

Achieving sub-nanosecond accuracy using GNSS Code based Time Transfer with Continuous Kalman Filter

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The NavIC System Time is physically realized through an ensemble of atomic frequency standards and is steered to the reference timescale system. The NavIC System Time is traceable to the Indian Standard Time i.e. UTC(NPLI) through the primary time transfer technique namely Two-way Satellite Time & Frequency Transfer (TWSTFT) with an accuracy of ~ 1 ns. However, as a backup option, the GNSS All-In-View (GNSS AV) time transfer technique is also operational which provides an accuracy of ~ 5 ns.

In the GNSS AV method, the first step is to estimate the time offset of local timescale with respect to GPS System Time realized by a well calibrated GNSS receiver at the site. This offset is estimated in real time by processing the raw pseudo range (code) measurements together with the satellite broadcast ephemeris and clock information. Therefore, the accuracy of this method majorly depends on the accuracy of the code range measurements together with the uncertainties in clock estimation and model uncertainties of the atmospheric corrections. By employing an advanced GNSS time transfer technique based on Precise Point Positioning (PPP), an accuracy of sub-nanosecond level can be achieved [1]. The PPP based time transfer technique utilizes the carrier phase measurements together with the precise products consisting of the satellite ephemeris, satellite clock offsets and the atmosphere corrections available at the IGS using which the improved accuracy is achieved as compared to the standard method. The usage of this method therefore is subject to the availability of external inputs. Further, the combined result for measurements spanning multiple days contains day-boundary discontinuities [2] and therefore one should correct for the shifts in the estimated time offset. Figure 1 show the timescale-GPS processed through online tool by Natural Resources Canada (NRCAN) after correcting day-boundary discontinuities.

An attempt has been made to improve the accuracy of the results obtained using the code range measurements by implementing an additional estimation technique viz. Kalman Filter. Wherein, the Kalman filter is applied on the time offset measurements computed using code measurements, which are noisier compared to carrier measurements, to estimate the precise phase and frequency offset. The results are verified by implementing the Kalman Filter on the time offset obtained using raw code range measurements available at 30s interval as shown in Figure 2. The results obtained using two methods are compared for the phase and frequency offset estimated. It can be observed that this method can also provide sub-nanosecond level accuracy as can be achieved using PPP based time transfer. Further, the implementation of this method does not depend on any external inputs thus making it a potential method for implementing in real time applications.

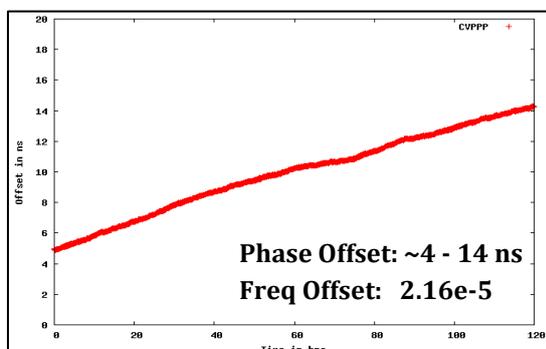


Figure1. TS – GPS using CVPPP after correcting day-boundary discontinuities

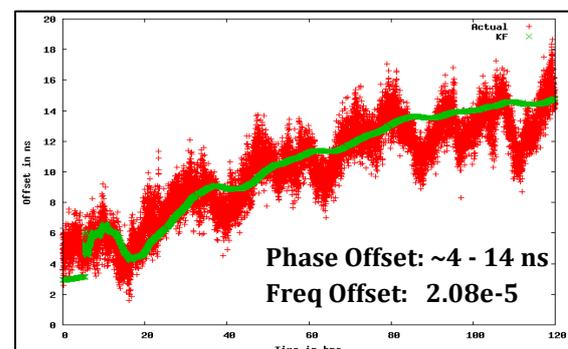


Figure2. TS – GPS using Code Measurements with Continuous Kalman Filter

1. Diego Orgiazzi, Patrizia Tavella and François Lahaye, Experimental Assessment of the Time Transfer Capability of Precise Point Positioning (PPP), 0-7803-9052-0/05/ 2005 IEEE.
2. Pascale Defraigne, Nicolas Guyennon, and Carine Bruyninx, GPS Time and Frequency Transfer: PPP and Phase-Only Analysis, Hindawi Publishing Corporation, International Journal of Navigation and Observation, Volume 2008, Article ID 175468, 7 pages, doi:10.1155/2008/175468.