Evaluation of RTK-GPS Performance with Low-cost Single-frequency GPS Receivers

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INTRODUCTION

RTK-GPS (realtime kinematic GPS) is one of the most precise positioning technology, with which users can obtain cm-level accuracy of the position in real-time by processing carrier-phase measurements of GPS signals. It is generally considered that geodetic-grade dual-frequency GPS receivers are necessary to achieve practical performance of RTK-GPS. Low-cost single-frequency GPS receivers have not been applicable to RTK-GPS because of these higher receiver noise, worse resistance to multipath and poorer ambiguity resolution performance. However, the geodetic-grade receivers have been still very expensive compared to the consumer-grade ones. This is one of the reasons why the RTK-GPS technology is still not popular and is used only for limited areas of applications like surveying. If the low-cost receivers were available for RTK-GPS, larger number of users, who require more accurate positions, would intend to utilize this technique. More applications of RTK-GPS, which has not been practical due to the cost issues, would become feasible.

The objectives of this study are to evaluate the RTK-GPS performance with the consumer-grade single-frequency receivers and to clarify the issues to apply them to RTK-GPS.

EVALUATION METHODS

At first, we measured the raw performances of the low-cost antennas/receivers, including antenna PCV (phase center variation), carrier-phase multipath, code-multipath and C/N0 (carrier to noise power density ratio), by the field calibration method. In this way, we gathered the GPS observation data from the target antenna/receiver and the reference antenna/receiver in the vicinity of the target. With both receivers' carrier-phase measurements, we determined the relative phase center position and PCV with respect to the reference phase center position. In the same time, the carrier-phase multipath and the carrier tracking noise could be estimated as the post-fit residuals of the carrier-phase measurement. The slant ionospheric delay was also estimated as the geometry-free linear combination of dual-frequency phase measurements of the reference receiver. The target receiver code minus phase observables corrected by the ionospheric delay variation shows the code multipath and the pseudorange noise of the target antenna/receiver. The C/N0 were obtained as one of the receiver raw measurements.

Secondary, using the raw pseudorange and carrier-phase measurements in the first step, the accuracy of continuous RTK-GPS and the proper fix rate of integer ambiguities were evaluated, at the baseline length of 1 m and 7 km. The RTK-GPS initialization performance was measured as the distribution of TTFF (time to first fix) with integer ambiguity resolution.

To measure the performance in the mobile environment RTK-GPS, the low-cost antenna mounted on the rooftop of a car and connected the receiver. We drove the car around the reference station, under baseline length of 1 km. The raw GPS observation data were logged and processed by the post-processing kinematic GPS analysis software. The integer ambiguity fix rate was evaluated for mobile RTK-GPS with the low-cost receiver/antenna.

We tried to evaluate the performances described above with the combinations of various antennas and receivers. For the target antennas, u-blox ANN-MS, AeroAntenna AT575, AntCom 4G15A2-XS-3, MicroPulse 2335TB, and Pioneer GPS-M1ZZ ant were used. Most of them are patch-type antennas with LNA. For the target receivers, we employed u-blox AEK-4T, u-blox EVK-5H, NovAtel Superstar II, Hemisphere Crescent and Garmin GPS-15 with raw measurement output. For the reference, a geodetic-grade dual-frequency antenna/receiver NovAtel GPS-702-GG/OEMV-3 were used.

RESULTS AND CONSIDERATIONS

As to the code measurements, the difference of antennas between geodetic-grade antennas/receivers and consumer-grade ones was large and much affected to the positioning accuracy, however, there was no large difference between carrier-phase performances between them. For the RTK-GPS TTFF with integer ambiguity resolution, the performance with single-frequency was much degraded compared to dual-frequency. The fix rate in the mobile environment RTK-GPS was also poor with the low-cost single frequency antenna/receiver.

CONCLUSION

The RTK-GPS with low-cost single-frequency receiver/antenna is feasible for the continuous precise positioning. However, it is not practical in the mobile environment RTK-GPS with many cycle-slips, because of the poor initialization performance.