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A simulation study for the design of the multi-needle Langmuir probe instrument

Chun-Sung Jao* (1) (2), Sayan Adhikari(3), Steffen M. Brask(3), Lasse Clausen(3), Wojciech J. Miloch(3)
(1) National Central University, Taoyuan, Taiwan; e-mail: csjao899@gmail.com
(2) National Cheng Kung University, Tainan, Taiwan
(3) University of Oslo, Oslo, Norway

Space scientists have utilized satellites and sounding rockets for the Sun-Earth environment exploration over decades. With the scientific payloads on the spacecraft, we conduct the field, wave, and particle measurements along the spacecraft's trajectory. Among these in-situ measurement missions, Langmuir probes are in widespread use for plasma measurement. Operating the classical Langmuir probes requires the electric voltage sweep on the probes. Then the obtained current-voltage characteristic can provide information on physical parameters such as ion density, electron density, and electron temperature base. However, for scientists to understand multiscale plasma physics in the space environment, recent space missions may demand plasma measurements with a higher sampling rate than the sweeping frequency. The so-called multi-needle Langmuir probe (m-NLP) instrument thus can win acceptance by its higher sampling rate (~kHz) in electron density measurements. The m-NLP instrument consists of two or more small fixed-bias cylindrical Langmuir probes that are small compared to the Debye length. Based on the Orbital Motion-Limited (OML) theory, we can directly infer the electron density from the collected current by the probes with different biases [1, 2]. For the employment of the m-NLP instrument in the in-situ measurement missions, we study the interaction between the instrument and its surrounding plasma by using a three-dimensional unstructured particle-in-cell code, Pietra [3]. We first study the wake formation behind a single Langmuir probe with a fixed positive bias [4]. According to the simulation results, higher electric bias and flow velocity can enhance the plasma wake perturbations. In the magnetized case, the plasma wake may become asymmetric and more extensive than in the unmagnetized case. Later we set up two or more probes in the simulation system to discuss the effects on the collected current of the Langmuir probes in the plasma wake. This study provides a practical reference for future design to avoid measurement errors in the m-NLP instrument.

References

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