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Research on the Test Method of the Interior Noise of the Receiver Based on the Satellite Signal Simulator

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***Abstract* –High precision GNSS (Global navigation satellite systems) receiver is used for precision geodetic survey, crustal movement monitoring, engineering deformation monitoring, and integrity monitoring system and so on. The interior noise level is an important index to affect the positioning accuracy of GNSS receiver. Further research on the evaluation method of this paper in the detection of GNSS receiver's interior noise level; put forward the research of interior noise of GNSS receiver evaluation method based on satellite signal simulator. Based on the original zero baseline test principle, the radio frequency navigation signal generated by simulation is used to receiver test. From the test results, it can be seen that the measurement results of the simulator based on zero baseline test is 0.5mm; the measurement results are 0.4mm based on the real environment, and the measurement values are better than the 1mm design requirements. Test results show that the high precision satellite signal simulator based on zero baseline tested results are feasible. However, with the increase of the baseline length, the baseline measurement error also increases. When the baseline length is greater than or equal to 10m, the baseline error is beyond the design requirements of the receiver's nominal target 1mm. The simulation environment is repeatable and controllable, which can directly test the interior noise of the GNSS receiver without reference to the GNSS receiver configuration, which is convenient and effective.**

Keywords –GNSS simulator, interior noise, GNSS receiver

I. INTRODUCTION

GNSS (global navigation satellite system, Global Navigation Satellite System) receiver can provide high precision data real-time, continuous, accurate and reliable, on the navigation satellite precise orbit determination, ionospheric correction and satellite signal integrity is critical to business judgment. High precision measurement of satellite navigation data can also be used in measuring direction posture, geodesy, precision engineering, precision measurement, earth dynamics research, regional surveying control network, crustal movement monitoring, engineering deformation monitoring, and integrity monitoring system and local area differential system for high accuracy measurement system,[1]. In addition to the commonly used high precision measurement receiver has the function of a common receiver and performance indicators, including data and high precision measurement in Post-processing is closely related to a series of index, which is the most important indicator of receiver noise and static measuring accuracy[2].

The interior noise of GNSS receiver (Receiver Interior Noise Level) is a comprehensive reflection of the deviation, the GNSS receiver signal channel delay locked loop and the code tracking loop caused by distance and phase measurement error. The interior noise level of GNSS receiver is a very important index to measure the performance of GNSS receiver. The interior noise level of the GNSS receiver is low, indicating that the receiver has the advantages of good performance and high quality [3,4].

II. RELATED RESULTS IN THE LITERATURE

Due to deviation, PLL (Phase-locked loop) inter-channel delay, code tracking loop deviation affect GNSS receiver performance for GNSS signal interference at the receiver, the resulting error for the receiver's noise. Receiver’s noise level is an important index to reflect the measurement performance of the receiver, how to evaluate the quality of phase data, positioning and evaluation of receiver accuracy.

In the prior art, the zero-baseline method and the ultra-short baseline method are used to detect the noise level in the GNSS receiver [5,6,7,8,9,10]. The zero-baseline method is GNSS test receiver interior noise of GNSS receiver positioning accuracy is affected by the size of the principle is an effective method, multiple GNSS receiver to receive satellite signals from the same antenna by a power distributor, observation data of two receivers selected any solution to the baseline, and its theoretical length is 0. In the production process of power divider clearance of the case, this method can eliminate the influence of antenna phase centre offset and instruments for error signal effect, multipath effect, satellite geometry effects, atmospheric propagation delay and the effect of ultra-short baseline measured error influence.

In the existing test, it is only for the outdoor test of the actual satellite signal, not involved in the satellite navigation signal simulator to receive satellite signal test. Therefore, this paper provides a GNSS receiver based on satellite navigation signal simulator to detect the interior noise of the system and methods.

III. DESCRIPTION OF THE METHOD

A. Layout

The measurement error of GNSS according to the source can be divided into three parts: the error of GNSS signal itself, including orbit error (ephemeris error); GNSS signal propagation path error, including solar radiation, tropospheric delay, multipath propagation and their effects or other causes of cycle slip; error of GNSS itself, including the receiver clock the difference between channels, deviation, PLL(Phase-locked loop), delay deviation, code tracking loop and antenna phase centre deviation. In order to eliminate errors, using the relative positioning of the actual measurement, benefit is the elimination of the satellite clock and receiver clock error, weaken the influence of the ionospheric delay and orbit error, can get better localization result. The relative error of the receiver is mainly from the phase observation data, and the phase observation data is the main index to evaluate the quality of the receiver.

