Study and Development of a New GNSS Receiver for Time and Frequency Transfer

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Abstract—Time and frequency transfer techniques based on GPS and GLONASS were studied. On the basis of Topcon GNSS receiver module, one new type of GNSS time and frequency transfer receiver named NIMTFGNSS-1 has been developed and its scheme has been accounted for. Compared with several popular GPS time and frequency transfer receivers made aboard in the world by the common clock difference experiments and the long baseline experiments, the performance of the receiver has been tested and verified. Its time and frequency transfer noise level can match those of the several commercial receivers and the time stabilities from the GPS code and carrier phase results in the common clock difference experiments using two NIMTFGNSS-1 receivers during a few days are separately within 1 ns and 100 ps and the GLONASS code results is with 4 ns.

I. Introduction

GPS(Global Positioning System) time and frequency transfer is one of the most useful tools for time and frequency transfer. With the quick development of GLONASS(GLObal NAvigation Satellite System), it has been the most significant supplementary means for GPS time and frequency transfer. BIPM(Bureau International des Poids et Mesures) has published UTC results with GLONASS involved in Cir.T[1] since January 2010. GNSS (Global Navigation Satellite System) time and frequency transfer receiver is the significant research direction in time and frequency area.

II. Principles Of Time And Frequency Transfer With Gnss

Time and frequency transfer methods by GNSS are divided into three types that are C/A code, P3 code and carrier phase time and frequency transfer according to the measurement signals. And the basic principle is as shown in fig. 1.

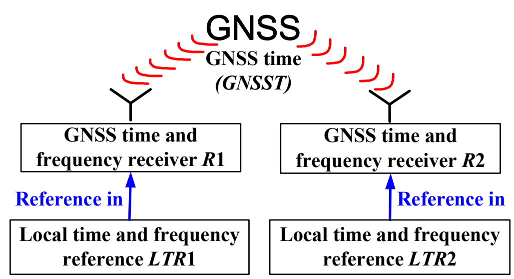


Figure. 1 Time and frequency transfer by GNSS

The two stations use the GNSS time and frequency transfer receivers R1 and R2 separately referenced to the corresponding local time and frequency standards LTR1 and LTR2[2]. The reference methods can be different in terms of the operation modes of the receivers. Thus, time and frequency transfer can be realized and the calculation is shown as (1)-(3). First, we can get the time and frequency transfer results $\Delta T1$ and $\Delta T2$ for each station, that is to say, the difference between the local time and frequency standard and GNSS time(GNSST). Then the difference between $LTR1$ and $LTR2$ can be calculated by the difference between $\Delta T1$ and $\Delta T2$.

$$\Delta T1 = LTR1 - GNSST \quad (1)$$

$$\Delta T2 = LTR2 - GNSST \quad (2)$$

$$LTR1 - LTR2 = \Delta T1 - \Delta T2 \quad (3)$$

III. GNSS TIME AND FREQUENCY TRANSFER RECEIVER

GNSS time and frequency transfer receiver especially for time and frequency transfer implements the comparison by measuring difference between the external time and frequency reference and GNSS time, while the general GNSS receiver cannot get this value other than the position. For the moment, in general, there are two kinds of operation modes for GPS time and frequency transfer receivers. In the first mode (mode 1), the receiver, e.g. a Septentrio Polarx2eTR, Polarx3eTR or Ashtech Z12-T, is operated with time and frequency directly synchronized to the local reference time scale by a internal phase lock loop. In the second mode (mode 2), the receiver, e.g. a AOA TTR6 or Dicom GTR50, is operated in a free running status without synchronization, and the link between the receiver time scale and the local reference time scale is established with a time interval counter(TIC). The operation mode of the time and frequency transfer receiver is indicated in fig. 2[3] and compared in [3].

