TIMEKEEPING OF NTSC IN RECENT YEARS

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Abstract

Since 2004, the National Time Service Center of Chinese Academy of Sciences (NTSC) has been greatly improving in the number of atomic clocks, time comparison system, remote time transfer system, and so on. With the improvement of frequency control technology for the master atomic clock, the accuracy and stability of the Coordinated Universal Time UTC (NTSC) have also noticeably increased. From 2008 to 2009, the deviation between UTC (NTSC) and UTC has been less than 20 ns. The middle-term and long-term stability of the local atomic time TA (NTSC) has also been greatly improved.

In this paper, the timekeeping system of NTSC and the remote Time Transfer System (GNSS CV and TWSTFT) are introduced first, and then the algorithm of TA (NTSC) is briefly described. The performance of the timekeeping system is discussed after an introduction to the hardware and local atomic time algorithm. Finally, we discuss the accurate and stability of UTC (NTSC) and TA (NTSC) by using the actual data of UTC - UTC (NTSC) and TAI - TA (NTSC) in recent years, which are downloaded from the BIPM Web site. The result of the discussion shows that the timekeeping technology and the time scale algorithm of NTSC have been improved in recent years.

I. INTRODUCTION

The National Time Service Center of Chinese Academy of Sciences (NTSC) is a professional institute that is engaged in the study on the generation, maintenance, dissemination, and application of time and frequency. Since 2004, NTSC has imported 13 sets of 5071A cesium clocks with high-quality cesium-beam tubes and two Sigma-Tau hydrogen masers. At present, NTSC has 19 cesium clocks and four hydrogen masers. The other devices in the timekeeping system have been updated, such as the AOG/HROG, GPS receiver, counter, and so on. So the stability and reliability of the time-keeping system have been greatly improved. NTSC has built seven time transfer links by using TWSTFT; the link between NTSC and PTB has been used in the TAI calculation **[1]**.

II. TIMEKEEPING SYSTEM AND TIME TRANSFER SYSTEM

The timekeeping system of NTSC consists of 19 cesium clocks, four hydrogen masers, an SDI HROG-5, an S620 counter, a time and frequency signal distribution system, a database, a monitor system, and a distance-time comparison system. Figure 1 shows the timekeeping of NTSC.

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14. ABSTRACT
Since 2004, the National Time Service Center of Chinese Academy of Sciences (NTSC) has been greatly improving in the number of atomic clocks, time comparison system, remote time transfer system, and so on. With the improvement of frequency control technology for the master atomic clock, the accuracy and stability of the Coordinated Universal Time UTC (NTSC) have also noticeably increased. From 2008 to 2009, the deviation between UTC (NTSC) and UTC has been less than 20 ns. The middle-term and long-term stability of the local atomic time TA (NTSC) has also been greatly improved.

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Figure 1 shows the time generation system, the comparison system, and the time application system; it also shows that the distance-time transfer technologies used by NTSC are GPS Common View (GPS CV) and Two-Way Satellite Time and Frequency Transfer (TWSTFT). Now there are five GPS receivers that have been running for 5 years. Two of them are single-frequency (SF) GPS receivers, and the other three are double-frequency GPS receivers. Figures 2 and 3 show the data of UTC (NTSC) – GPS (SF1) and UTC (JATC) – GPS (SF2).

If the system difference between the UTC (NTSC) and UTC (JATC) is removed, then using the GPS CV to process the data, we can obtain the results in Figure 4, and the standard deviation of the difference is 0.703927.

The first TWSTFT by NTSC was established in the late 1990s between NTSC and NICT (CRL). Then NTSC continued studying TWSTFT. So far, NTSC has established eight TWSTFT links with NICT, NMIJ, PTB, TL, VSL (stopped), PSG (stopped), TL, KRISS, and so on. Figure 5 shows the TWSTFT NET between NTSC and other labs (the green line is the TWSTFT link).

BIPM published the TWSTFT data between NTSC and PTB in the Circular T 257 in May 2009, and then the TWSTFT data were used in the TAI calculation. Because of the malfunction of the satellite IS8, the two-way links between NTSC and the European labs were interrupted in February 2010. Recently, the new link based on satellite AM2 has been established, and some experiments have been done. The results before February 2010 are given in Figures 6 and 7.

From Figures 6 and 7, we can find that the time transfer precision is up to the mustard. The precision is better than 0.5 ns, and the A-type uncertainty compared with UTC improved from 1.5 ns to 0.5 ns **[2]**.

