Evaluation of GNSS Timing Performance in China and Belarus

Comparative analysis on timing bias of GPS, GLONASS, Galileo and BDS

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***Summary*—Timing reference is one of the main importance in Compatibility and interoperability of GNSS. For high precision users, the offsets between different navigation system time lead to different timing results, which cause GNSS timing performance not comparable. Utilizing UTC as the unified time, The paper proposes the method to evaluates the bias between satellites broadcasting UTC and actual UTC, which reflects the real UTC precision obtained by users. Through the third-party data from BDS monitoring station, the evaluation uncertainty is verified under 5ns.**

Since 2015, the evaluation system of GNSS timing performance started operating in Xi'an, China. Through the international cooperation, last December we established another GNSS evaluation system in Minsk, Belarus. The paper comparative analyzes timing performance of GPS, GLONASS, Galileo and BDS.

Keywords—timing; UTC; evaluation; calibration; GNSS

I. INTRODUCTION

Each navigation system has independent system time such as GPST, GST and BDT. Although time offsets such as GGTO and BGTO seem to avoid this problem, sometimes it may add extra timing bias as time offsets erros in different navigation message [1]. In order to directly compare GNSS timing performance, we select the satellites broadcasting UTC to unify the timing reference. Here we show the evaluation method of GNSS timing performance, absolute calibration of receiver delay, verifying the evaluation uncertainty, GNSS timing bias between China and Belarus.

II. EVALUATION METHODS OF GNSS TIMING PERFORMANCE

The UTC parameter in navigation message can modify user time from GNSST to UTC, in this way GNSS timing is the process for users to obtain UTC from the satellites signal. With the real UTC published by BIPM, making the connection between the twos can evaluate the GNSS timing performance.

As the real UTC (UTCr) published by BIPM gives the values of [UTC–UTC(k)], we place the receiver in National Time Service Center, utilizing UTC(NTSC) as the local time [2]. Thus we can calculate the timing bias between satellites broadcasting UTC and UTC(NTSC), with the evaluation method showed as follows [3]:

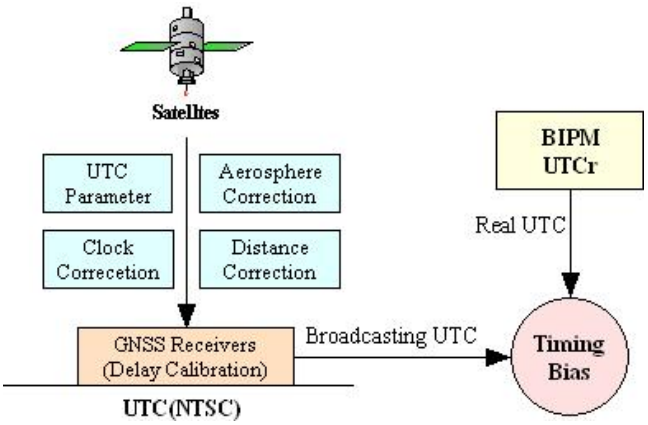

Fig. 1. Evaluation principle of GNSS timing performance.

By pseudorange modification, the UTC parameter, ionospheric and tropospheric correction, satellite clock correction and distance correction are deducted, and different satellite broadcasting UTC can be calculated by different signal structure.

To make sure the local time accurately synchronizes with UTC(NTSC), the receiver delay should be absolutely calibrated [4]. Using a GNSS hardware simulator instead of the real satellites, the absolute calibration method showed as follows [5]:

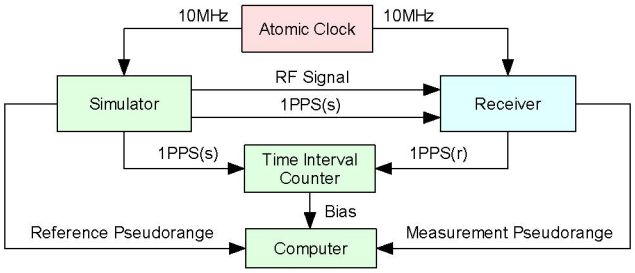

Fig. 2. Absolute calibration method of GNSS receiver delay.

Before calibration, the simulator should be self-calibrated through TtC (Time-to-Code) measurement. The receiver delay is not a fix value, and it can be defined as the group delay under different signal, also affected by temperature, SNR, reference clock phase and others [6].

III. EVALUATION UNCERTAINTY

Taking BDS for example, we select CV (Common-View) comparison data between UTC(NTSC) and BDS monitoring station to testify the uncertainty of timing evaluation method.