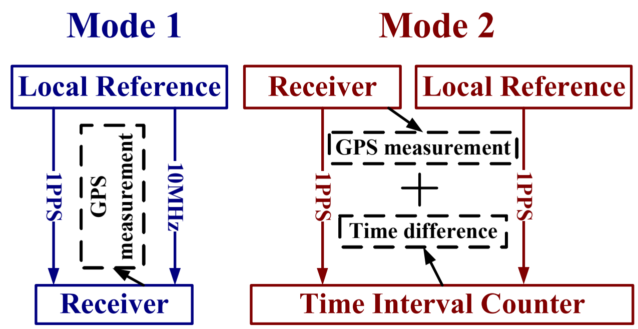


Figure. 2 Operation mode

IV. DESIGN AND REALIATION

Based on the GNSS module of Topcon company, one new type of GNSS time and frequency receiver named NIMTFGNSS-1 for rack using or portable using is designed with mode 1, with which the receiver noise performance is better[3], as shown in fig. 3. The scheme of the receiver is illustrated as follows in fig. 4. After temperature sensitivity evaluation[3] of the receiver engine, we have the receiver engine board located in one temperature chamber so that its ambient temperature can be controlled within the stability of less than 0.3(1 sigma) degrees, which would decrease the measurement uncertainty of the receiver due to the variation of the environmental temperature.

Figure. 3 NIMTFGNSS-1 receiver

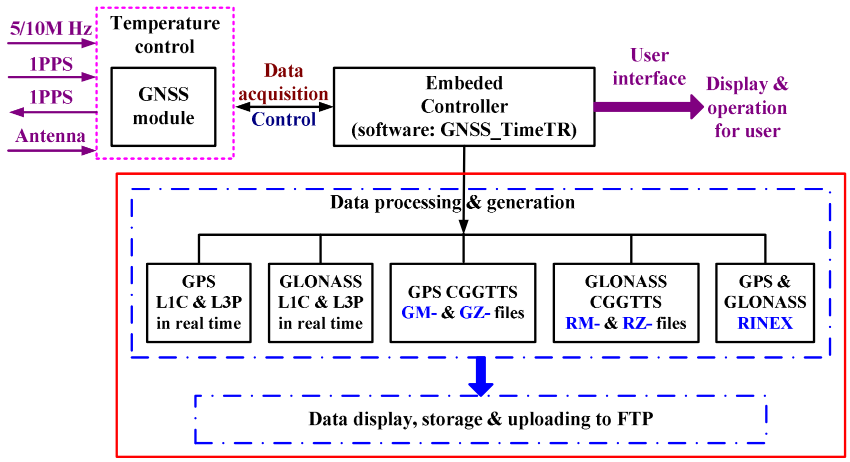
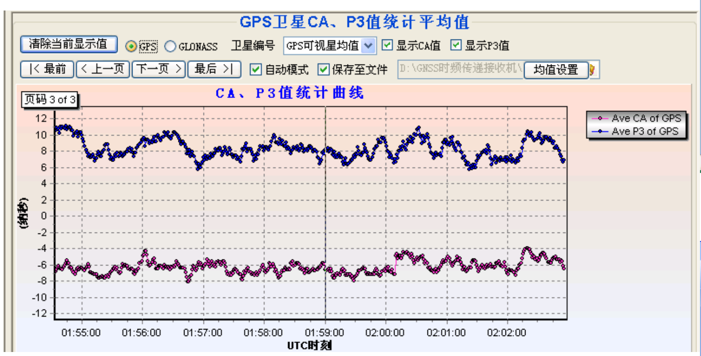
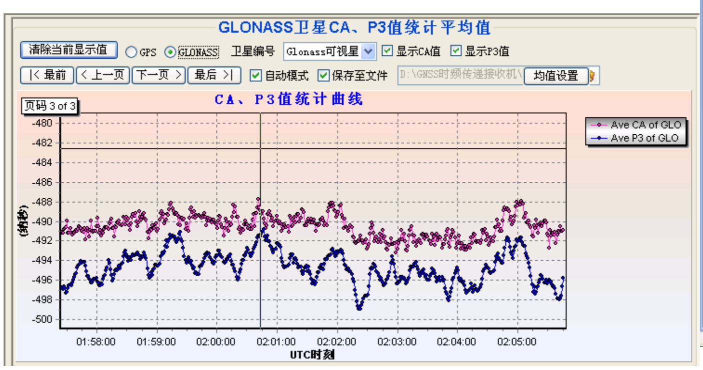


