# A COMPAROTIVE STUDY OF GPS P3 AND GPS L3

Gun Li[1, 2] Bian Li[1, 2] Shao-Wu DONG[1]

[1] National Time Service Center, Chinese Academy of Sciences

3 Eastern Road of Lintong Region, Xi’an, Shaanxi, 710600, CHINA

[2] Graduate University of Chinese Academy of Sciences

19Yuquan Rd. (jia) Shijingshan Beijing, 100039, CHINA

Abstract-**More recently, GPS carrier phase measurement using geodetic receivers is widely conducted for accurate time and frequency comparisons. Time transfer experiments were conducted using the Ashtech Z12T receivers whose internal frequency is provided by an external 20 MHz clock and an external 1 pps (pulse per second) of a reference clock. The results of time comparison has shown that the stability of time transfer using carrier phase is better than that of GPS common-view time transfer using GPS C/A or P3. The self-developed processing software was used to the cycle slip detection and ambiguity resolution determination. The objective of this paper is to compare the GPS P3 and GPS L3 time transfer. The GPS P3 and L3 data have been obtained using an Ashtech Z12T at NTSC and an Ashtech ZIIX3 at NICT. The main results and analysis are given in Section 3 and Section 4. For a long baseline comparison, the RMS of L3 is better than that of P3. The stability of frequency of L3 is better than that of P3 for short term $\tau < 6d$ ), however, for $\tau > 6d$ the stability of L3 and P3 is almost at the same level.**

## I. INTRODUCTION

The Bureau International des Poids et Measures (BIPM), in France is charged with providing the time standard UTC (Coordinated Universal Time). The BIPM collects data via GPS or TWSTFT from more than 200 atomic clocks and a few primary “absolute” frequency standards from more than 50 time laboratories around the world. Once a month, BIPM uses these data to produce the standard international references for frequency and time, International Atomic Time (TAI) and UTC, which is equal in rate to TAI, but adjusted by an integer number to seconds to account for variations in the rotation of the earth. [1,2] Each time laboratory (k) contributing to the determination of TAI maintains a local realization of UTC, called UTC(k). Most time links used for TAI have based on GPS common view technique, and on Ku-band Two-way time transfer using geo-stationary satellites (TWSTFT) [2,3]. GPS code-based common view or carrier phase common view are carrier out by having two ground stations observe the same satellite at the same time, These techniques have the advantage of removing the GPS satellite clock error, atmosphere delay, broadcast orbit and broadcast ionosphere corrections. It is very important to mitigate the delay of ionosphere in time transfer. In the days of single-frequency receivers, a ionosphere delay correction model was requires so that mitigation the propagation delay due to ionosphere. Lots of old receivers use the broadcast Klbuchar model for the correction, since the first use of IGS (International GPS service) ionosphere TEC-map (total electron content) as one useful method in July 1999, the corrections are now applied to all TAI GPS common-view links, [4] which has improve the precision of ionosphere mitigation significantly. Recently, GPS carrier phase measurement using geodetic-like receivers Ashtech Z12T is widely conducted for accurate time and frequency comparisons, which have been performed for determining clock differences at the level of a few hundred pico-seconds. [5,6] The precision of GPS carrier phase time transfer is approximately 10 times better than GPS common view

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time transfer. [6] The potential capability and application using GPS carrier phase, rather than C/A code with the common view technique to transfer precise time and frequency, has been recognized, described and discussed by many researchers in the reference [6~14]. The one main reason is dual frequency carrier phase measurement provide ionosphere-free technique L3. Since 2003, GPS P code measurements obtained with calibrated geodetic processing technique have widely used for P3 measurement, which provide another useful method for correcting the ionosphere delays in time transfer. While geodetic-quality carrier phase receivers have demonstrated high quality frequency transfer results, the Ashtech Z12T receiver used for precise time transfer requires knowledge of the hardware delays at each site. In the experiment, the receiver at NICT has calibrated in 2005. The receiver at NTSC has also calibrated by BIPM's traveling receiver, but the calibration has something wrong, therefore, the objective of this paper is to compare the stability of GPS P3 and L3 techniques.

In contrast to ionosphere delays, we estimate the stability level that may be achieved by GPS P3 and L3 by these two methods. In this paper, $P_1$ will represent the precise pseudorange on frequency $f_1$, $P_2$ will represent the precise pseudorange on frequency $f_2$,, and the $P_3$ ionosphere-free linear combination of $P_1$ and $P_2$. likewise, L1 denotes the carrier phase measurement on $f_1$, L2 carrier phase measurement on $f_2$, L3 ionosphere-free linear combination of $L_1$ and L2.