The other time transfer systems include an NTP time service system, a telephone time transfer system, a long-wave time and frequency transfer (BPL), a short-wave time transfer (BPM), a BPC time service, and a satellite time service.

III. ALGORITHM OF TA (NTSC)

The time scale algorithm of TA (NTSC) is classical ALGOS **[3]**. The atomic clocks are located in two places, one in Lintong where the headquarters of NTSC is located, and the other in Pucheng where the radio stations division is located. The distance between Lintong and Pucheng is about 70 km, and they are connected in real time with a microwave link. When calculating TA (NTSC), microwave time transfer and GPS CV are both used in the time comparison. Through the two time transfer methods, we can take the clock data from the Pucheng radio station, and transmit the standard time to the long-wave and short-wave radio station.

IV. PERFORMANCE OF TIMEKEEPING SYSTEM

The timekeeping system of NTSC was set up in 1970s, and from then on, it has been continually operating for more than 30 years. In 2004, the system was updated, including the hardware and software, and a new backup timekeeping system was set up in that year. Now the two timekeeping systems are running simultaneously and they back up each other. Now, the master clock of the two systems is a Sigma-Tau hydrogen maser numbered H226, which was imported from the USA in 2004. The master clock system of the two systems is shown in Figure 8.

The performance of the master clock system is one of the key factors which directly affect the time-keeping performance. Before 5 December 2007, the master clock of the NTSC timekeeping system was H226; from 6 December 2007 to 3 November 2009, the master clock was cesium clock Cs2143; and on 4 November 2009, H226 was selected as the master clock again instead of Cs2143. Figure 9 shows the performance of the master clock system when the master clock was H226 and Cs2143.

Linear fitting the HDEV data, we find the slope of fitting line is -1; that is to say, the noise exhibited by the master clock system is White PM or Flicker PM **[2,4]**. Comparing the two pictures in Figure 9, we can find that the performance of the master clock system is affected by the master atomic clock, so we should select the best clock as the master clock.

V. TAI-TA (NTSC) AND UTC-UTC (NTSC)

According to the BIPM Circular T bulletin, there are 69 laboratories maintaining their UTC (k) and providing their atomic data to the BIPM for the calculation of T AI. For 2009, the stability of TA (NTSC) and that of the other important time labs are shown in Table 1.

Part of the important timekeeping laboratories and its UTC – UTC (k) in 2009 are shown in Figure 10. Except for UTC (OP), the other labs' UTC – UTC (k) are all within ±40 ns.

In 2009, the laboratories whose |UTC-UTC(k)| were less than 20 ns are AOS, NICT, USNO, NIST, NTSC, IT and NRL, and Figure 11 shows the results. From Figure 11, one can find that, though |UTC – UTC (NTSC)| is within 20 ns, its short-term stability is less than that of the other laboratories, because the control data are too acute. Now we are studying how to steer UTC (NTSC), and hope to made UTC (NTSC) run smoothly.

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[4] H. Yuan, 2008, *"Analysis of main noise type of an atomic clock,"* **Journal of Instruments, 29** (8), 187-191.

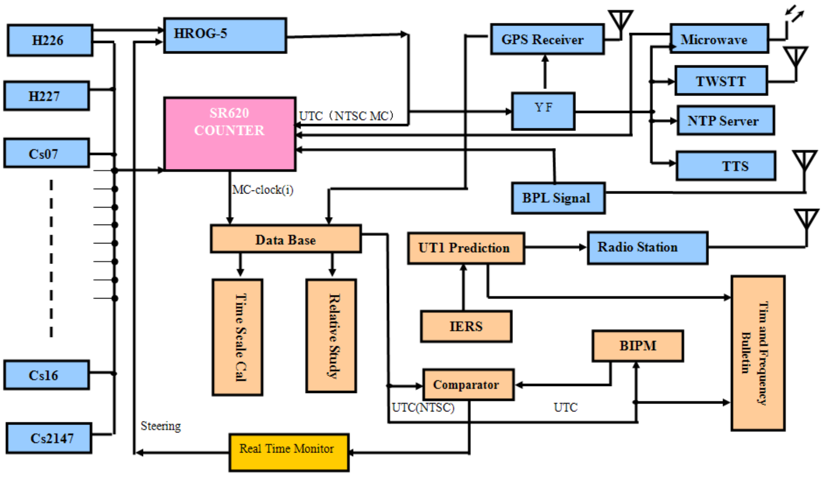


Figure 1. The timekeeping system of NTSC.