Figure. 4 Scheme of the receiver

The receiver can generate the C/A and P3 code CGGTTS files(GM- file for GPS C/A code, GZ- file for GPS P3 code, RM- file for GLONASS C/A code and RZ- file for GLONASS P3 code) and Rinex files of GPS and GLONASS, and generate and show the real-time time difference data in at least 1 second as shown in fig. 5. The receiver interface software named GNSS_TimeTR is shown in fig. 6.

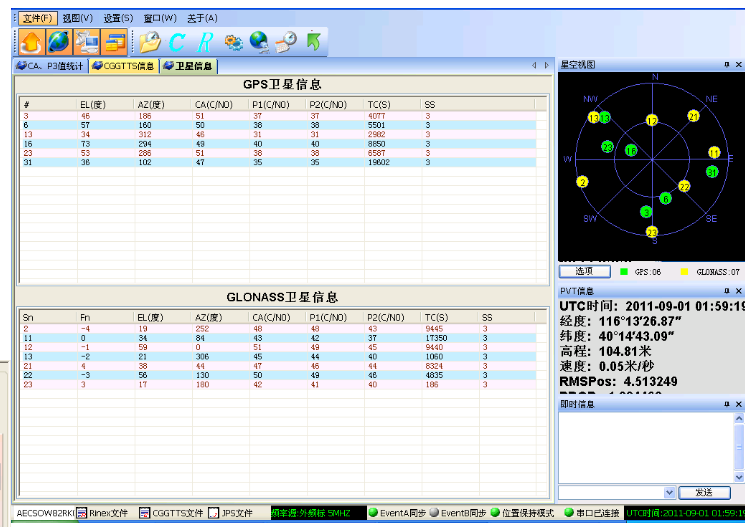


(a) GPS

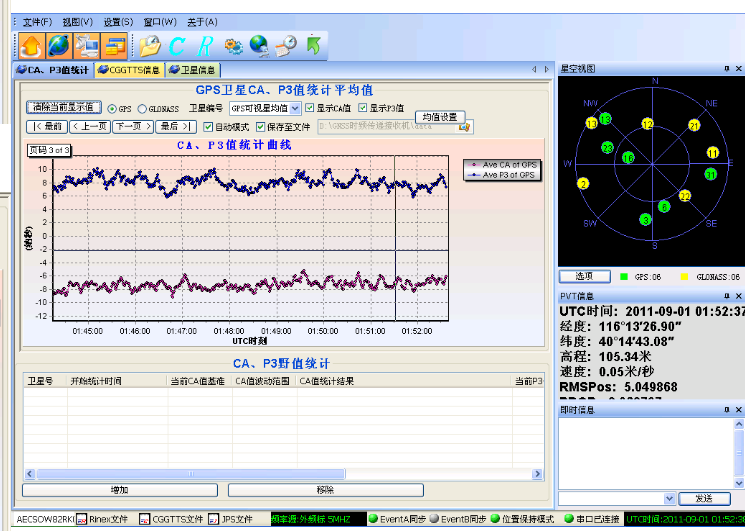


(b) GLONASS

Figure. 5 Real-time time difference in one second



(a) Interface display 1



(b) Interface display 2

Figure. 6 Interface software (GNSS_TimeTR)

V. Performance Verification

The CCD(Common Clock Difference) experiments among one NIMTFGNSS-1 receiver(IM07, rack using type) and another two kinds of time and frequency transfer receivers including Septentrio PolaRx2eTR(IM2P) and PikTime TTS-4(TTS4) receivers have been implemented at NIM Hepingli campus. However, only GPS P3 transfer performance can be compared because Septentrio PolaRx2eTR receiver just generates GPS P3 CGGTTS file. The results during the same period show that the GPS P3 transfer performance of the new time and frequency transfer receiver can match that of the other two receivers in fig. 7. As seen in the fig., the standard deviation during 7 days is about 1ns using the common view(CV) processing method. As well, the CCD experiments among another NIMTFGNSS-1 receiver (IM03, portable using type) Septentrio PolaRx3eTR(BJ2P) and Dicom GTR50(IM06) receivers at NIM Changing campus have been implemented. We can get the similar conclusion in fig. 8 to that from fig. 7. All the receivers used in the experiments haven't been calibrated, and the time difference values for some links between two receivers in the following figures are removed by some different offsets for better view.

