ABOUT COMPASS TIME AND ITS COORDINATION WITH OTHER GNSSs

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Abstract

Compass is the global satellite navigation system of China, which is in the process of construction. The first test satellite was lunched on 17 April 2007. As timekeeping infrastructure is the most important part for a GNSS system, the traceability of Compass system time (named BDT) and its coordination with other GNSSs are discussed, as is the possible link from Compass time to national standard time. The National Time Service Centre (NTSC) will most probably act as the backup timing center of the Compass system, through which Compass time can finally be traced to UTC. Offering the time offset between Compass time and other GNSS systems is considered in order to facilitate the user's need for interoperability. A prospective technique for coordinating Compass with other GNSSs, and suggestions on promoting international cooperation are proposed.

INTRODUCTION

A satellite navigation system, which is an important basic space establishment, can be of enormous benefit to society and its economy. Many countries attach importance to a satellite navigation system. China, a large developing country in the world that has spacious land and sea areas, also regards highly the construction of a satellite navigation system and has started to build its own, called CNSS (Compass Navigation Satellite System).

The space segment of CNSS consists of five geostationary earth orbit (GEO) and 30 medium earth orbit (MEO) satellites. The ground segment consists of a Master Control Station, an Upload Station, and a Monitor Station. The user segment consists of Compass user terminals, which are compatible with GPS, GLONASS, and Galileo. The carrier frequency of CNSS is 1195.14 ~ 1219.14 MHz, 1256.52 ~ 1280.52 MHz, 1559.05 ~ 1563.15 MHz, and 1587.69 ~ 1591.79 MHz. Two kinds of service will be provided. One is the Open Service, which is designed to provide users with positioning accuracy within 10 meters, velocity accuracy within 0.2 meter per second, and timing accuracy within 50 nanoseconds. The other is the Authorized Service, which will offer "safer" positioning, velocity, timing, communication services, and integrity information for authorized users.

China has sent three satellites into geostationary orbit (80 °E, 140 °E, 110.5 °E) starting in 2000, and since then the Compass Navigation Test System has been established. The existing three-satellite Compass navigation system has played an important role in offering efficient positioning, timing, communication services, and differential GPS information in surveying, telecommunications, transportation, meteorology, forest fire prevention, disaster forecast, and public security. In order to test and validate CNSS, the fourth experimental satellite was launched on February 2007 and brought into use on 26 March 2007.

COMPASS TIME AND ITS TRACEABILITY

COMPASS TIME SCALE (BEI DOU TIME, BDT)

The time reference system is at the heart of any GNSS. The Compass time reference (Bei Dou System Time), named BDT, is based on atomic time. Similar to GPS time, Compass time is a continuous time scale, which does not introduce any leap seconds. BDT is derived from the atomic clock ensemble in the Compass ground control center, and can be traced to the Chinese national official time, UTC (NTSC), which is kept by the National Time Service Center (NTSC), Chinese Academy of Sciences. To keep the BDT close to Coordinated Universal Time (UTC) or International Atomic Time (TAI), the UTC (NTSC) will be used as an intermediate time scale.

TRACEABILITY TO UTC (NTSC)

NTSC also acts as the backup timing center of the Compass system time. At present, the NTSC maintains an ensemble of 19 Agilent 5071A commercial cesium clocks, two hydrogen masers made by Symmetricom, and another two cavity-tuned hydrogen masers made by the Shanghai Astronomical Observatory (CAS). TA (NTSC) is computed with an algorithm from all of the clocks. The physical standard time and frequency signals from the timekeeping system of the Standard Time and Frequency Laboratory of NTSC are used to control both BPM short-wave and BPL long-wave time transmission stations. The master clock system consists of one hydrogen maser and one microphase-stepper.

Different techniques for the remote time link have been used at NTSC. The UTC (NTSC) is traced to UTC by, at present, a two-way satellite time and frequency transfer system and GPS multi-channel all-in-view comparison. In 2006, UTC (NTSC) was kept to within ±20ns of UTC, and so through this time link network, BDT will be synchronized with UTC within an accuracy of about 100 ns. The relationship among UTC, UTC (BDT), and UTC (NTSC) is as follows:

$$[\mathrm{UTC\ (BDT)} - \mathrm{UTC}] = [\mathrm{UTC\ (BDT)} - \mathrm{UTC\ (NTSC)}] + [\mathrm{UTC\ (NTSC)} - \mathrm{UTC}]. \qquad (1)$$

UTC(BDT) will be synchronized to UTC (NTSC) mainly by TWSTFT, and other remote time link techniques will be backups, including the GNSS common-view technique, all-in-view, and GNSS carrier-phase time transfer.

PROSPECTIVE TECHNIQUE APPROACHES TO COORDINATE COMPASS WITH OTHER GNSSs

Interoperability is one of the most important aspects in the design of the Compass timing system. The time differences of BDT–GPS and BTD–Galileo are measured in the Compass central control station, and will be broadcast as part of the navigation message of the GNSS systems. So the three navigation systems can be used simultaneously, and that will improve the reliability and availability of the navigation applications **[5,6]**.

