Using IGS RTS Products for Real-Time Subnanosecond Level Time Transfer

Guojun Li, Yuting Lin, Fengfeng Shi, Jialin Liu, Yuting Yang and Junwen Shi

Abstract Time transfer by precise point positioning has the defect of long latency resulting from IGR products. GPS common-view can be updated once every 16 min, but with a precision of about 3–5 ns. A real-time precise point positioning time transfer algorithm using IGS RTS (Real-time Service) products was proposed. It was proved to be practical through the time transfer experiments among 4 time laboratories in Western Europe. The time transfer results show that the accuracy of the new algorithm can be reach to 0.30 ns for RMS and 0.25 ns for STD. Moreover, the stability of the time transfer results is up to 2E−15 at 1 day averaging.

Keywords IGS RTS · Time transfer · Real-time precise point positioning Subnanosecond

1 Introduction

Presently, the time transfer methods for time laboratories participating in TAI (International Atom Time) consist of GPS AV (GPS All-in-view) [1], GLONASS AV (GLONASS All-in-view) [2], GPS PPP (GPS Precise Point Positioning) [3], TWSTFT (Two-way Satellite Time and Frequency Transfer) and et al. As an important time transfer method, GPS PPP accounts for 48% time links with increasing proportion in recent years [4]. It's widely used in worldwide time laboratories.

GPS PPP has great advantages in high-precision time and frequency transfer over a long distance. It can provide a frequency stability of 1E−15 to 1E−16 over an averaging period of 1 day, moreover, as type B uncertainty is less than 0.3 ns [5, 6]. However, GPS PPP requires precise ephemeris products. The ephemeris

G. Li (✉) · Y. Lin · F. Shi · J. Liu ·
Y. Yang · J. Shi
Beijing Satellite Navigation Center, Beijing, China
e-mail: 1010551750@qq.com

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products used in BIPM for GPS PPP time transfer is the IGR (IGS Rapid), whose latency is 17–41 h [7]. The IGU is a real-time precise ephemeris product for real-time cm-level positioning. The accuracy of satellite clocks is about 0.15 ns for the IGU observed half, and is 3 ns for the IGU predicted half. Thus, the IGU is unusable for real-time subnanosecond level time transfer.

There are many researches on GPS PPP, which mainly focus on post-processing time transfer [8, 9]. Many time laboratories can hardly monitor the real-time time and frequency signals. The methods for nanosecond and subnanosecond level time transfer are far from practical applications. In this paper, firstly, we briefly introduced the organization of IGS RTS and the usages of IGS RTS products. Secondly, the accuracy and availability of IGC01 were analyzed. Thirdly, the experiment, GPS PPP time transfer with IGC01 among four time laboratories in Western Europe, proved that it was feasible to realize subnanosecond level time transfer with IGS RTS products.

2 The IGS RTS Products

2.1 The Organization of the IGS RTS

Since its inception in 1994, IGS has produced high-quality GNSS data products from a cooperative global infrastructure. The IGS products enable access to the definitive global reference frame for scientific, educational, infrastructure, and people's livelihood. With the growing developments of GNSS application, IGS users have expressed a desire for real-time products. In 2001, the IGS Real-Time Working Group (RTWG) was established [10]. During the IGS 2002 Workshop, held under the theme "Towards Real-Time", a framework for development of a real-time service (RTS) was defined [11]. In 2007, the IGS Real-time Pilot Project started to be constructed, and the RTWG declared that the pilot project had reached the initial operating capability.

The IGS RTS is overseen by the RTWG. Parts of importation organizations are as follow [12]:

(1) Analysis centers, including BKG, CNES, DLR, GFZ, ESA/ESOC, GMV, Geo++, NRCan, TUW and WUHAN, has responsibility for the generation of precise ephemeris products with observations provided by global GNSS tracking networks. In addition, NRCan, ESA/ESOC, and BKG are in charge of supervision, coordination and operation.
(2) Combination centers, including ESA/ESOC, BKG and NRCan, produce the official combination products by realigning, detection and elimination of outliners and averaging.
(3) The products distribution centers, including two primary products distribution centers and a number of secondary centers, use Networked Transport of RTCM via Internet Protocol (NTRIP) for streaming GNSS and differential correction