Experimental Analysis of the Time Transfer Capability of BD-1

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Abstract—BD-1 system is a new Local Navigation Satellite System developed by china; It has communication and time transfer capability, and is an important project of china development. BD-1is composed of navigation system, control system and user receiver. The user receiver asks for the position or communication request, and receives the position or communication results calculated in control system by the navigation satellite. BD-1 presents the position， navigation，communication and time transfer services for the terminal users. The time transfer principle of BD-1 is introduced in this paper, the experimental results is analysed to assess the time transfer capability of BD-1. The difference between the 1PPS of BD-1 receiver and the 1PPS of the local UTC time which is given by the reference atomic clock is measured in the experiment. The measurement is last for 780 seconds, and repeats at least 10 times. For every 780 seconds, each 15 seconds data is processed by the quadric least square method, and get 52 time difference value, and the 52 data is processed by the linear least square method. Finally, the difference between the BD-1 time and the local UTC time is calculated. According to the experiment results, the time difference is 33.8 ns, the Standard deviation is 1.36E-10s, and it excels the reported precision of BD-1.

Keywords— BD-1, GNSS, time transfer, 1PPS, least square method

Ⅰ INTRODUCTION

The GNSS and time transfer system is one of the important elements of the developed information society[1]. The precise time is the basic parameter of the science research, experiment, and engineering application etc. It provides the time base of the measurement and metrology[2]. Precise time transfer has broad application in industry and national defence field, such as communication, electric power system and arm control system [3]. For a developed country, the global navigation and time transfer system can provide support in every side; satellite navigation and time transfer is the necessary developing direction of the future[4,5].

At the present time, the satellite navigation and time transfer system includes Global Position System (GPS) of USA, GLONASS of Russia, BD-1 of china, and Galileo of Europe [6]. GPS is the most mature one of them, but GPS is controlled by American army and is not very dependable for other countries, so they investigated their own navigation system[7,8]. The time transfer principle of BD-1 is introduced, and the time transfer capability of it is analysed by the experiment in this paper. In the experiment, the difference between the 1 PPS of local UTC time and BD-1 receiver is measured; once per second, last for 780 seconds, and repeat 10 times. For every 780 seconds, each 15 seconds data is processed by the quadric least square method, and get 52 time difference value, and this 52 data is processed by the linear least square method. Finally, the difference between the 1PPS of BD-1 receiver and the 1PPS of the local UTC time is calculated.

Ⅱ. THE TIME TRANSFER PRINCIPLE OF BD-1

Time transfer is the receiver gets the difference between the local time and the standard time of BD-1, and adjusts the local clock to control the difference. For BD-1, the control centre on the ground will help the users to complete the time transfer. The BD-1 is shown in Fig.1.

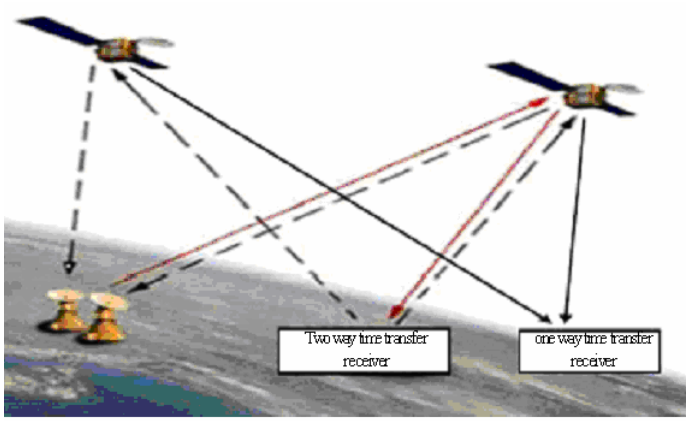

Fig .1. BD-1 system

The BD-1 system provide two time transfer mode: one way time transfer mode and two way time transfer mode. The one way time transfer precision is 100ns, the two way time transfer precision is 20 ns. In one way time transfer mode, the users do not need communicate with the control centre, it only receive the broadcast signal, get the difference between the local time and BD-1 reference time lonely; in two way time transfer mode, the users communicate with the control centre, it send the time transfer application, the control center calculates the time difference of the user, and transmits it to the receiver, then the users adjust the local clock according to the difference.

2.1 One way time transfer mode

In one way time transfer mode, the time mark is modulated in the transmit signal, and the broadcast signal is send to the receiver after a series of delay, such as troposphere delay, ionosphere delay and Sagnac effect. The user measures the time difference between the receive signal and local signal, and calculate the clock difference by the satellite position, delay correct information and the receiver position. In general, for users who precise coordinate is known, the synchronization can be realized by observe one satellite; the time transfer stability can be improved by observe two satellites. The one way time transfer principle is shown in Fig.2.

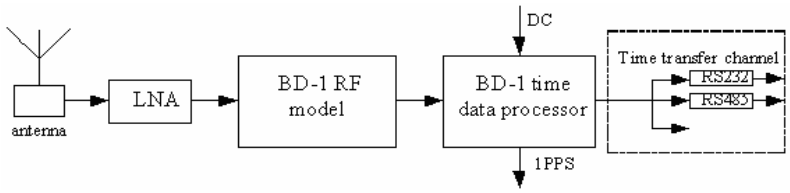

Fig.2. One way time transfer principle

2.2 Two way time transfer mode

In two way time transfer mode, all information are processed in the control centre, the users only need return the received time mark signal. The flow is: the control system sends the time mark ST_0 to satellite at time T_0, the satellite sends it to the users, and the users transmit the ST_0 to the control system by the satellite at time T_1. The control system differences the transmitted and received time mark, and gets the two way time transfer delay (T_1–T_0). The one way time transfer delay can be obtained by divide 2, it is transmitted to the users, and the users adjust their clock time by this one time transfer delay and the time mark. The two way time transfer principle is shown in Fig.3.

