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A computationally efficient approach for isolating satellite phase fractional cycle biases based on Kalman filter

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Integer ambiguity resolution (AR) can significantly shorten the convergence time and improve the accuracy of Precise Point Positioning (PPP). Phase fractional cycle biases (FCB) originating from satellites destroy the integer nature of carrier phase ambiguities. To isolate the satellite FCB, observations from a global reference network are required. Firstly, float ambiguities containing FCBs are obtained by PPP processing. Secondly, the least squares method (LSM) is adopted to recover FCBs from all the float ambiguities. Finally, the estimated FCB products can be applied by the user to achieve PPP-AR. During the estimation of FCB, the LSM step can be very time-consuming, considering the large number of observations from hundreds of stations and thousands of epochs. In addition, iterations are required to deal with the one-cycle inconsistency among observations. Since the integer ambiguities are derived by directly rounding float ambiguities, the one-cycle inconsistency arises whenever the fractional parts of float ambiguities exceed the rounding boundary (e.g., 0.5 and -0.5). The iterations of LSM and the large number of observations require a long time to finish the estimation. Consequently, only a sparse global network containing a limited number of stations was processed in former research.

In this paper, we propose to isolate the FCB based on a Kalman filter. The large number of observations is handled epoch-by-epoch, which significantly reduces the dimension of the involved matrix and accelerates the computation. In addition, it is also suitable for real-time applications. As for the one-cycle inconsistency, a pre-elimination method is developed to avoid the iteration of the whole process. According to the analysis of the derived satellite FCB products, we find that both wide-lane (WL) and narrow-lane (NL) FCB are very stable over time (e.g., WL FCB over several days rsp. NL FCB over tens of minutes). The stability implies that the satellite FCB can be removed by previous estimation.

After subtraction of the satellite FCB, the receiver FCB can be determined. Theoretically, the receiver FCBs derived from different satellite observations should be the same for a single station. Thereby, the one-cycle inconsistency among satellites can be detected and eliminated by adjusting the corresponding receiver FCB. Here, stations can be handled individually to obtain “clean” FCB observations. In an experiment, 24 h observations from 200 stations are processed to estimate GPS FCB. The process finishes in one hour using a personal computer. The estimated WL FCB has a good consistency with existing WL FCB products (e.g., CNES, WHU-SGG). All differences are within $\pm$ 0.1 cycles, which indicates the correctness of the proposed approach. For NL FCB, all differences are within $\pm$ 0.2 cycles. Concerning the NL wavelength (10.7 cm), the slightly worse NL FCB may be ascribed to different PPP processing strategies. The state-based approach of the Kalman filter also allows for a more realistic modeling of stochastic parameters, which will be investigated in future research.