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ORIGINAL ARTICLE

GPS-based precise orbit determination of Low Earth Orbiters with limited resources

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Abstract The combination of GPS measurements and high-fidelity dynamic models via a Kalman filter/smoother, known as the reduced dynamic technique, allows 3D positioning of Low Earth Orbiters to the sub-decimeter level. Such accuracies can only be achieved if the GPS data are nearly continuous, post-processed and a dual-frequency receiver is utilized. The focus of this study is to quantitatively analyze the degradations in position accuracy in the presence of various limitations or constraints, which can be brought on by mission hardware limitations, for example, on micro- or nanosatellites. The constraints explored in this study are as follows: the use of single-frequency data only; real-time processing; limited dynamic modeling due to computing capabilities; and non-continuous GPS receiver operation due to power limits. The experiments are conducted with 6-h data arcs for 7 separate days using data from the CHAllenging Mini-Satellite Payload. A 3D root mean square (rms) error of 15 cm is observed in the best-case solution, in which dual-frequency data are post-processed with all available data. Various levels of accuracy degradations are observed as constraints are placed on this best-case solution. The 3D rms error of the post-processed, single-frequency solution is 68 cm and 1.3 m for the real-time, dual-frequency solution. In very challenging environments, for example, with the receiver on for only 10 min of a 90-min orbit, the 3D rms increases to 350 m.

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Introduction

This study focuses on the positioning of Low Earth Orbiters (LEOs), which are satellites or spacecraft that orbit the earth at altitudes as low as a few hundred kilometers. The reduced dynamic technique (Yunck et al. 1990), which was first demonstrated on the TOPEX/Poseidon mission in 1992, promised sub-decimeter tracking accuracy. Since the success of the reduced dynamic technique, much work has been done in the satellite positioning field, such as improvements in dynamic models and processing efficiencies (Montenbruck 2000; Svehla and Rothacher 2003; Jaggi et al. 2007).

The most accurate positioning solution is produced by post-processing dual-frequency data from a continuously operating GPS receiver with the utilization of full dynamic models. The purpose of this study is to determine the absolute and relative decrease in orbit accuracy with respect to this best-case solution under various constraints, which can be caused by mission hardware limitations. The results obtained may be particularly interesting with application to micro-, nano- or CubeSat missions. Due to the recent increase in CubeSat missions requiring accurate positioning solutions, such as the Canadian Advanced Nanospace eXperiment (CanX) program, the need to explore the effect of hardware limitations on orbit accuracy has become more relevant. GPS receivers on board nanosatellites such as CanX-2 cannot always be in continuous operation due to power constraints, yet require meter-level positioning accuracy (Kahr et al. 2011). The constraints explored in this study are as follows: real-time processing