Precise orbital data and the modeling of troposphere should be used in order to obtain high precision corrections to the time transfer measurements. The precise data obtained from IGS website. The data used at these experiments are the RINEX files generated by the geodetic GPS receiver.

The main results and analysis are given in Section 3 and Section 4. For a long baseline comparison, the RMS of L3 is better than that of P3. The stability of frequency of L3 is better than that of P3 for short term $\tau < 6d$ ), however, for $\tau > 6d$ the stability of L3 and P3 is almost at the same level. Further study will conduct in the near future.

## II. GPS P3 AND L3 MEASUREMENTS

### 2.1 GPS observable equations

In this section we represent the principle of P3 and L3 briefly which have already introduced in details in Reference [6].

The GPS pseudorange observables $\rho_{i,k}^{j}$ for a given satellite $j$, receiver $i$, and frequency k can be written as follows:

$$\begin{aligned}\rho_{i,k}^{j} &= P + c(\delta_r - \delta_s) + \delta\rho_{trop} \\ &+ \delta\rho_{ion}^{\rho_k}\delta\rho_{m}^{\rho_k} + \varepsilon^{\rho_k}\end{aligned} \tag{1}$$

Where $\rho_{i,k}^{j}$ is the pseudorange of receiver $i$ and the $j-th$ GPS satellite, the geometric range, $P$, is the difference in the satellite position at the time of transmission and the receiver position at the time of reception, c is the speed of light in a vacuum, $\delta_r$ *and* $\delta_s$ are the receiver and satellite clock offsets with respect to GPS time respectively, $\delta\rho_{trop}$ *and* $\delta\rho_{ion}^{\rho_k}$ are the propagation delay due to the troposphere and the ionosphere respectively, $\delta\rho_{m}^{\rho_k}$ is the multipath error, $\varepsilon^{\rho_k}$ represents un-modeled errors and receiver noise.

Analogously, the typical model of GPS carrier phase observables can be written as

$$\begin{aligned}\phi_{i,k}^{j}\lambda_k &= P + c(\delta_r - \delta_s) + \delta\rho_{trop} \\ &+ \delta\rho_{ion}^{\phi_k} + \delta\rho_{m}^{\phi_k} + \lambda_k b_{i,k}^{j} + \varepsilon^{\phi_k}\end{aligned} \tag{2}$$

Where $\phi_{i,k}^{j}$ is the carrier phase measurement of the receiver $i$ and the $j-th$ GPS satellite, and $\lambda$ is the GPS carrier wavelength, the phase biases $b_{i,k}^{j}$ is defined by

$$b_{i,k}^{j} = n_{i,k}^{j} + \delta\phi_{i,k} - \delta\phi_{k}^{j} \tag{3}$$

Where n is an integer number of cycles, $\delta\phi_{i,k}$ is the un-calibrated delay of the receiver and associated equipment, and $\delta\phi_k^j$ is the un-calibrated delay originating in the satellite. Both of the Eq. (1) and Eq.(2), for a dual frequency GPS receiver, the ionospheric delay can be effectively removed by using appropriate linear combination of the L1 and L2 phase data. The troposphere delay can be determined by modelling the troposphere Saastamoinen model, which required knowledge of the standard atmosphere values for temperature, atmospheric pressure and vapor pressure coefficients.

### 2.2 GPS ionosphere-free observables

The ionosphere is a dispersive medium at GPS frequencies (L1=1575.42MHz,L2=1227.60MHz). This causes the group velocity to be delayed by an amount equal in magnitude but opposite to the phase velocity .in other words,

$$\rho_{ion}^{\rho_k} = -\rho_{ion}^{\phi_k} \qquad (4)$$

Furthermore, to first order, the ionosphere delay is proportional to $1/f^2$. This allows construction of the ionosphere-free of the pseudorange observable $\rho_{i,3}^j$

$$\begin{aligned} \rho_{i,3}^j &= \frac{f_1^2}{f_1^2 - f_2^2}\rho_{i,1}^j - \frac{f_2^2}{f_1^2 - f_2^2}\rho_{i,2}^j \\ &= 2.55\rho_{i,1}^j - 1.55\rho_{i,2}^j \end{aligned} \qquad (5)$$

$$\rho_{i,3}^j = P + c(\delta_r - \delta_s) + \delta\rho_{trop} + \delta\rho_{multi}^{\rho_3} + \varepsilon^{\rho_3} \qquad (6)$$