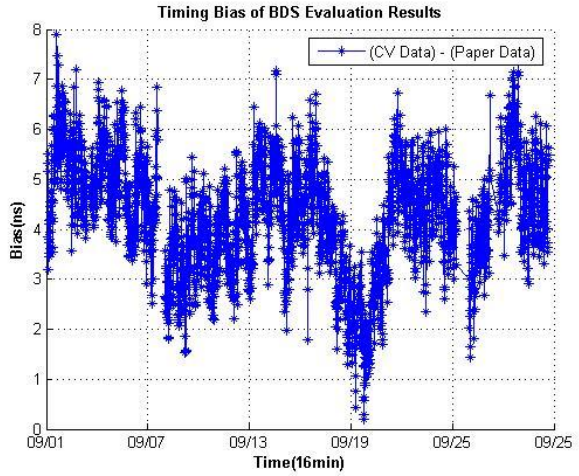

Fig. 3. Timing bias difference between CV and evaluation results.

The bias represents (see Fig. 3.) the CV data (UTC bias from BDS monitoring station) subtract evaluation results (UTC bias from our method). RMS value of the bias is 4.42ns.

IV. EVALUATION RESULTS IN CHINA AND BELARUS

Calculating the average timing bias of visible satellites evaluation results, we can get the multiple evaluation results to characterize navigation system timing performance. Here is the BDS timing evaluation results in China and Belarus under different signal structure, and testing time is from January 4th to January 10th.

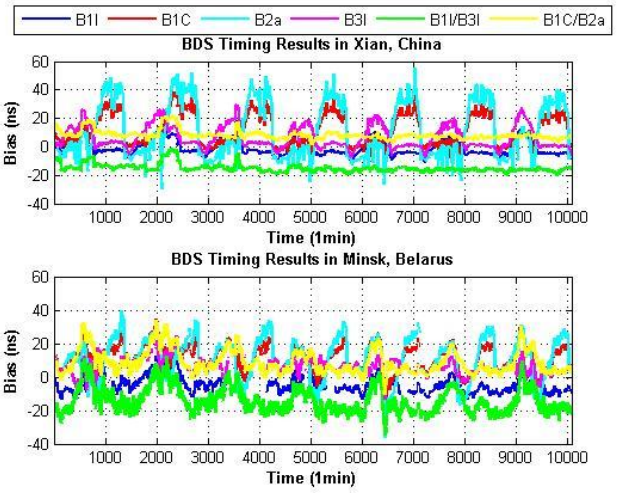

Fig. 4. BDS timing evaluation results in China and Belarus.

Taking B1I/B3I results for BDS, L1P/L2P results for GPS, L1P/L2P results for GLONASS, E1/E5a results for Galileo, Here is the GNSS timing evaluation results in China and Belarus.

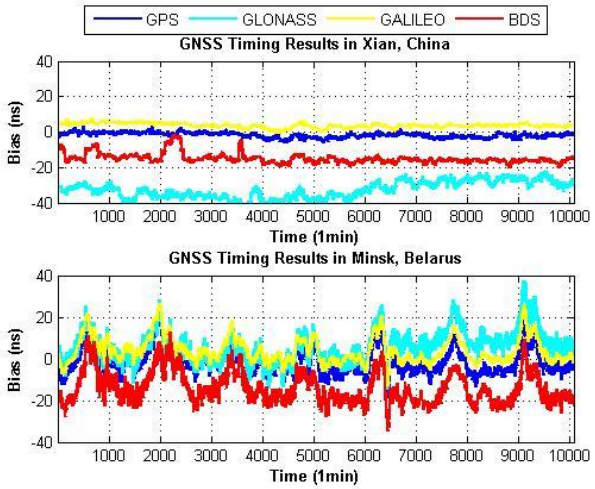

Fig. 5. GNSS timing evaluation results in China and Belarus.

Taking the absolute values of bias, through ascending order we use the 95% point corresponding to evaluation results as the timing accuracy.

TABLE I. GNSS TIMING ACCURACY (UNIT:NS)

Country	Timing Accuracy			
	GPS	***GLONASS***	***Galileo***	***BDS***
China	4.02	39.81	5.71	17.97
Belarus	12.07	20.86	15.84	30.29

V. CONCLUSIONS

Through GNSS CV between Xi'an and Minsk, we placed a rubidium clock in Belarus to synchronize with UTC(NTSC). From GNSS evaluation results, periodic variation in Belarus was affected by clock stability and CV accuracy. In China we selected BDS2 satellites (GEO/IGSO) due to better elevation and Carrier-to-Noise ratio, which caused the fluctuation of BIC and B2a results as less signals obtained. Meanwhile, the receiver in Belarus mostly tracked BDS3 satellites (MEO/IGSO), and the elevation from low to high increased the ionospheric correction errors. Until now GNSS evaluation system in Belarus is being tested, shortly PPP time transfer will be applied instead of CV as well as Kalman filtering steering the clock before formal operation.

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