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Particle-In-Cell Modeling and Analysis of an Electric Antenna for the BepiColombo/MMO spacecraft

Yohei Miyake (1), Hideyuki Usui (2), and Hirotsugu Kojima (3)

(1) Academic Center for Computing and Media Studies, Kyoto University, Kyoto, Japan (y-miyake@media.kyoto-u.ac.jp), (2) Graduate School of Engineering, Kobe University, Kobe, Japan, (3) Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan

The sophisticated calibration of a space-based electric antenna should be performed based on precise knowledge of electric antenna characteristics in space plasma environment. However, it is often difficult to know practical antenna characteristics considering the effects of plasma kinetics and spacecraft-plasma interactions by means of only theoretical approaches. Furthermore, some modern electric field instruments, such as the Cluster EFW instrument and MEFISTO for the BepiColombo/MMO spacecraft, are designed based on a "hockey puck" principle, which introduces much complexity in their overall configurations. Thus a strong demand arises regarding the establishment of a numerical method that can solve the complex configuration and plasma dynamics for evaluating the electric properties of such modern instruments.

For the self-consistent antenna analysis, we have newly developed an electromagnetic (EM) particle simulation code named EMSES. The code is based on the particle-in-cell technique and also supports a treatment of inner boundaries describing spacecraft conductive surfaces. This enables us to naturally include the effects of the inhomogeneous plasma environment such as a plasma and photoelectron sheaths created around the antenna. The support of the full EM treatment is also important to apply our tool to antenna properties for not only electrostatic (ES) but also EM plasma waves.

In the current study, we mainly focus on ES features and photoelectron distribution in the vicinity of the electric field instrument MEFISTO. Our simulation model includes (1) a photoelectron guard electrode, (2) a bias current provided from the spacecraft body to the sensing element, (3) a floating potential treatment for the spacecraft body, and (4) photoelectron emission from sunlit surfaces of the conductive bodies. Of these, the photoelectron guard electrode is a key technology for producing an optimal condition of plasma environment around MEFISTO. Specifically, we introduced a pre-amplifier housing called "puck" located between the conductive boom and the sensor wire. The photoelectron guard is then simulated by forcibly fixing the potential difference between the puck surface and the spacecraft body. For the modeling of the photoelectron guard electrode and the current biasing, we use the Capacity Matrix technique in order to assure the conservation condition of total charge owned by the entire spacecraft body. Our preliminary simulation run successfully showed an intended behavior of the above numerical models. By using the model, we started numerical analysis on an ES structure around MEFISTO and current-voltage characteristic of the instrument.

We report some simulation results on the influence of the guard electrode on the surrounding plasma environment and the electric properties of MEFISTO.