Analogously, the ionosphere-free GPS carrier phase observable $L_3$ can now be written as

$$\begin{aligned} L_{i,3}^j &= \frac{f_1^2}{f_1^2 - f_2^2}\phi_{i,1}^j\lambda_1 - \frac{f_2^2}{f_1^2 - f_2^2}\phi_{i,2}^j\phi_{i,1}^j\lambda_2 \\ &= 2.55\Phi_{i,1}^j - 1.55\Phi_{i,2}^j \end{aligned} \qquad (7)$$

$$\begin{aligned} L_{i,3}^j\lambda_3 &= P + c(\delta_{RT} - \delta_{st}) + \delta\rho_{trop} \\ &+ \delta\rho_{multi}^{\Phi_3} + \lambda_1 B_{i,3}^j + \varepsilon^{\Phi_3} \end{aligned} \qquad (8)$$

where the new phase bias term

$$B_{i,3}^j = \frac{f_1^2}{f_1^2 - f_2^2}\lambda_1 b_{i,1}^j - \frac{f_2^2}{f_1^2 - f_2^2}\lambda_2 b_{i,2}^j \qquad (9)$$

The time differences between the two reference sources were estimated by performing the carrier phase single–difference measurements, which are the differences between the carrier phase measurements simultaneously observed by a pair of receivers from the same satellite. The carrier and code measurements data in RINEX data file are used for the single-difference measurements. It is very important to detection and the repair of cycle slip in the carrier phase measurements. We use a new algorithm for detecting cycle slips in dual frequency GPS rather than single frequency, which including two steps. We also use an ambiguity resolution algorithm in data processing.

## III. DATA PROCESSING AND ANALYSIS

Time transfer data for each of the two methods have been studied for the NTSC-NICT in this paper. For comparison, the TWSTFT data have been obtained from regular international time transfers, which take place three days per week (Tuesday and Friday). GPS P3 and L3 data have been obtained using Geodetic-like receiver Ashtech ZIIXT and ZIIX3T at NTSC and NICT. The GPS C/A data have been obtained using a single frequency multi-channel VP3 receiver at NTSC, a dual frequency, multi-channel Euro-80 receiver at NICT for comparison. The self-developed processing software was used to the cycle slip detection and ambiguity resolution determination. The precise orbit data from IGS is used. The troposphere model used in the processing is the standard Hopfield's model. And the multi-path error and un-modeled error was deleted in EQ. (1) and (2) Figure 1 shows the data processing floatchart simply.

To further evaluate the accuracy of time comparisons reduced from different method, we propose to use RMS errors of comparison results. Figure 2 and 3 are the time transfer Results using GPS carrier phase L3 and P-code P3 common view techniques between NTSC and NICT from MJD=53490~53538, the RMS is 2.6ns and 1.5ns respectively. The receiver at NTSC is un-calibrated, so we cannot make calibrated time transfer measurements. Therefore, The Modified Allan variance of TWSTFT, GPS C/A, GPS P3 and L3 are also represent in order to compare the frequency stability of each method. . Figure 4 shows the results of the stability of frequency of P3, TWTFT and C/A. The analysis indicates better behavior of TWSTFT for all and 5 represent the results of the stability of frequency by two transfer methods. The stability by GPS L3 much better than can be achieved with the GPS P3 for $\tau < 6d$ , whereas, for $\tau > 6d$ , the stability of L3 and P3 is almost at the same level.

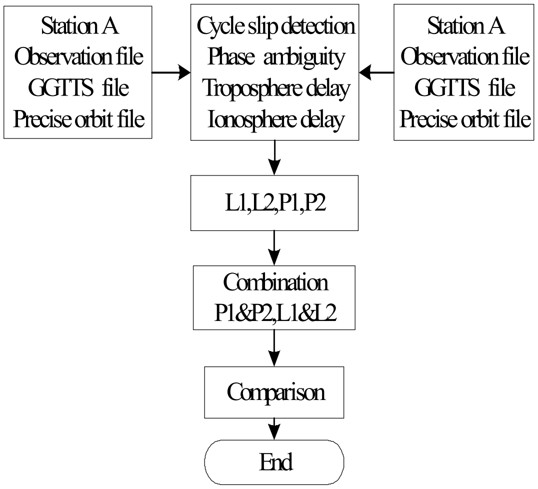

Figure 1. The floatchart of data processing.

