequency of photoelectron cloud. This effect can be well understood by the RC parallel equivalent circuit. On the other hand, in the absence of photoelectron emission, such modification of the impedance cannot be observed in the frequency range near the electron plasma frequency. This indicates the current due to the actual motion of the dense photoelectrons contributes this impedance modification. We will discuss the dependence of this effect on the static magnetic field and the arrival direction of the sunlight.