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POD and PPP with multi-frequency processing

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Precise Orbit Determination (POD) and Precise Point Positioning (PPP) are methods for estimating the orbits and clocks of GNSS satellites and the precise positions and clocks of user receivers. These methods are traditionally based on processing the ionosphere-free combination. With this combination, the delay introduced in the signal when passing through the ionosphere is removed, taking advantage of the dependency of this delay with the square of the frequency. It is also possible to process the individual frequencies, but in this case it is needed to properly model the ionospheric delay. This modelling is usually very challenging, as the electron content in the ionosphere experiences important temporal and spatial variations. These two options define the two main kinds of processing: the dual-frequency ionosphere-free processing, typically used in the POD and in certain applications of PPP, and the single-frequency processing with estimation or modelisation of the ionosphere, mostly used in the PPP processing.

In magicGNSS, a software tool developed by GMV for POD and PPP, a hybrid approach has been implemented. This approach combines observations from any number of individual frequencies and any number of ionosphere-free combinations of these frequencies. In such a way, the observations of ionosphere-free combination allow a better estimation of positions and orbits, while the inclusion of observations from individual frequencies allows to estimate the ionospheric delay and to reduce the noise of the solution. It is also possible to include other kind of combinations, such as geometry-free combination, instead of processing individual frequencies. The joint processing of all the frequencies for all the constellations requires both the estimation or modelisation of ionospheric delay and the estimation of inter-frequency biases. The ionospheric delay can be estimated from the single-frequency or dual-frequency geometry-free observations, but it is also possible to use a-priori information based on ionospheric models, on external estimations and on the expected behavior of the ionosphere. The inter-frequency biases appear because the delay of the signal inside the transmitter and the receiver strongly depends on its frequency. However, it is possible to include constraints in the estimator regarding these delays, assuming small variations over time.

By using different types of combinations, all the available information from GNSS systems can be included in the processing. This is especially interesting for the case of Galileo satellites, which transmit in several frequencies, and the GPS IIF satellites, which transmit in L5 in addition to the traditional L1 and L2. Several experiments have been performed, to assess the improvement on performance of POD and PPP when using all the constellations and all the available frequencies for each constellation. This paper describes the new approach of multi-frequency processing, including the estimation of biases and ionospheric delays impacting on GNSS observations, and presents the results of the performed experimentation activities to assess the benefits in POD and PPP algorithms.