Some technical issues included in GNSS interoperability are as follows **[5,6]**:

- Signal structure and frequency selection;
- Geodetic and time reference frames;
- Constellation configuration;
- System policies and service guarantees.

We concentrate on the determination of time offsets among Compass and other GNSS systems. Three methods are introduced here.

DETERMINATION VIA MULTI-MODE GNSS TIMING RECEIVER

In this method, the multi-mode GNSS timing receiver is used. The creation and maintenance of Compass system time, similar to other GNSS systems, is accomplished by the Compass ground control center, and it is realized by applying satellite clock corrections to Compass satellites. The space signals of all GNSS systems are received by the multi-mode GNSS timing receiver. The time offset of GNSS system time is calculated by the receiver. The principle of time offset determination is shown in Figure 1.

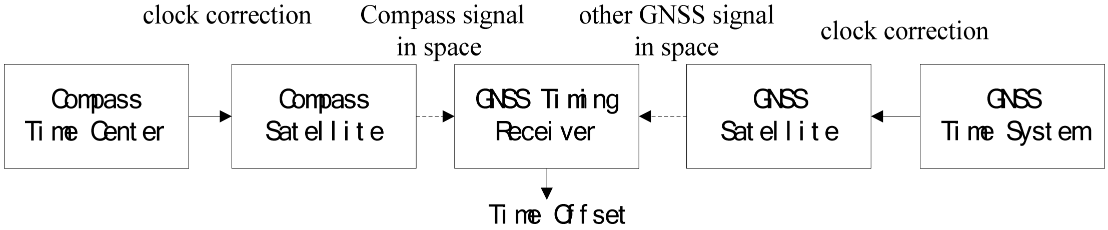

Figure 1. Determination via a multi-mode GNSS timing receiver.

Determination via Reception of Other GNSS Signals in the Compass Time Center

In the time center of Compass, the 1 pps (1 pulse per second) signal of Compass system time is input to one channel of a time-interval counter; the 1 pps output of the GNSS timing receiver is input to another channel. Because the output of one GNSS receiver is the realization of its system time, the time offset between Compass time and another GNSS system time is measured. The principle of time offset determination is shown in Figure 2.

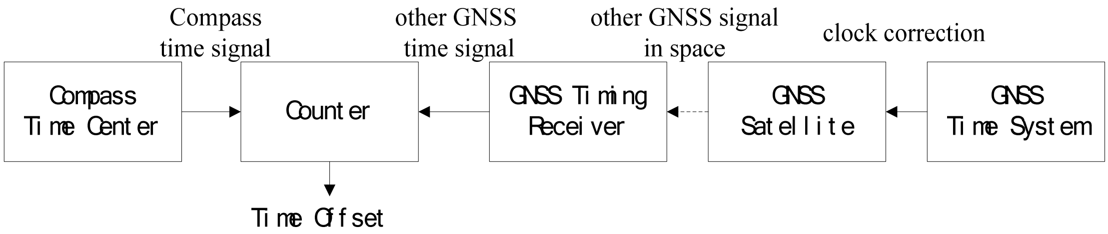

Figure 2. Determination via reception of other GNSS systems signal in the Compass time center.

Determination via Time Comparison with Other GNSS Time Centers

This method is realized by establishing a remote time link between the Compass ground control station and other GNSS time centers, by two-way satellite time and frequency transfer (TWSTFT) and/or GNSS common view (CV). The principle of time offset determination is shown in Figure 3.

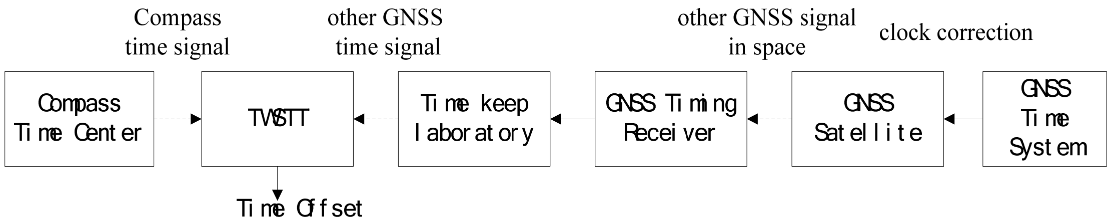

Figure 3. Determination via time comparison with other GNSS time centers.

Comparing the three methods mentioned above, the third is high in accuracy, but high in cost also. If the TWSTFT link is unavailable between two time centers, then an intermediate station must be added, which will be higher in cost and complex in operation. The first is the most economical one.

CONCLUSION

On the basis of the Compass Navigation Test System, China has started to build CNSS (the Compass Navigation Satellite System). The first satellite of CNSS, which is in medium earth orbit (MEO), was launched in April 2007, and is under In-Orbit Validation at present. The system has been implemented in the expected time. The system is expected to cover China and parts of neighboring countries by 2008, and then step by step develop into a global constellation. CSNPC (the China Satellite Navigation Project Center) has charge of the research, building, and management of CNSS.

In order to promote the compatibility and interoperability between the Compass Navigation Satellite System and other GNSS systems, and to improve the application of positioning, navigation, and timing services, China is willing to cooperate with other countries (including the EU) in order to develop the satellite navigation industry together.

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