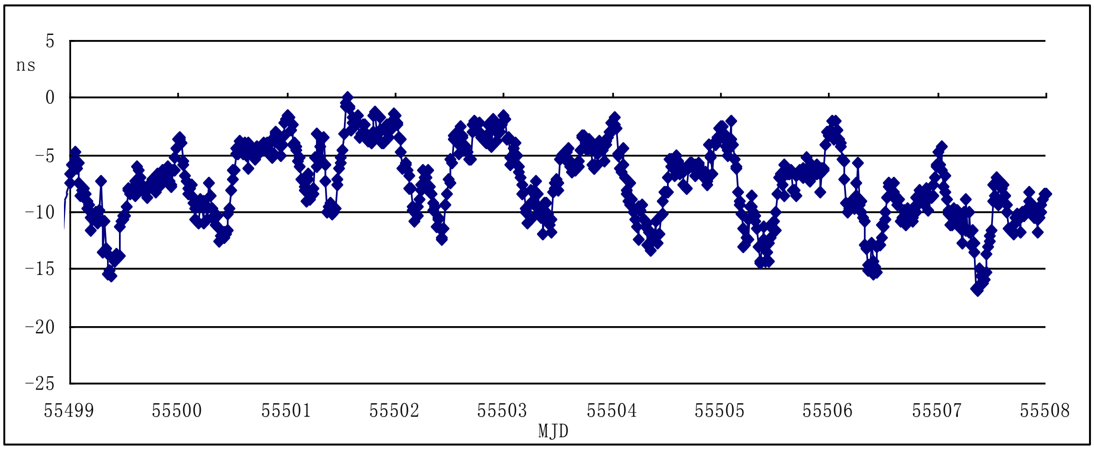


Figure 2. UTC (NTSC) – GPS (SF1).

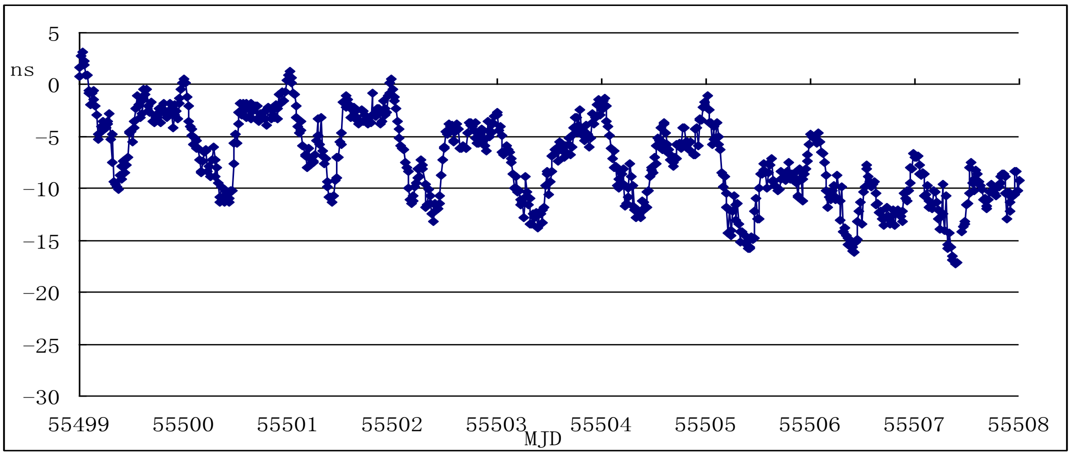


Figure 3. UTC (NTSC) – GPS (SF2).

