Application of miniaturized atomic clocks in kinematic GNSS Single Point Positioning

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Kinematic GNSS Single Point Positioning (SPP) requires epoch-wise estimation of a receiver synchronization error w.r.t. GPS system time. Modeling this error source will improve the accuracy of the up-coordinate and make the adjustment more robust. However, due to the limited long-term (> 1 s) frequency stability of the receiver's internal quartz oscillator and its generally poor accuracy, clock modeling is not possible with standard devices. Recent developments of low-priced miniaturized atomic clocks, especially Chip Scale Atomic Clocks (CSAC), allow for usage in kinematic GNSS applications. Thus, replacing the internal oscillator by one of these more stable external frequency standards opens up the possibility of modeling the receiver clock error in a physically justified way. In our case study, we will investigate the impact of such oscillators on GNSS code observations and kinematic positioning.

In a first part, we will discuss the performance of three different atomic frequency standards—namely Symmetricom SA.45s CSAC, Jackson Labs LN CSAC, and Stanford Research Systems PRS10—that were characterized in terms of their frequency stabilities at Physikalisch-Technische Bundesanstalt in Braunschweig, Germany. The devices' 10 MHz output signals were compared to the phase of an active Hydrogen-Maser by means of a phase comparator with a selectable sampling interval of 1 s or 100 s. In principle, the resulting Allan variances show good agreement with manufacturer's data. However, these values seem to be too optimistic in some cases, especially for averaging times below 100 s. Our results will be used as adequate input data for receiver clock modeling in GNSS SPP.

In order to analyse the impact of clock performance when connected to GNSS receivers, a static experiment was carried out on the rooftop of the Geodetic Institute Hannover. The measurement configuration consisted of five JAVAD receivers of the same type connected to one geodetic Leica choke ring antenna. Four receivers were driven by the three abovementioned atomic clocks (JL CSAC provides two different 10 MHz signals) and one by its internal oscillator. We collected data for three days with a sampling interval of 1 s. We will present the concept of clock modeling in an Extended Kalman Filter for code-based SPP. Our approach is evaluated with the abovementioned real GNSS observation data. Preliminary results show improvements of the up-coordinate residuals RMS of up to 23 % when applying receiver clock modeling. This proves the validity of our approach and thus its feasibility and applicability for code-based kinematic GNSS applications. Finally, we will test our concept with true kinematic data sets taking also Doppler observations into account.