Measurement of the Time Delay of GPS Timing Receiver Based on UTC(NTSC)

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***Abstract*—GPS provides a method for accurate timing. The measurement of the time delay of timing receiver is a difficult task with the existing method, high in cost and complex in operation. A new and simpler measurement method is presented in this paper, based on the time difference between UTC(NTSC) which is the time scale kept in National Time Service Center and the output of 1pps signal by the GPS timing receiver. On the basis of the international comparison link of UTC(NTSC) and UTC, and the time difference between UTC and GPST, a new method for the measurement of the time delay of GPS timing receiver is given. This method is easy to do. The error of with this method is also analysized.**

***Key Words*: receiver, time delay, GPS**

I. INTRODUCTION

The technology of high-accuracy long-distance time frequency transfer is an important guarantee for the accuracy of the UTC, which is a common reference for all the countries in the world [1,2]. The ever-improving performance of the high-accuracy atomic frequency standard requires the technology of long-distance time frequency comparison to match it. In recent years, the technology of long-distance time transfer has witnessed a rapid development. GPS has provided us with a method for high-accuracy time transfer, and hence the important means of time transfer based on GPS, such as the single way, common view and all view. All these methods require a precise measurement of the time delay of the GPS timing receiver.

The current measurement of the time delay of timing receivers cannot meet the demand of practical application. For instance, the geodetic-type carrier phase receiver displays an excellent performance in frequency transfer, however, due to the limited ability to measure the time delay of the receiver, the time transfer is far lower than the frequency transfer in accuracy[3,4].

In the application of GPS in time transfer, the absolute measurement of the timing receiver is required, which is a difficult task with the existing methods, costly and complex. In this paper, a study is made of the measurement of the GPS timing receiver and a simple low-cost method is presented for the measurement of the time delay of the timing receiver based on UTC(NTSC), which is the time scale of the National Time Service Center, Chinese Academy of Sciences.

II. THE COMMON METHOD FOR THE MEASUREMENT OF THE TIME DELAY OF GPS TIMING RECEIVERS

The measurement of the time delay of GPS timing receivers falls into two kinds, namely, the absolute measurement and the relative measurement. The relative measurement, simple in operation and high in accuracy, finds its application mainly in the experiment of time comparison, in which the difference of the time delays of two receivers is measured.

The absolute measurement refers to the measurement of the absolute time delay of a receiver, which is the time delay from the reception of the signals at the receiving antenna to the output of the 1pps signals by the receiver. The principle of the absolute measurement is shown in Fig.1. The signal simulator simulates the signals of wave band L sent by the GPS satellite and the corresponding time signal (1pps). The antenna of the receiver receives the signals of wave band L sent by the simulator and sends them to the receiver for the demodulation and timing. Eventually, the GPS time signal reemerges as the output 1pps signal of the receiver. A time interval counter is used to measure the time difference between the 1pps signal sent by the simulator and that output by the receiver. This time difference is called the absolute time delay of the receiver[4].

The most difficult part in the absolute measurement is the adjustment of the signal simulator, namely, to adjust the synchronization of the signals of wave band L and the 1pps signal sent by the simulator. In addition, the multi-pathway interference with the signals is a major factor affecting the measurement, as the measurement is usually done indoors. The antenna of the receiver is usually placed in the specially designed darkroom with wave-absorbing material to reduce the emission of the signals[4,5,6].

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In one word, special instrument is required for the absolute measurement of the timing receivers with the common method and it is complex in operation and high in cost. To reduce the cost and complexity, and to improve the accuracy, we present a method for the measurement based on UTC(NTSC) of the National Time Service Center, Chinese Academy of Sciences.

III. MEASUREMENT OF THE TIME DELAY BASED ON UTC(NTSC)

The time scale of China, the UTC(NTSC), is kept in the National Time Service Center of the Chinese Academy of Sciences. Its time signals undergo regular international comparison and therefore it is a resource that can be made full use of. Our method for the measurement of timing receivers is based on this consideration.

The framework of the basic principle of the measurement is shown in Fig.2. The system time of GPS (GPST) is broadcast by the GPS signal. The timing receiver receives the satellite signals and reproduces the system time through the output of the 1pps signal, with the time delay of the receiver included.

With a time intervals counter, the time difference between the output of 1pps signal of the receiver and the 1pps signal of the UTC(NTSC) is measured. The time difference $\Delta\tau_1$ can be written as:

$$\Delta\tau_1 = UTC(NTSC) - (GPST + \tau_{rec})$$

From the data of international comparison in the National Time Service Center, we can get the result of the time comparison $\Delta\tau_2$ between the time service center and UTC, and also the result of the time comparison $\Delta\tau_3$ between UTC and GPST .

$$\Delta\tau_2 = UTC - UTC(NTSC)$$

$$\Delta\tau_3 = UTC - GPST$$

Then the time delay of the timing receiver is as follows:

$$\tau_{rec} = \Delta\tau_3 - \Delta\tau_2 - \Delta\tau_1$$

What is worth noting is that the default output of the receiver is usually UTC. With this method, the output must be set as GPST, which is applicable in the common receivers. If the receiver can not be set as GPST, then the link between UTC and GPST must be modified to the link between UTC and UTC(USNO), the link in figure 3 can be used.