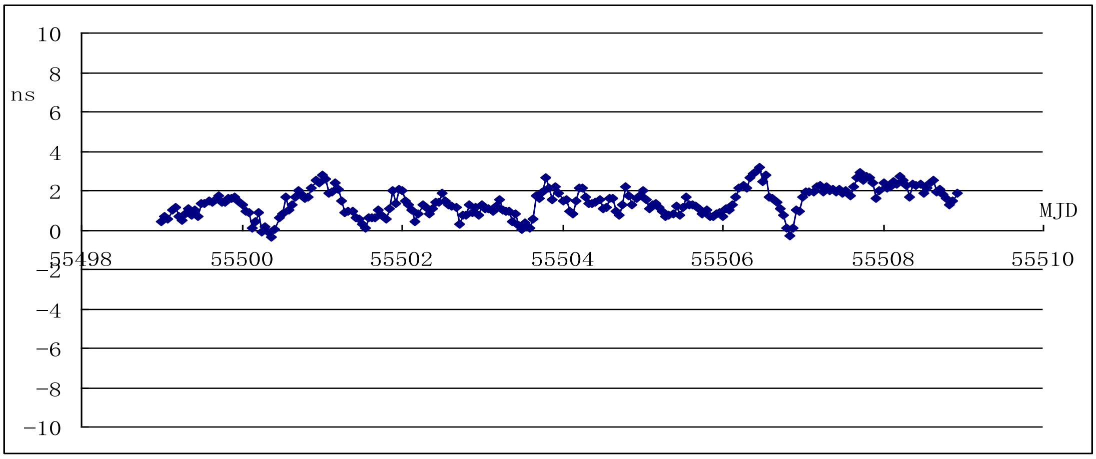


Figure 4. The difference of the two GPS SF receivers.

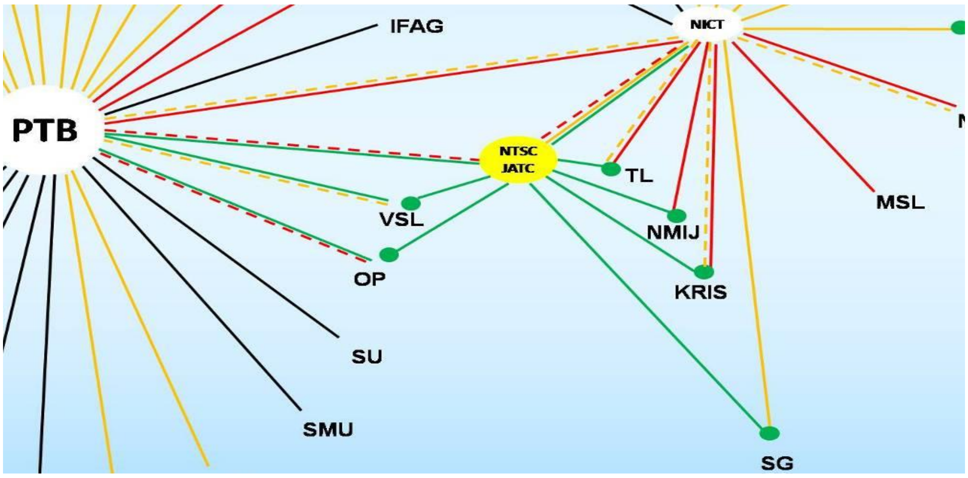


Figure 5. TWSTFT link with NTSC.

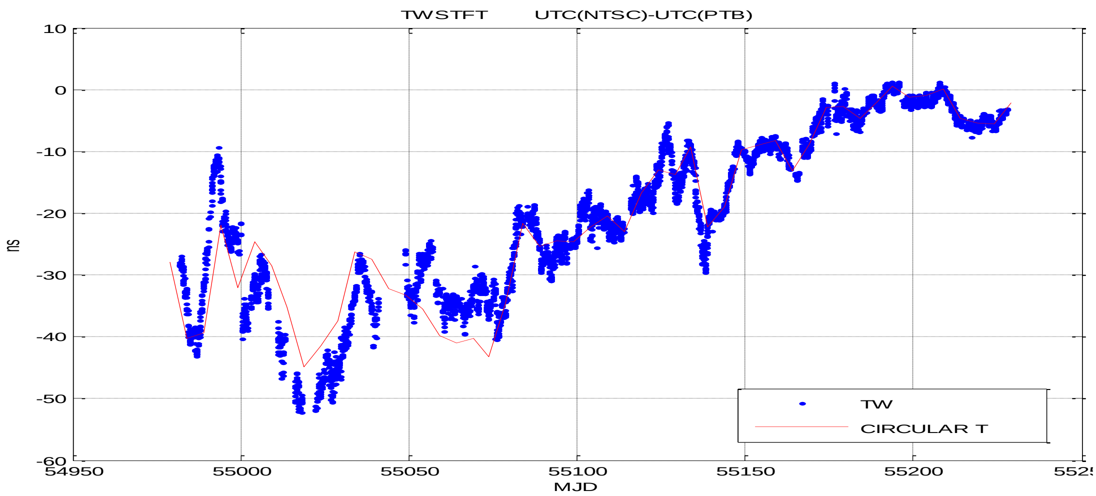


Figure 6. TWSTFT between NTSC and PTB.