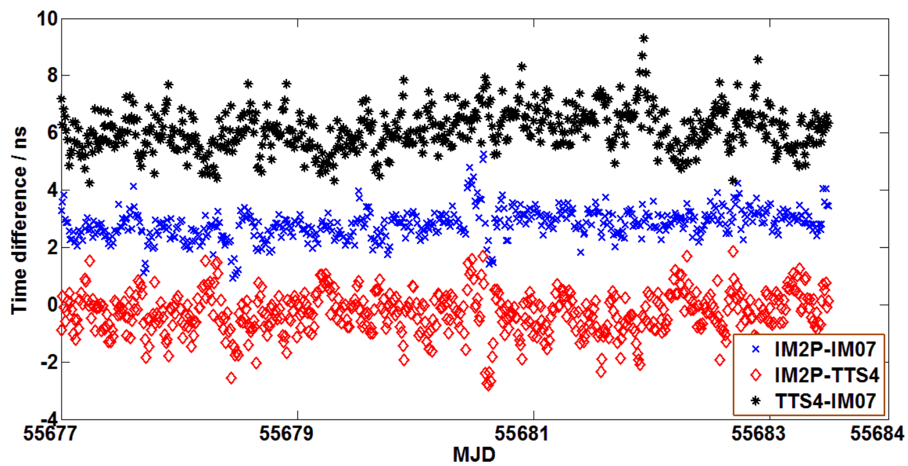


Figure. 7 Performance comparison 1

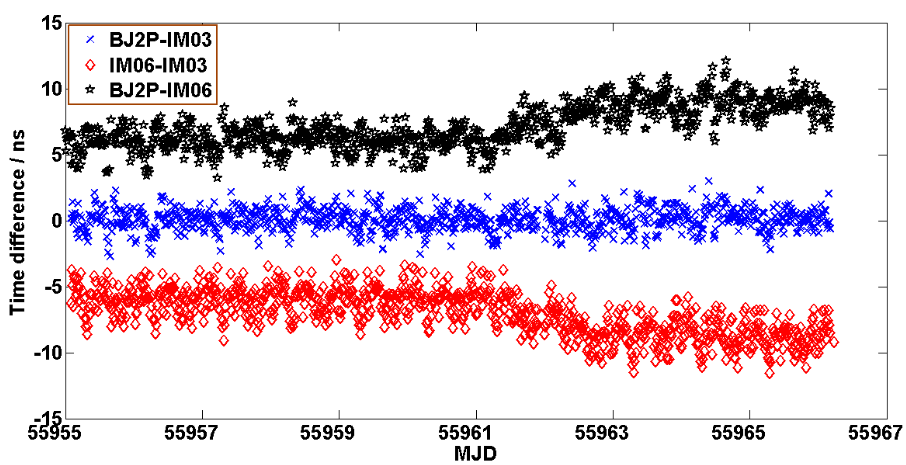


Figure. 8 Performance comparison 2

We have also done the CCD experiments among the IM03 and IM07 and IM2P. The CCD results between IM03 and IM07 by GPS carrier phase using PPP(Precise Point Position) technique are shown in fig. 9 and the standard deviation is 85 ps. And the CCD results between IM03 and IM07 using GPS C/A code(L1C) and P3 code(L3P) are shown in fig. 10 and the standard deviation are 0.89 ns and 0.81 ns separately.

