Feasibility analysis of GNSS-based navigation for LUMIO mission

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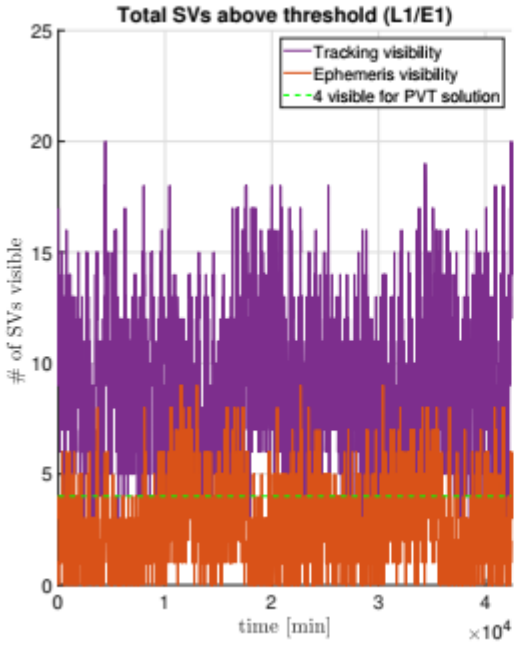
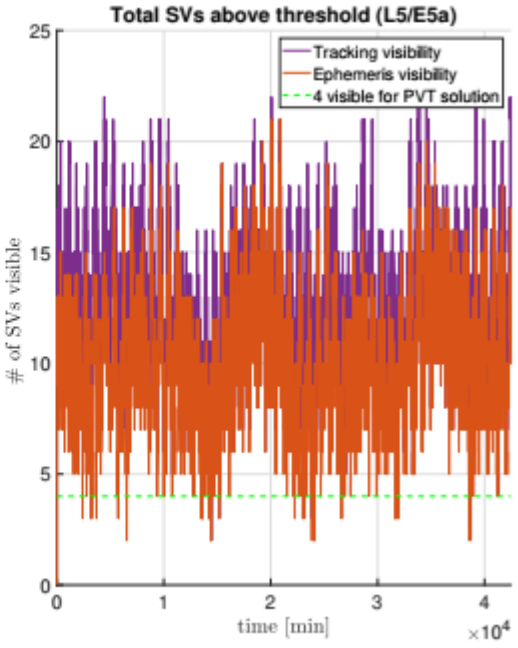
Abstract:

The use of GNSS navigation in lunar environment has yet to be tested. ESA for its lunar in-orbit development plan is developing a spaceborne GNSS receiver for an In-Orbit Demonstrator on-board the commercial Lunar Pathfinder mission scheduled for Q3/4 2023 and a lunar Cube-Sat mission by 2023. ESA is also evaluating the deployment of lunar based navigation infrastructures to augment and complement the GNSS service.

The paper presents the design of a realistic model of the GNSS constellations GPS and Galileo in order to perform a navigation performances analysis in lunar environment. Starting from the visibility analysis, the link-budget of each visible GNSS spacecraft is estimated using for each one realistic data for the transmitted power and typical values for the needed parameters. The navigation performances are evaluated in this scenario. The model implemented is applied to the trajectory of the LUMIO CubeSat mission and the results are commented. LUMIO is a lunar CubeSat mission designed to observe e measured meteoroids impact on the far side of the Moon in order to refine the current meteoroid models with experimental data unfeasible to acquire from ground-based observations. The targeted operational orbit is an halo orbit in the Earth–Moon L2 point with a period around half an Earth-Moon Synodic Period. As by mission requirements, LUMIO has been designed to perform autonomous onboard navigation. As baseline an optical-based navigation system has been selected since, combined with an EKF, it has been demonstrated to be able to satisfy the navigation requirements with an accuracy of < 30 km more than 99,7% of the time. The navigation analysis in this work can be compared to such a requirement to evaluate if a GNSS-based navigation solution could be employed as well.

The ephemerides visibility analysis has been performed for L1 and L5 signal bands for the simulation time of one Earth-Moon synodic period. The results are summarized in Table 4.9. As the full autonomous navigation is considered, requiring the receiver to demodulate the satellite ephemeris from the navigation message, the GPS+Galileo L1/E1 receiver performances are surely inadequate to satisfy the navigation requirements, at least for a stand-alone GNSS implementation, with an estimated 1æ position accuracy of around ª950 km. The GPS+Galileo L5/E5a receiver performances instead, are well below the LUMIO navigation requirements, with a navigation solution available 99.5% of the time and with position accuracy better than 3 km. Since the results are one order of magnitude below the requirements, the simulation confirms the feasibility of using a standalone GNSS-based navigation solution for the LUMIO mission, assuming a sensitivity of at least 15 dB-Hz. The figure below shows the number of available GPS and Galileo satellites, tracking visibility and ephemeris visibility comparison for signal bands L1 and L5 (15 dB-Hz threshold).


Total SVs above threshold (L1/E1)
Tracking visibility
Ephemeris visibility
4 visible for PVT solution
# of SVs visible
time [min]
×10^4


Total SVs above threshold (L5/E5a)
Tracking visibility
Ephemeris visibility
4 visible for PVT solution
# of SVs visible
time [min]
×10^4