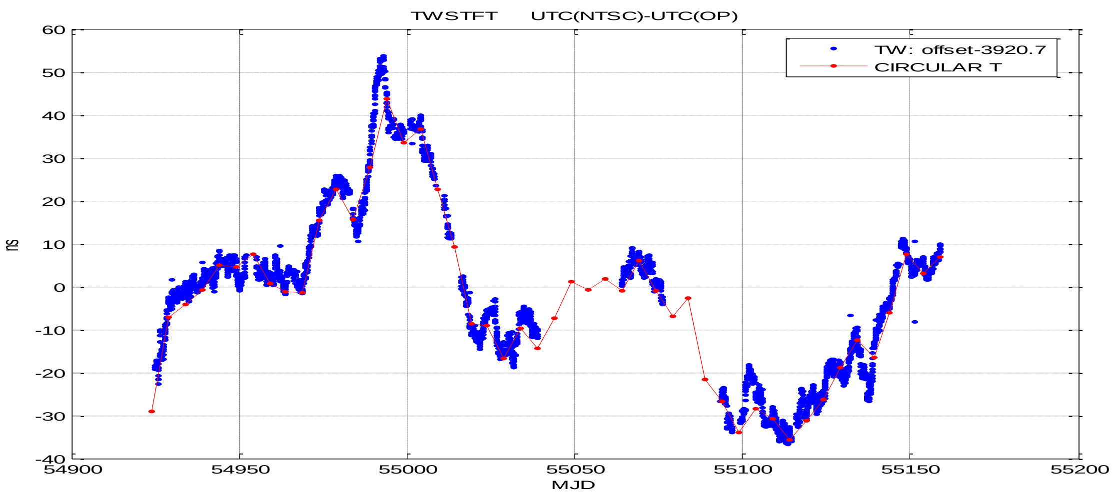


Figure 7. TWSTFT between NTSC and OP.

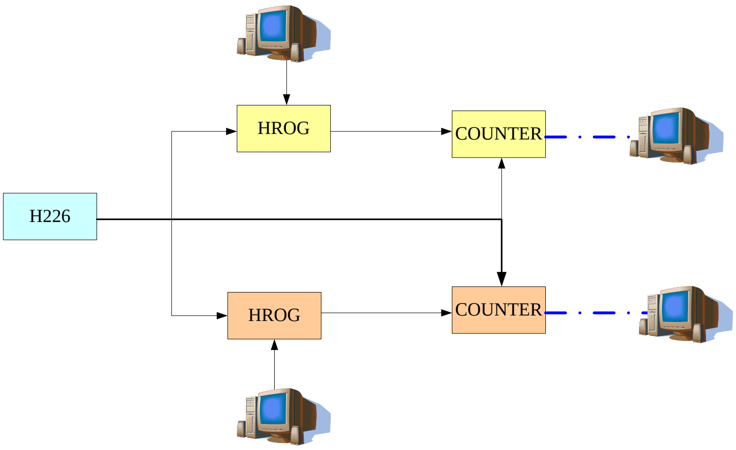
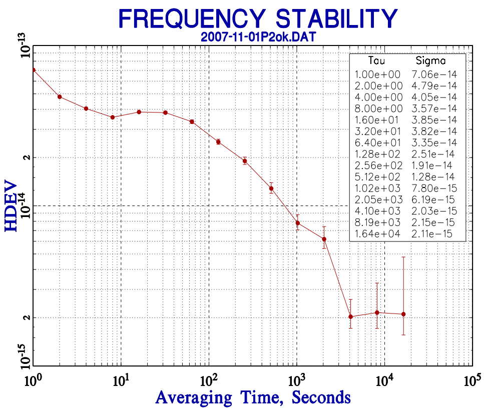
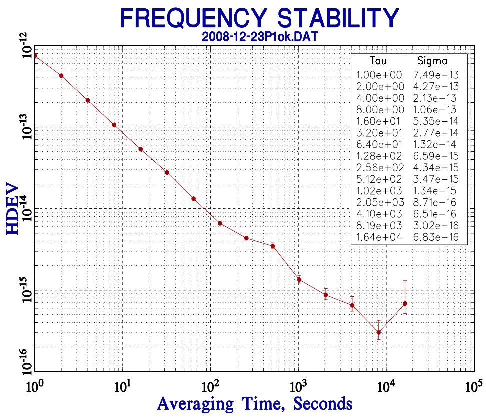


Figure 8. The master clock system.



Master clock: H226



Master clock:Cs2143

Figure 9. The performance of the master clock system.

Table 1. Stability of TA (k) (data from BIPM Web site).