IV. ERROR ANALYSIS OF THE MEASUREMENT

A measurement method must be judged by its accuracy. The error with the method based on UTC(NTSC) comes from two sources: one is the error with the receiver in reproducing the system time of GPS; the other is the error of measurement and time transfer.

The error of the reproduction of GPS time by the receiver varies with different receivers. Usually there is ephemeris error, satellite clock error, the modification error of the additional time delay of the ionosphere, the modification error of troposphere refraction, the output timing signal error of the receiver, etc. The sum of these errors is the accuracy of the reproduction of GPS time by the receiver, which can be found in the operation manual.

The difference between measurement and time transfer covers three quantities, namely, $\Delta\tau_1$ 、 $\Delta\tau_2$ and $\Delta\tau_3$. An analysis is made of these three quantities respectively.

$\Delta\tau_1$ is measured by the counter, the uncertainty of the measurement adjustment is lower than 0.5ns and the random error of the measurement is less than 0.1ns.

$\Delta\tau_2$ is the comparison error between UTC(NTSC) and UTC. The report of BIPM Circle T shows that the uncertainty of adjustment is 5.0ns and the random comparison error is 1.5ns.

$\Delta\tau_3$ is obtained by the BIPM from the IGS precise orbit in Paris Observatory, the modification data of satellite clock and the UTC-UTC (OP). The report of BIPM Circle T shows that the uncertainty of time difference is 10ns and the random comparison error is 2.2ns.

Then the accuracy of the error of measurement and the time transfer is as follows.

$$\sqrt{0.5^2 + 5.0^2 + 10^2} = 11.2ns$$

The random error of the measurement and the time transfer is as follows.

$$\sqrt{0.1^2 + 1.5^2 + 2.2^2} = 2.7ns$$

To sum up, the measurement accuracy of the time delay of receivers is determined by the accuracy of the reproduction of the GPS time by the receiver and the accuracy of the measurement and time transfer. The error of the reproduction of the GPS time by the receiver can be reduced by the average over a long period, and thus the overall measurement accuracy can be improved.

V. CONCLUSION

The time delay of timing receiver can be measured through the direct comparison between the 1pps signals of the UTC(NTSC) and GPS, according to the international comparison data of UTC(NTSC). With this method, it is simple to operate and a high performance can be obtained with a low cost.

The error with the method based on UTC(NTSC) comes from two sources: one is the error with the receiver in reproducing the system time of GPS; the other is the error of measurement and time transfer. The random error of of measurement and time transfer is no more than 2.7ns.

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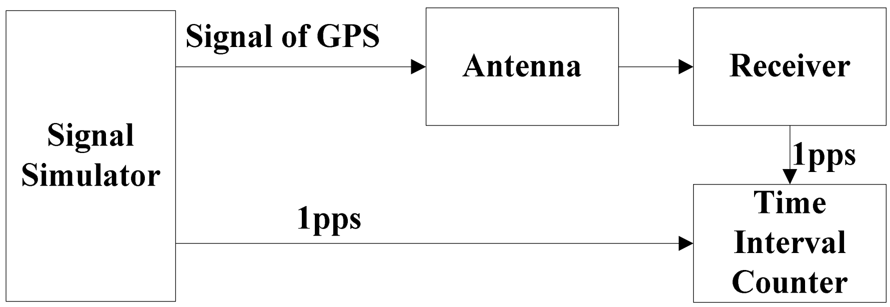

Figure 1. Heterodyne frequency measurement method

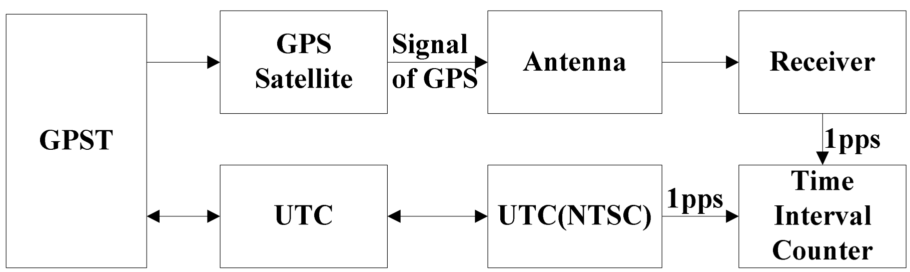

Fig.2 Measurement of time delay of timing receivers based on UTC(NTSC)

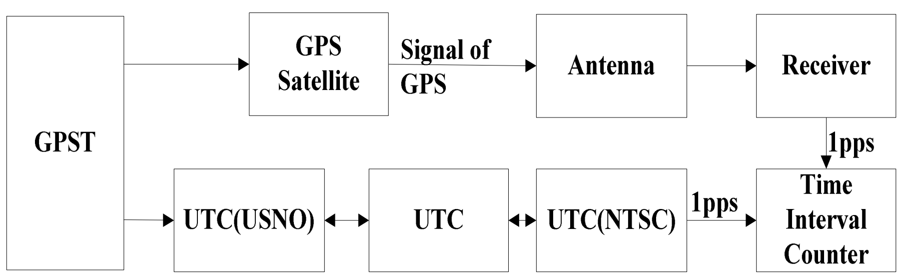

Figure 3 The link when the output is UTC