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Author: Mr. Norbert Witternigg
Joanneum Research, Austria, norbert.witternigg@joanneum.at

Mr. Günther Obertaxer
Austria, Guenther.Obertaxer@joanneum.at
Dr. Michael Schönhuber
Joanneum Research, Austria, michael.schoenhuber@joanneum.at
Prof. Giovanni B. Palmerini
Sapienza University of Rome, Italy, giovanni.palmerini@uniroma1.it
Mr. Filippo Rodriguez
Italy, fil74rod@hotmail.it
Mr. Luigi Capponi
Italy, luigi.capponi@spacesys.eu
Mrs. Chiara Mozzetti
Italy, chiara.mozzetti@spacesys.edu
Mr. Jean-Jacques Floch
Germany, jean-jacques.floch@astrium.eads.net
Mr. Francis Soualle
Germany, Francis.Soualle@astrium.eads.net
Mr. David Fernandez Prim
Germany, david.fernandez.prim@gmail.com
Mr. Rigas T. Ioannides
The Netherlands, rigas.ioannides@esa.int

WEAK GNSS SIGNAL NAVIGATION IN LUNAR MISSIONS

Abstract

Weak GNSS signals could be exploited in future lunar missions to increase navigation robustness, flexibility and autonomy. In these applications GNSS reception suffers from very low signal levels, partial visibility of the GNSS sources and unfavourable geometry, making use of either secondary lobes or the signals' spill over around the Earth mask. Objective of a recent ESA study was to evaluate the challenges of such a navigation technique using GPS and future Galileo reception with carrier to signal levels as low as 10 to 15 dBHz. Investigated mission phases included transfer orbit, low lunar orbits, lunar ascent and descent as well as surface operation and navigation at the Lagrangian points.

The suggested GNSS receiver architecture is a software based snapshot receiver with limited ground station aiding to help with the information from navigation data messages; integration with external aiding sensors is considered in specific mission phases (i.e. ascent and descent, and the dark side of lunar orbits). The proposed approach strongly builds on the on-board navigation solution propagator, including a kinematic model to provide data during partial signal outages.

The availability of GNSS signals, in terms of geometrical line-of-sight, strength and Doppler shift has been computed. Different antenna accommodations have been analysed for the user spacecraft bound to the Moon as they define, through their gain, the level of the exploitable signal. The simulated snapshot

receiver implements the acquisition stage for either GPS L1/CA signals or data-less pilot signals of the Galileo E1C and E5 a-Q/b-Q channels. Acquisition uses block averaging pre-processing with coherent and non-coherent combining. Performance was tested using synthetic input with random content navigation messages, suggesting that a receiver sensitivity down to about 10 dBHz can be reached when using Galileo pilot signals and coherent integration time of 500 ms. While introducing some constraints on clock stability and initial coarse position, the snapshot architecture allows extended integration time and avoids stability and continuity issues at low carrier to noise ratio.

When additional input is needed, the propagator implements the data fusion between GNSS and aerospace grade sensors through an Extended Kalman Filter. The propagator also provides a valid solution during periods of GNSS signal outage by introducing internal knowledge of the trajectory.

Simulations proven successful behaviour of the proposed architecture during different phases lunar missions. GNSS-based navigation could help, by means of the improved autonomy, to strongly limit the cost of the lunar mission tracking.