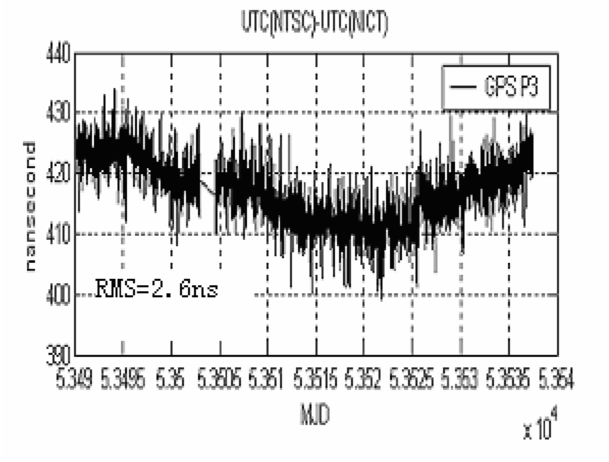

Fig.2. Data for the GPS P3

[UTC(NTSC)-UTC(NICT)].

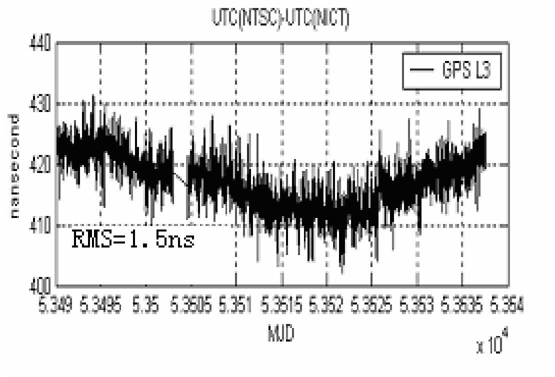

Fig.3. Data for the GPS L3 [UTC(NTSC)-UTC(NICT)].

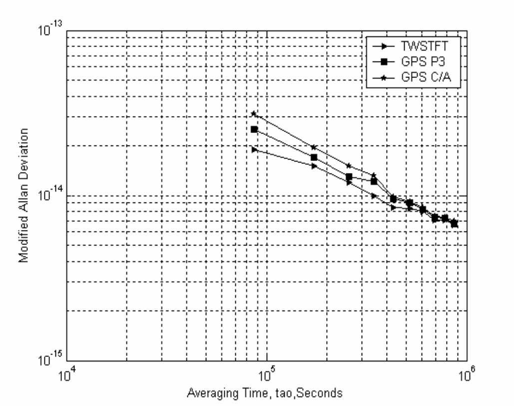

Fig.5. Frequency stability

of UTC(NTSC)-UTC(NICT)] by GPS P3,

GPS C/A and TWSTFT.

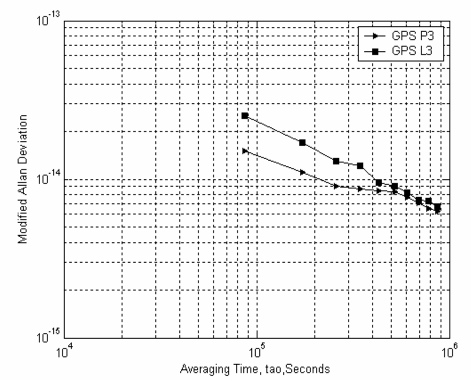

Fig.4. Frequency stability of
[UTC(NTSC)-UTC(NICT)] by GPS P3,GPS L3.

## IV. CONCLUSIONS

Time transfer experiments were conducted using the Ashtech Z12T receivers whose internal frequency is provided by an external 20 MHz clock and an external 1 pps of a reference clock. The results of time comparison has shown that the stability of time transfer using carrier phase is better than that of GPS common-view time transfer using GPS C/A or P3. The further investigation has provided valuable information about the stability of GPS P3 and L3. The experiments have demonstrated that the stability of carrier phase-based is better than GPS Code-based C/A or P3. For a long baseline comparison, the RMS of L3 is better than that of P3. The stability of frequency of L3 is better than that of P3 for short term( $\tau < 6d$ ), however, for $\tau > 6d$ the stability of L3 and P3 is almost at the same level. The self-developed processing software was used to the cycle slip detection and ambiguity resolution determination. We are undertaking a number of experiments to improve the stability of GPS P3 and GPS carrier phase time transfer. As mentioned above, the software for cycle slip detection and ambiguity resolution determination are more urgently. In addition, to obtain calibration measurement, we will re-correct the calibration results of the Astech Z12T receiver at NTSC. It is important to take into account the effect of earth solid tide. In the near future, we will consider reducing the effect in distant time transfer.

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