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GNSS Global Real-time Augmentation Positioning: Real-time Precise Satellite Clock Estimation, Prototype System Construction and Performance Analysis

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Abstract

Lots of ambiguities in un-differenced (UD) model lead to lower calculation efficiency, which isn’t appropriate for the high-frequency real-time GNSS clock estimation, like 1Hz. Mixed differenced model fusing UD pseudo-range and epoch-differenced (ED) phase observations has been introduced into real-time clock estimation. In this contribution, we extend the mixed differenced model for realizing multi-GNSS real-time clock high-frequency updating and a rigorous comparison and analysis on same conditions are performed to achieve the best real-time clock estimation performance taking the efficiency, accuracy, consistency and reliability into consideration. Based on the multi-GNSS real-time data streams provided by multi-GNSS Experiment (MGEX) and Wuhan University, GPS+Beidou+Galileo global real-time augmentation positioning prototype system is designed and constructed, including real-time precise orbit determination, real-time precise clock estimation, real-time Precise Point Positioning (RT-PPP) and real-time Standard Point Positioning (RT-SPP). The statistical analysis of the 6h-predicted real-time orbits shows that the root mean square (RMS) in radial direction is about 1cm to 5cm for GPS, Beidou MEO and Galileo satellites, and about 10cm for Beidou GEO and IGSO satellites. Using the mixed differenced estimation model, the prototype system can realize high-efficient real-time satellite absolute clock estimation with no constant clock-bias and can be used for high-frequency augmentation message updating (such as 1 Hz). The real-time augmentation message signal-in-space ranging error (SISRE), a comprehensive accuracy of orbit and clock and effecting the users’ actual positioning performance, is introduced to evaluate and analyze the performance of GPS+Beidou+Galileo global real-time augmentation positioning system. The statistical analysis of real-time augmentation message SISRE is about 4cm to 7cm for GPS, while 10cm for Beidou IGSO/MEO, Galileo and about 30cm for Beidou GEO satellites. The real-time positioning results prove that the GPS+BeiDou+Galileo RT-PPP comparing to GPS-only can effectively accelerate convergence time by about 60%, improve the positioning accuracy by about 30% and obtain averaged RMS 4cm in horizontal and 6cm in vertical; additionally RT-PPP accuracy in the prototype system can realize positioning accuracy with about averaged RMS 1m in horizontal and 1.5m to 2m in vertical, which are improved by 60% and 70% to SPP based on broadcast ephemeris, respectively.

Keywords: GPS/BeiDou/Galileo; Real-time Augmentation Positioning System; Real-time Precise Clock Estimation; Precise Orbit Estimation; PPP; Prototype System Construction

1 Introduction

Up to the end of 2016, China had launched 23 BeiDou satellites and 14 BeiDou-2 in-orbit satellites including 5 Geostationary Earth Orbit (GEO), 6 Inclined Geo-Synchronous Orbit (IGSO) and 3 Medium Earth Orbit (MEO) satellites have been providing stable and reliable Navigation, Positioning and Time (PNT) service for the Asia-Pacific area. Shortly after completion of the

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