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Performance Assessment of a Gnss-Based Troposphere Path Delay Estimation Software

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Error budgets of Deep Space Radio Science experiments are heavily affected by interplanetary and Earth transmission media, that corrupt, due to their non-unitary refraction index, the radiometric information of signals coming from the spacecraft. An effective removal of these noise sources is crucial to achieve the accuracy and signal stability levels required by radio science applications.

Depending on the nature of these refractions, transmission media are divided into dispersive (that consists of ionized particles, i.e. Solar Wind and Ionosphere) and non-dispersive ones (the refraction is caused by neutral particles: Earth Troposphere). While dispersive noises are successfully removed by multifrequency combinations (as for GPS with the well-known ionofree combination), the most accurate estimation of tropospheric noise is obtained using microwave radiometers (MWR). As the use of MWRs suffers from strong operational limitations (rain and heavy clouds conditions), the GNSS-based processing is still widely adopted to provide a cost-effective, all-weather condition estimation of the troposphere path delay.

This work describes the development process and reports the results of a GNSS analysis code specifically aimed to the estimation of the path delays introduced by the troposphere above deep space complexes, to be used for the calibration of Range and Doppler radiometric data.

The code has been developed by the Radio Science Laboratory of the University of Bologna in Forlì, and is currently in the testing phase. To this aim, the preliminary output is compared to MWR measurements and IGS TropoSINEX products in order to assess the reliability of the estimate.

The software works using ionofree carrier-phase observables and is based upon a double-difference approach, in which the GNSS receiver placed nearby the Deep Space receiver acts as the rover station. Several baselines are then created with various IGS and EUREF stations (master or reference stations) in order to perform the differentiation. The code relies on several IGS products, like SP3 precise orbits and SINEX positions available for the master stations in order to remove several error components, while the phase ambiguities (both wide and narrow lane) are resolved using the modified LAMBDA (MLAMBDA) method.

The double-differenced data are then processed by a Kalman Filter that estimates the contingent positioning error of the rover station, its Zenith Wet Delay (ZWD) and the residual phase ambiguities. On the other hand, the Zenith Hydrostatic Delay (ZHD) is preliminarily computed using a mathematical model, based on surface meteorological measurements.

The final product of the developed code is an output file containing the estimated ZWD and ZHD time-series in a format compatible with the major orbit determination software, e.g. the CSP card format (TRK-2-23) used by NASA JPL's Orbit Determination Program.