The interior noise level of the GPS is represented by the statistics constructed from the difference between the measured values and the standard values,

$$\Delta d = D - L \tag{1}$$

Type: D is a measurement of noise inside the GPS receiver, D is the concept of the measured value, L is the standard value.

The mean of $\Delta \bar{d}$ is:

$$\Delta \bar{d} = \frac{\sum_{i=1}^{n} \Delta d_i}{n} \tag{2}$$

Thevariance of $Var(\Delta d)$ is：

$$Var(\Delta d) = \frac{1}{n-1}\sum_{i=1}^{n}(\Delta \hat{d}_i - \Delta\bar{d})^2 \tag{3}$$

The Standarddeviation $\sigma(\Delta d)$ is：

$$\sigma(\Delta d) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta \hat{d}_i - \Delta\bar{d})^2} \tag{4}$$

Theskewness of *skewd*is：

$$skewd = \frac{\sum_{i=1}^{n}(d_i - \bar{d})^3}{(\sigma(\Delta d))^3} \tag{5}$$

Thekurtosis of *kurt* is：

$$kurt = \frac{\sum_{i=1}^{n}(d_i - \bar{d})^4}{(\sigma(\Delta d))^4} \tag{6}$$

In fact, the interior noise level is a statistic, a receiver needs a lot of observations, and the weighted average can get a reliable result. In the standard test, need to focus on the statistic characteristics ofΔd, such as the variance and standard deviation. The level of the GPS interior noise level or the degree of dispersion of the comprehensive evaluation, the smaller the standard deviation, the smaller the degree of dispersion of the interior noise level, the higher the stability of the instrument.

The mean value is the tendency of the interior noise level. The standard deviation and variance reflect the stability and uniformity of the interior noise level. The smaller the value, the discrete degree is smaller, the credibility is higher; the skewness is asymmetric degree of interior noise level distribution reflects the degree of symmetry or deviation, skewness is negative, means that the probability density function of the left than the right side of the long tail. Most of the values are on the right side of the average. Skewness is positive, means that in the right side of the tail of the probability density function than on the left side of the long, most of the value in the average value of the left. The skewness is zero, said numerical relatively evenly distributed on both sides of the average value of kurtosis; also called kurtosis, reflects the degree of concentration in the noise level distribution, usually to normal distribution. The kurtosis value is 3, and then the number distribution was normal, called mesokurtosis. The kurtosis value less than 3 indicates that the kurtosis is gentle. The kurtosis is lower than the normal distribution curve, called flat distribution. The kurtosis value greater than 3 indicates higher kurtosis. The kurtosis is higher than that of the normal distribution curve, called spire distribution[11].

The satellite navigation signal simulator is used for simulating real-time multi satellite signals received by different environment of GNSS receiver antenna aperture, it can provide the simulation environment for the development, function and performance test of GNSS receiver, but also can be used for GNSS system level simulation test, to determine the final scheme for GNSS application, can reduce the risk of the use of GNSS save the cost and shorten the development cycle.

B. Method

The reference input interface of an external atomic frequency standard signal access a satellite navigation signal simulator, atomic frequency standard for providing clock reference signal; the output interface of a GNSS receiver connected to the satellite navigation signal simulator. The simulation start time and stop time of the satellite navigation signal simulator, the latitude and longitude values of the navigation frequency points and the coordinates are set. Start the satellite navigation signal simulator, radio navigation signals of the satellite navigation signal simulator generates the GNSS receiver acquisition, tracking and calculation of measurement after deriving the original observation data and save. The received original observation data is processed by the GNSS receiver processing software to generate the interior noise value of the GNSS receiver.

