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ORBIT DETERMINATION AND TIME SYNCHRONISATION IN LUNAR ORBIT WITH GNSS - LUNAR PATHFINDER EXPERIMENT

Abstract

The internal roadmap for deep space exploration proposed by the International Space Exploration Coordination Group (ISECG) clearly identifies the Moon as the first step towards a larger solar system exploration. The use of Earth Global Navigation Satellite System (GNSS) signals at Moon altitude has been extensively studied in the past, within and outside the European Space Agency (ESA). This interest has been reflected in "The Interoperable Global Navigation Satellite Systems Space Service Volume" booklet issued by the International Committee on GNSS (ICG). NASA, with their MMS mission, has recently demonstrated the reception of GPS signals at a distance which is about half-way between Earth and Moon, marking an important step towards the use of this technology in future lunar operational missions. The very weak signals received in cis-lunar space and the particular unfavorable geometry with all the signal coming from a similar region of the sky (i.e. high Dilution Of Precision, DOP, values), requires the development of advanced techniques as part of the spaceborne GNSS receiver, both at signal processing level (higher sensitivity) and at navigation filter level.

The current approach for deep space orbit determination and time synchronization relies on ground based solutions such as radiometric measurements via TTC link or advanced solutions such as optical links (e.g.: laser ranging and optical time transfer) or very large baseline interferometry (VLBI) techniques. This approach suffers from relatively high cost, complexity in the sharing of spare ground resources (e.g.: access to deep space network, DSN) and poor performances for real-time on-board orbit determination and time synchronization (often in orders of kilometers or tens of kilometers).

Based on ESA and NASA analysis presented in several publications, a lunar mission using a spaceborne GNSS receiver could achieve performances around 50-100m 3D RMS orbit determination and microsecond level time synchronization accuracy with high availability in real time on-board, without the need of frequency ground contact. ESA is developing a spaceborne receiver that is expected to provide outstanding performances in cis-lunar space missions and plans to demonstrate this technology as part of the Lunar

Pathfinder mission planned to be launched at end of 2023. The present contribution provides details of the experiment (including concept of operations, duration, etc.), the GNSS antenna and GNSS receiver and expected performances, potentially including real hardware in the loop tests with radio frequency constellation simulators and the engineering model of the GNSS receiver.