4D Real Time Kinematic Positioning

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SUMMARY

The existing carrier-phase based real time kinematic positioning provides three dimensional positioning solutions only. The relative receiver clock biases are estimable with code-based differential GPS solutions, but being limited to the accuracy of 10 nanoseconds or so. Many applications, such as time synchronizations between GNSS network stations, require precise relative clock solutions. This paper presents the models and algorithms for four dimensional real time kinematic (4D-RTK) positioning and experiment results. The existing 3D RTK model uses double-differenced (DD) code and phase measurements. With this model, relative position biases and float ambiguities are determined simultaneously, and the integer ambiguities are then searched and fixed to their integer solutions based on so-called least squares (ILS) procedures. Next, the 3 D position states are computed with the integer fixed DD phase measurements. To estimate the relative clock bias, one additional single differenced (SD) phase observational equation can be introduced for the reference satellite, in which there are three types of parameters: 3D position parameters common to these in the DD models, one SD phase bias, and one relative clock bias. Together with SD code observational equations, both SD phase bias and relative clock bias are estimable with the given 3D position solutions already precisely determined from the DD measurements. Due to the constant nature of the SD phase bias, the clock estimate can be improved from time to time, theoretically to the accuracy in the same order as the vertical position solutions of the RTK system. In practice, for easy transition of references satellites from time to time, all SD code and phase measurements are used to estimate the clock bias and SD phase biases for satellites. Experiment studies were performed with a 24-h GPS data set from the US CORS network. At each epoch, three position and one clock parameters are obtained. The results demonstrated that while the position error range between +/-5 centimetres, the standard deviations of the clock biases converge from about 40 centimetres to 4 centimetres within 10min. In summary, the relative clock estimation to the accuracy of 0.1to 0.2 nanoseconds were achieved with the experiment data set, showing the consistence between the 4D RTK theory and practice.

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