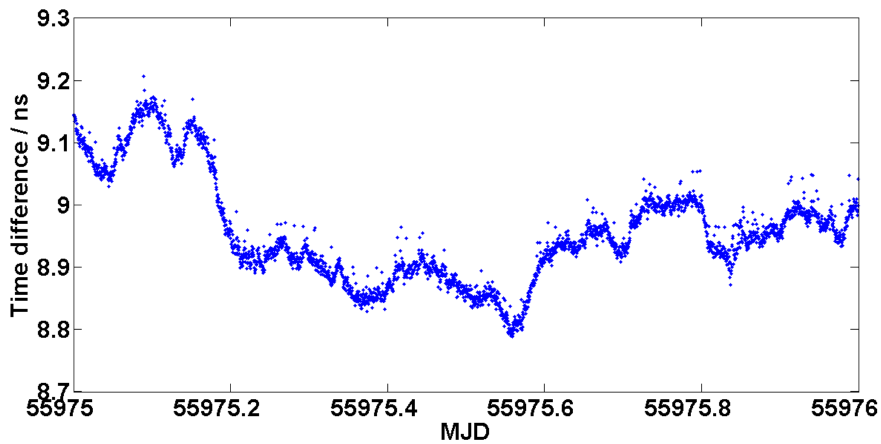


Figure. 9 Performance comparison 3

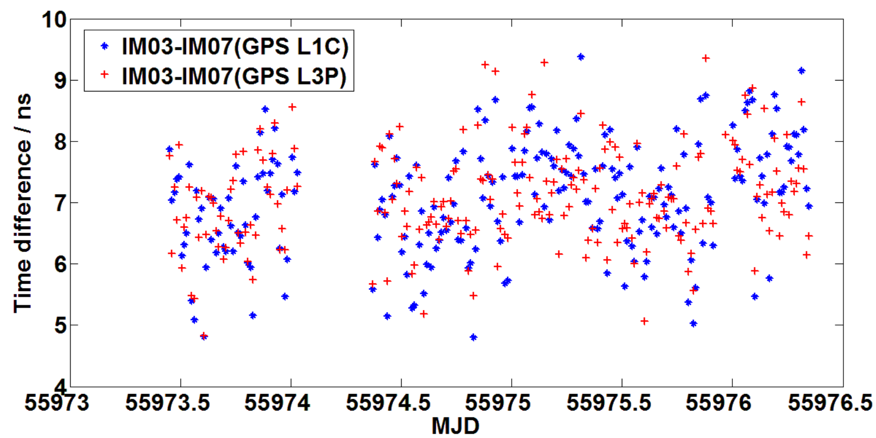


Figure. 10 Performance comparison 4

And the CCD results between IM03 and IM07 using GLONASS C/A code(L1C) and P3 code(L3P) are shown in fig. 11 and the standard deviation are 3.7 ns and 3.4 ns separately. They are much bigger than those using GPS probably due to the inter-frequency bias for GLONASS system[4,5].

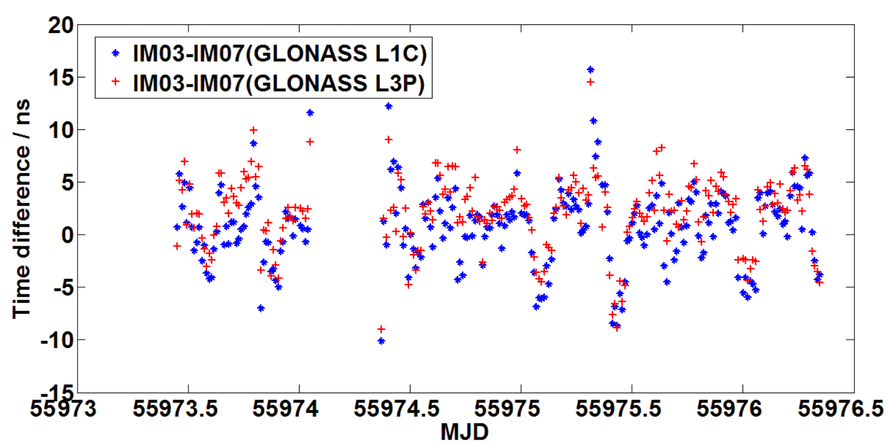


Figure. 11 Performance comparison 5

VI. Long Baseline Experiments

For the long baseline performance of time and frequency transfer, we use the data of the link between Ashtech Z12-T receiver(PT02) in PTB and IM03 receiver in NIM, and we use the data of the link between PikTime TTS-3 receiver(PT05) and IM2P for comparison in fig. 12. We have got the link data between IM03 and IM07, located separately in Hepingli campus and Changping campus that is about 40 km baseline, and used IM2P and IM06 for comparison in fig. 13 and partial enlarged view in fig. 14.

