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IMPROVED GNSS-BASED ORBITAL FILTER FOR EARTH TO MOON NAVIGATION

Abstract

Although it is quite challenging to develop a GNSS receiver for very high Earth altitudes, such a receiver can increase the autonomy of a space vehicle, as well as the robustness and the accuracy of its navigation system, at a relatively low cost. Advanced signal processing techniques need to be adopted in order to account for very noisy measurements and bad geometry at high altitudes. We choose to operate a receiver during an Earth-Moon Transfer Orbit (MTO) mission to test the receiver at various altitudes far beyond the GNSS constellations. Following our previous studies carried out for the “WeakHEO” GNSS receiver proof of concept specifically designed for Earth to Moon navigation, we have shown that a GNSS-based Orbital Filter (OF) can be an attractive solution to significantly improve the achievable navigation performance. For the “WeakHEO 2”, a more advanced second version of the previous receiver, in this research, we attempt to further improve the navigation accuracy and perform tests with a prototype receiver platform in real time. Firstly, a Weighted Least Square (WLS) algorithm is adopted to obtain an optimized GNSS solution which accounts for the large range of signal powers incident at the antenna. Secondly, an adaptive tuning method for the Orbital Filter is derived to consider GNSS geometry variation and signal power difference. This shows an important improvement compared to the previous filter which processes the GNSS results assuming they have spatially equal white noise. Thirdly, an efficient method is provided to increase the number of available observations. In this method fractional pseudoranges are used as observations without the need for synchronization with the navigation data frame. This overcomes the problem that the frame synchronization is particularly difficult for the very weak signals seen during the MTO. Finally, this work is implemented and tested on the weakHEO2 prototype receiver using a state-of-the-art FPGA development platform. This GNSS receiver prototype was developed at the ESPLAB in EPFL and is conceived to navigate up to the Moon altitude. Thus, hardware-in-the-loop tests using our WeakHEO2 receiver prototype connected to a Spirent GSS8000 simulator are presented to show the navigation performance of the proposed solution with real time observations.