Numerical Modeling of Plasma Wave Electric Field Effects on Spacecraft Charging

*Yohei Miyake[1], Takeshi Kiriyama[3], Yuto Katoh[2], Hideyuki Usui[3]

1. Education Center on Computational Science and Engineering, Kobe University, 2. Graduate School of Science, Tohoku University, 3. Graduate School of System Informatics, Kobe University

Based on the particle-in-cell (PIC) method, we numerically model the modulation of a spacecraft potential in the presence of time-varying electric fields of plasma waves. Recent observations by Van Allen Probes showed apparent spacecraft potential fluctuations associated with chorus wave detection [e.g., Malaspina et al., 2014], and a major physical factor of the effect was speculated as photoelectron-escape current modulations due to wave electric field. Although its dependencies on wave frequency and magnetic field strength have been examined experimentally [Wang et al., 2014a; 2014b], there are a number of remaining issues such as effects of wave polarization or configuration of spacecraft chassis and probes. In particular, in-space spacecraft potential measurements are conducted by seeing a potential difference between spacecraft chassis and electrostatic probes, and thus it is necessary to consider the difference of their responses to external wave electric fields.

In this paper, we perform plasma particle simulations to address such unresolved issues. Our original PIC simulation code EMSES has a capability of reproducing plasma wave excitation/propagation as well as spacecraft charging in a self-consistent manner. Meanwhile, such analysis with realistic physical parameters requires too large computational resources, because the typical spatial scale of plasma wave lengths is much greater than that of the near-spacecraft environment. Thus, we propose another modeling of the phenomena by applying a spatially-uniform and time-varying electric field to the whole simulation domain as an external force term. We have confirmed that this model can reproduce the photoelectron-driven spacecraft potential fluctuations in case of a circular-polarized wave electric field. We have also constructed a theoretical model to explain the simulated potential fluctuations in consideration of a photoelectron escaping current though an RF sheath around the spacecraft [Boehm et al., 1994].

Keywords: plasma wave, spacecraft charging, wave electric field, chorus waves, photoelectron emission, particle-in-cell simulation

