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Satellite clock corrections estimation to accomplish real time ppp: experiments for brazilian real time network

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The real time PPP method requires the availability of real time precise orbits and satellites clocks corrections. Currently, it is possible to apply the solutions of clocks and orbits available by BKG within the context of IGS Pilot project or by using the operational predicted IGU ephemeris. The accuracy of the satellite position available in the IGU is enough for several applications requiring good quality. However, the satellites clocks corrections do not provide enough accuracy (3 ns $\sim$ 0.9 m) to accomplish real time PPP with the same level of accuracy. Therefore, for real time PPP application it is necessary to further research and develop appropriated methodologies for estimating the satellite clock corrections in real time with better accuracy. Currently, it is possible to apply the real time solutions of clocks and orbits available by Federal Agency for Cartography and Geodesy (BKG) within the context of IGS Pilot project. The BKG corrections are disseminated by a new proposed format of the RTCM 3.x and can be applied in the broadcasted orbits and clocks. Some investigations have been proposed for the estimation of the satellite clock corrections using GNSS code and phase observable at the double difference level between satellites and epochs (MERVAT, DOUSA, 2007). Another possibility consists of applying a Kalman Filter in the PPP network mode (HAUSCHILD, 2010) and it is also possible the integration of both methods, using network PPP and observables at double difference level in specific time intervals (ZHANG; LI; GUO, 2010). For this work the methodology adopted consists in the estimation of the satellite clock corrections based on the data adjustment in the PPP mode, but for a network of GNSS stations. The clock solution can be solved by using two types of observables: code smoothed by carrier phase or undifferenced code together with carrier phase. In the former, we estimate receiver clock error; satellite clock correction and troposphere, considering that the phase ambiguities are eliminated when applying differences between consecutive epochs. However, when using undifferenced code and phase, the ambiguities may be estimated together with receiver clock errors, satellite clock corrections and troposphere parameters. In both strategies it is also possible to correct the troposphere delay from a Numerical Weather Forecast Model instead of estimating it. The prediction of the satellite clock correction can be performed using a straight line or a second degree polynomial using the time series of the estimated satellites clocks. To estimate satellite clock correction and to accomplish real time PPP two pieces of software have been developed, respectively, “RT_PPP” and “RT_SAT_CLOCK”. The system (RT_PPP) is able to process GNSS code and phase data using precise ephemeris and precise satellites clocks corrections together with several corrections required for PPP. In the software RT_SAT_CLOCK we apply a Kalman filter algorithm to estimate satellite clock correction in the network PPP mode. In this case, all PPP corrections must be applied for each station. The experiments were generated in real time and post-processed mode (simulating real time) considering data from the Brazilian continuous GPS network and also from the IGS network in a global satellite clock solution. We have used IGU ephemeris for satellite position and estimated the satellite clock corrections, performing the updates as soon as new ephemeris files were available. Experiments were accomplished in order to assess the accuracy of the estimated clocks when using the Brazilian Numerical Weather Forecast Model (BNWFM) from CPTEC/INPE and also using the ZTD from European Centre for Medium-Range Weather Forecasts (ECMWF) together with Vienna Mapping Function VMF or estimating troposphere with clocks and ambiguities in the Kalman Filter. The daily precision of the estimated satellite clock corrections reached the order of 0.15 nanoseconds. The clocks were applied in the Real Time PPP for Brazilian network stations and also for flight test of the Brazilian airplanes and the results show that it is possible to accomplish real time PPP in the static and kinematic modes with accuracy of the order of 10 to 20 cm, respectively.