Non-sinusoidal waveforms of electric potential produced by photoelectrons and spacecraft charging detected by Arase PWE

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Measurement of the electric field is key to understanding the magnetospheric dynamics as a response to the solar wind. For this objective, many spacecraft have employed the double probe technique with long wire antennas extending from a spinning spacecraft body. Despite improvements of the technique achieved by past satellites, accurate measurement of the electric field is still difficult and challenging particularly in a tenuous magnetospheric plasma for several reasons, such as a long Debye shielding distance, dominance of photoemission in the current balance of probes, positive charging of a spacecraft body, unstable electric potential of the spacecraft. On most of the recent satellites, a bias current is fed to the probes to reduce the resistance of probes to the ambient plasma and thereby stabilize the probe potential.

In the Arase satellite case, the Wire Probe Antenna (WPT) connected to the Electric Field Detector (EFD) of the Plasma Wave Experiment (PWE) is responsible for the electric field measurement. The WPT is two pairs of double probes comprising 60-mm-diameter spheres on tips of 15-m wire antennas. Although the antenna length is limited due to an issue of the development cost, Arase attempted to minimize the effects of asymmetric emission of photoelectrons from the spacecraft body by setting its spin axis within 15 degrees from the sun direction. Nevertheless, in a tenuous plasma, the measurement suffers from a fairly persistent, apparent sunward electric field with a strange, non-sinusoidal waveform of potential difference between the probes and the spacecraft.

In order to understand how the spurious sunward field appears, we examined the observed potential waveform data, and modeled the photoelectron cloud and the spacecraft charging by assuming a single negative charge outside the spacecraft and a positive charge on the spacecraft body, respectively. The photoelectrons are emitted from the sunlit side of the spacecraft, and there will be a sunward concentration of photoelectrons. Also, there will be a sunward shift of positive charge on the spacecraft however high the skin conductivity is. We set the model charges shifted toward the sun at different distances from the center of the spin of the wire antennas. Even with small angle of the spin axis with respect to the Sun, the model charges are off the spin axis, and the distance of a probe from each electric charge varies depending on the spin phase. Separation of positive and negative charges causes difference in electric potential arising from them, producing a non-sinusoidal waveform of electric potential at the probe. For each spin of Arase we calculate the electric charges and the best-fit position of the negative charge that can well reproduce the observed waveforms of potential difference between the probes and the spacecraft. With this simple model, the apparent sunward electric field is partly reproduced although an effect of spin-modulation of photoemissions arising from variation of the illuminated cross-section of the spacecraft has not yet been considered.

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