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Plasma particle simulations on spacecraft wake effects on electric field measurements

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Electrostatic wakes formed behind spacecraft in streaming plasmas are often identified as a potential source of errors in electric field measurements based on the double-probe technique. Particularly in tenuous plasma environments, a positively-charged spacecraft causes enhancement of wake structures and their resultant potential signatures, leading to serious spurious electric fields observed by double-probe instruments [1]. For study of the wake effects, we perform particle-in-cell simulations on the wake structure around the Cluster satellite. In the simulations, we include numerical models of both spacecraft body and conducting booms simultaneously in the simulation system and consider the presence of multi-species ion streams.

For the analysis, we use our own plasma particle simulation code EMSES. Conceptually EMSES can solve floating potentials of multiple conducting elements in a self-consistent manner. Meanwhile, an extreme difference between typical boom radii (of the order of mm) and spacecraft dimensions (of the order of m) is too difficult to simulate within a limited spatial resolution. Therefore, we use a fixed-potential boundary condition for the conducting surfaces instead of the self-consistent treatment of floating potentials. We mimic the extremely-thin boom wire by setting an effective potential value to nearest neighbor grid points from the boom center axis, which is lessened from a real boom potential according to the distances of the grid points from actual boom wire surfaces. The current analysis focuses on the wake structures around the positively-charged Cluster satellite in a tenuous, streaming plasma with multi-species ions (proton and O+).

The simulation result exhibits the wake formation for both proton and O+ densities. However, the wake structures for the two species are clearly different; the wake signature of proton density is largely enhanced compared with the spacecraft and boom geometries, while the wake has a more geometric structure for O+ density. We find a single negative potential peak at about 80 m downstream of the spacecraft body, while potential is positive at a probe position because of the positive spacecraft and boom potential influence. The rate of the positive potential decay is greater for downstream than that for upstream, resulting in potential difference between opposed probe positions. This potential difference may cause a spurious electric field with magnitude of 3–5 mV/m. The field magnitude tends to be smaller for larger proportion of O+ ions. The current analysis should be followed by a dependency analysis on an angle formed between the boom and flow directions, which is left as a future work.

[1] E. Engwall et al., Wake Formation Behind Positively Charged Spacecraft in Flowing Tenuous Plasmas, Phys. Plasmas, 13, 062904, 2006.

Keywords: Electric field sensor, Spacecraft wake, PIC simulation