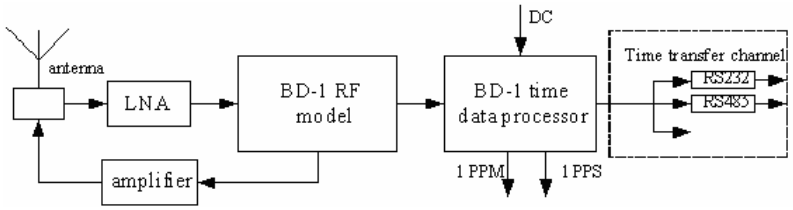

Fig.3. Two way time transfer principle

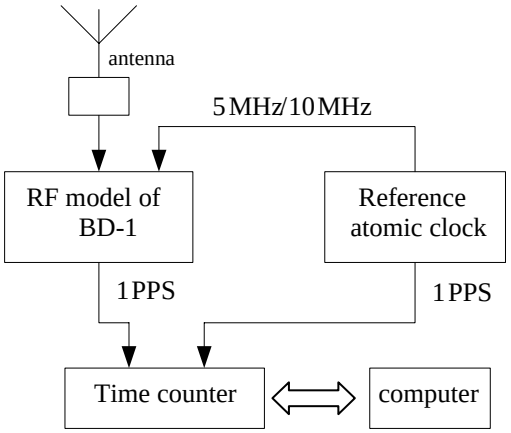

Fig.4. Measure principle of BD-1 receiver

III. EXPERIMENT ANALYSIS

In order to verify the time transfer precision of BD-1, the time and frequency laboratory of Beijing institute of radio metrology and measurement uses the cesium atomic clock as the reference clock, measures the time difference between the BD-1 receiver and the atomic clock in one way time transfer mode. The measurement principle is shown in Fig.4.

In the experiment, the time difference is measured per second, every measurement last for 780s, and repeat 10 times. For every 780 seconds, each 15 seconds data is processed by the quadric least square method, and get 52 time difference value, and this 52 data is processed by the linear least square method. Finally, the difference between the 1PPS of BD-1 receiver and the 1PPS of the local UTC time is calculated. The *ith* time difference Δt_i is calculated according to formula (1):

$$\Delta t_i = \Delta t'_{UTCi} - \Delta t_s \tag{1}$$

Δt_i : time difference of the *ith* measurement.

$\Delta t'_{UTCi}$: time difference between the local UTC time and the BD-1 receiver of the *ith* measurement.

Δt_s : time difference between the local UTC time and the international UTC time.

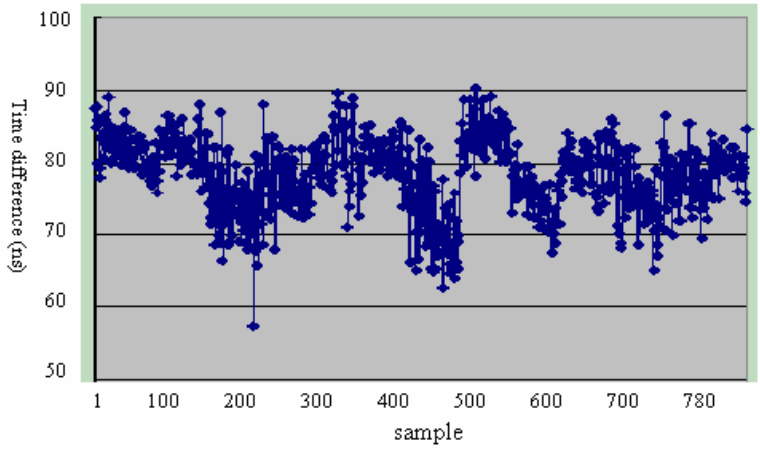

Fig.5. Time difference between BD-1 and reference atomic clock

Finally, the time difference is calculated by average the Δt_i . The time stability is calculated according to formula (2) using least square method.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{p}(t_i - t_i')^2}{p-2}} \quad (2)$$

σ : linear standard deviation.

p : number of the quadratic time difference, $p = 52$

t_i : median time difference of the *ith* 15 second data using quadratic least square method.

t_i' : time difference corresponding to t_i calculated by linear least square method.

Table 1. Experiment result

Time difference(max)	33.8ns
Standard deviation/sqrt(16)	1.36E-10s
Uncertainty	1.68834E-10s

Fig.5. shows the time difference between BD-1 and reference atomic clock, which has the max difference 33.8 ns. The 16 groups measurement data which doesn't have jump is processed in the experiment, the results is shown in Table 1, the Standard deviation is 1.36E-10s, and this result is better than the reported one way time transfer mode precision of BD-1.

IV. CONCLUSIONS

BD-1 is a navigation satellite system developed by china; The time transfer technology using BD-1 is developing and will be used widely. The time transfer principle of BD-1 is introduced in this paper, the experimental results is analysed to assess the time transfer capability of BD-1. The difference between the 1PPS of BD-1 receiver and the 1PPS of the local UTC time which is given by the reference atomic clock is measured in the experiment. The measurement is last for 780 seconds, and repeats at least 10 times. For every 780 seconds, each 15 seconds data is processed by the quadric least square method, and get 52 time difference value, and this 52 data is processed by the linear least square method. Finally, the difference between the BD-1 time and the local UTC time is calculated. According to the experiment results, the time difference is 33.8 ns, the Standard deviation is 1.36E-10s, and it excels the reported precision of BD-1.

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