We also compared the results for the GLONASS P3 link between IM07 and PT05 and the GLONASS P3 link between TTS4 and PT05 in fig. 15, and IM07 and TTS4 were both referenced to UTC(NIM). By comparison, generally we can see that the link data using NIMTFGNSS-1 receiver are similar to those using another types of the time and frequency transfer receivers in terms of fig. 12~15. That states that GPS or GLONASS transfer noise level performance of NIMTFGNSS-1 in the long base line can match the other types of time and frequency transfer receivers. The data gaps in fig. 12 and 13 came from the tests of the interface software after some new modification.

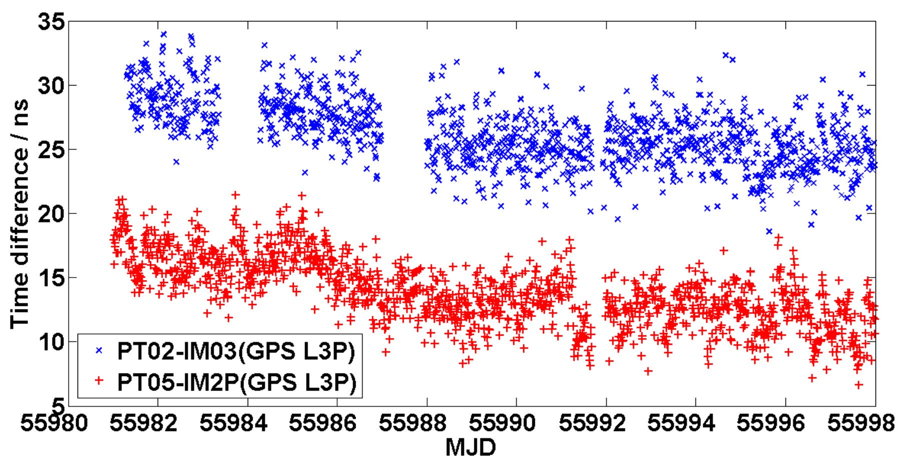


Figure. 12 Performance comparison 6

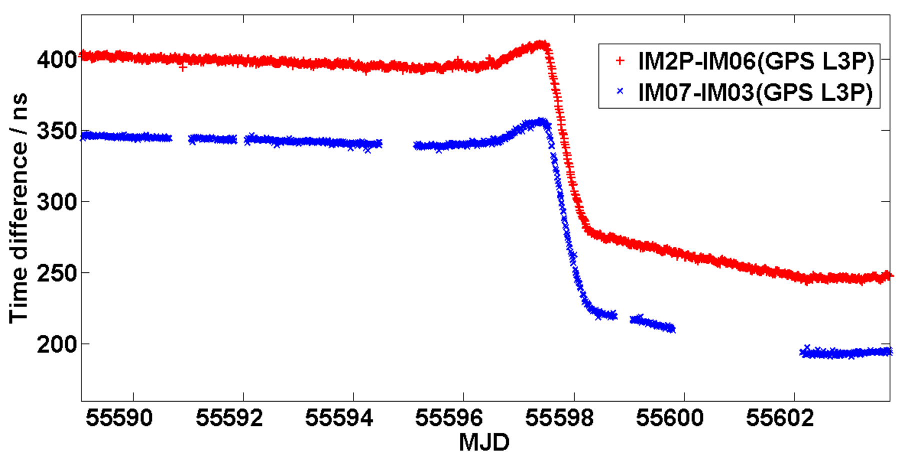


Figure. 13 Performance comparison 7

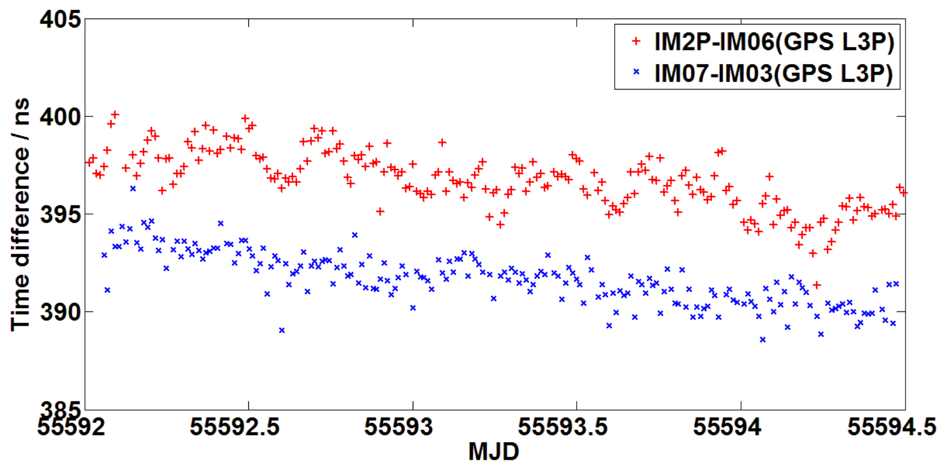


Figure. 14 Performance comparison 8

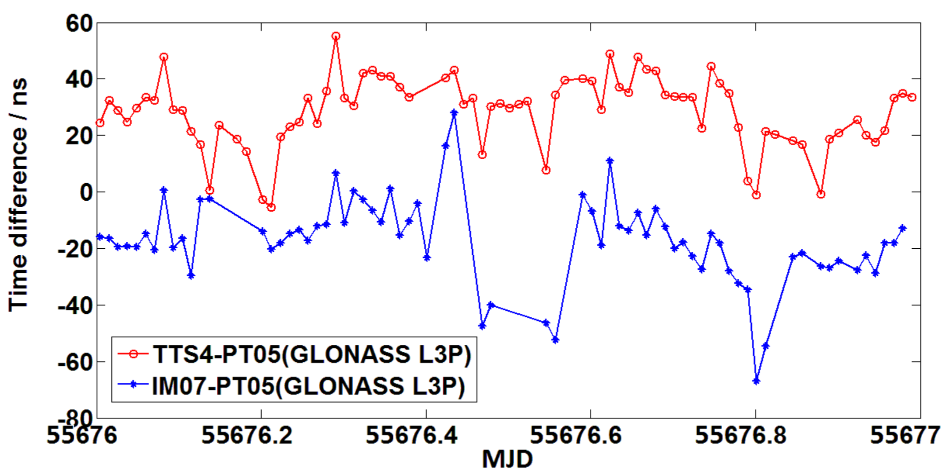


Figure. 15 Performance comparison 9

VII. CONCLUSION

The operation modes of GNSS time and frequency transfer receivers have been described and GNSS receivers including portable using type and rack using type for time and frequency transfer have been developed. The noise performance of the receiver itself and the long baseline performance have been verified by the CCD experiments in NIM and the long baseline time and frequency transfer experiments in the links between NIM and PTB and between the two campuses of NIM. The time stabilities (standard deviation) of GPS C/A and P3 code CCD experiments using CV method in 16-min interval for several days data are within 1 ns and those of GLONASS C/A and P3 code are within 4 ns. The corresponding time stabilities of GPS carrier phase CCD experiments using PPP method in 30-s interval for one day data is within 100 ps. The noise level performance for time and frequency transfer using the self-developed new receivers can match that using the present types of the main commercial time and frequency transfer receivers, including Septentrio PolaRx2eTR and PolaRx3eTR receivers, PikTime TTS-3 and TTS-4 receivers, Ashtech Z12-T receiver and Dicom GTR50 receiver.

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