τ	CH	F	NICT	NIST	NTSC	PTB	TL	USNO
5days	5.6E-15	5.5E-15	3.9E-15	2.8E-15	4.2E-15	5.4E-15	4.1E-15	3.1E-15
10days	4.1E-15	3.1E-15	2.5E-15	1.8E-15	3.0E-15	4.1E-15	2.7E-15	1.3E-15
30days	3.3E-15	1.5E-15	1.3E-15	1.2E-15	1.5E-15	2.6E-15	3.1E-15	6.9E-16
60days	3.2E-15	8.8E-16	8.3E-16	1.7E-15	1.2E-15	2.3E-15	2.9E-15	7.9E-16

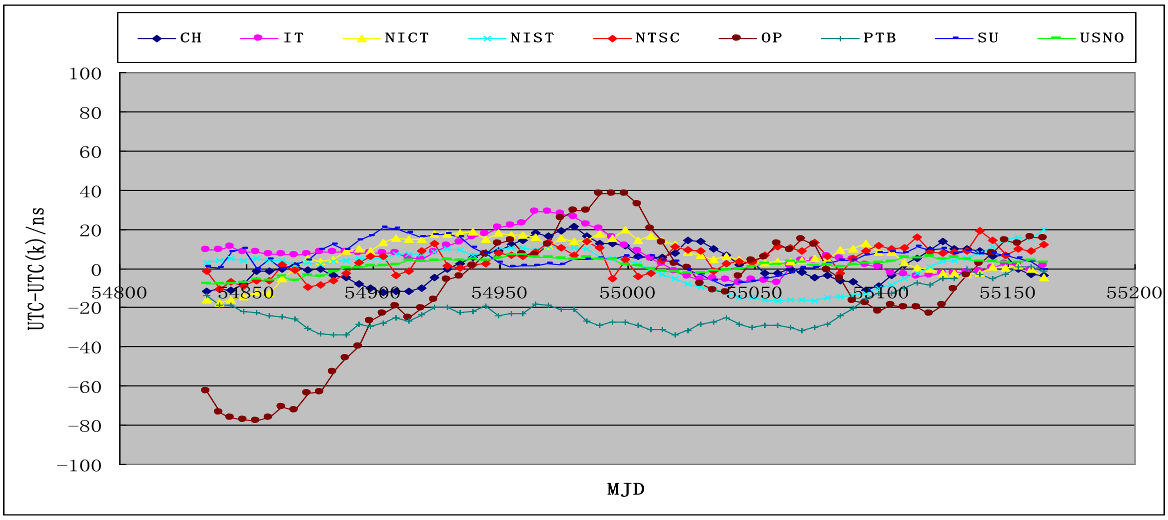


Figure 10. Participating labs' UTC – UTC (k) in 2009.

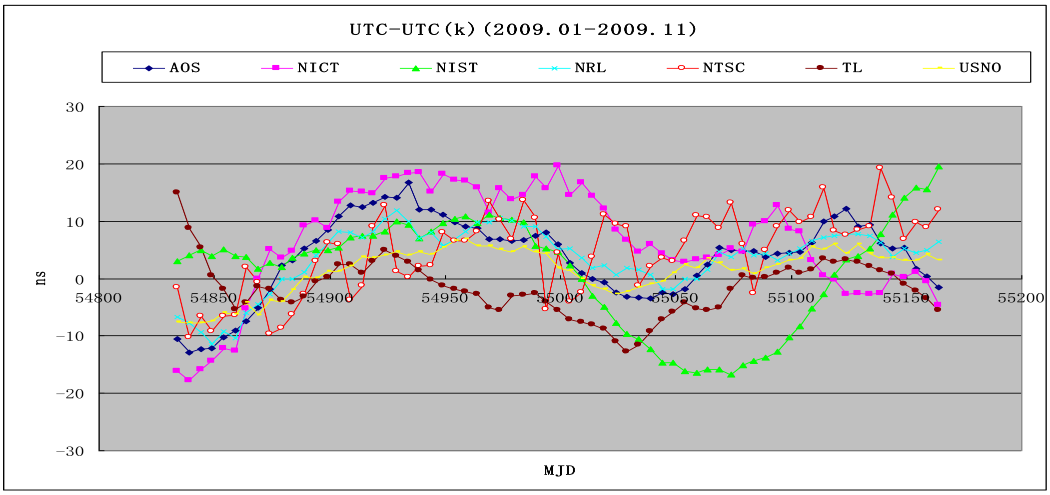


Figure 11. Labs' |UTC – UTC (k)| ≤20 ns.