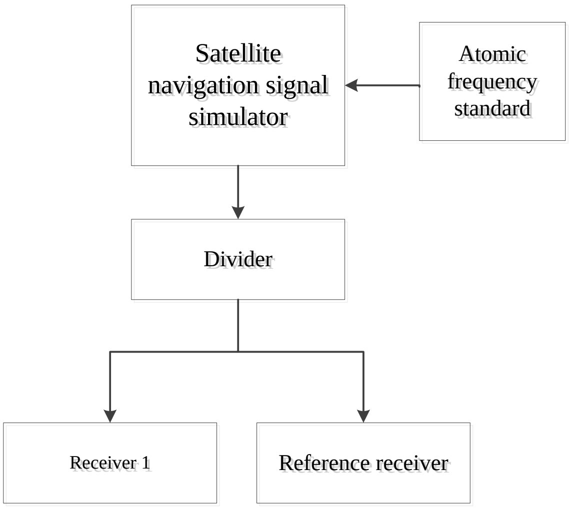

Fig.1. connection diagram of test system

Using B1, B2, L1, L2 zero baseline and ultra-short baseline measurement accuracy to reflect the receiver noise level. Test connection diagram shown in figure 1, 2. The satellite signal simulator to choose static scene, the output signal through the divider access two high-precision receiver, two high-precision receiver will also receive the data Post-processing solution can be obtained by zero baseline measurements; adjust the satellite signal simulator scene location records two times on the positions of the difference of distance at baseline the reference signal output by a power divider access two high-precision receiver, two receivers will successively receive data for Post-processing analysis, static baseline measurement results can be obtained, and then reference and base line values can be static measuring accuracy.

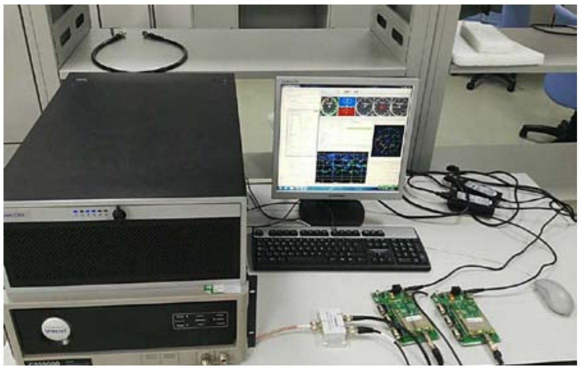

Fig. 2.Diagram of test system

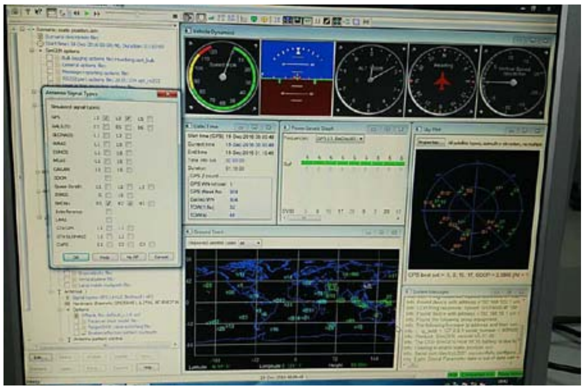

Fig. 3.Simulator settings

(1) Set up the satellite signal simulator (Fig.3) according to the following requirements:

The error parameters such as satellite orbit, satellite clock error, ionospheric delay and tropospheric delay are set to the time-varying error model.

Satellite constellation set: 6 BD satellites &6 GPS satellites, PDOP (Position Dilution Of Precision) ≤5, and the number of visible satellites ≥ 7, the elevation angle ≥ 15 degrees.

User trajectory model: static scene.

Set test system outputB1, B2 frequency of BDS, L1, L2 frequency of GPS satellite signals, the satellite signal through the power divider connected receiver RF input, set up the test system output signal to be measured every star receiver RF input or external LNA RF input signal power (if any) -130dBm.

(2) The measured device is positioned to receive BDS+GPS satellite signal, set the sampling rate of 0.1Hz (10s), and check whether it is the normal state, set the storage data type should at least include B1, B2, L1, L2 pseudo range and carrier phase measurements of the original.

(3)After the completion of the work, according to the specified time to boot, into the static measurement data acquisition, data acquisition process satellite signal simulator to keep the static scene.

(4) Data acquisition process for 1 to 2 hours.

(5)After the observation is completed, copy the collected original observation data for post-processing.

(6) In the ultra-short baseline test, change the position of the receiver in the static scene of the satellite signal simulator; repeat the steps (2) to (5) without changing the scene information, recording the positional deviation before and after the change, and as the baseline reference value.

IV. RESULTS AND DISCUSSIONS

Assuming that the 1 receiver in the scene of the scene and the scene of the 2 acquisition of the number of D11, D12, No. 2 receiver in the scene of the scene and the scene of 2 data collected at D21, D22,. D11 and D21 do zero baseline post-processing analysis to get the results of the noise test; D12 and D22 to do static baseline post-processing analysis, and then compared with the baseline reference value can be obtained static measurement accuracy. In the process of data calculation, the uniform parameter settingssee Table 1.

Table1. Parameter settings

Parameter	Value
Elevation angle	15°
Sampling rate	0.1s
Frequency point	B1+B2+L1+L2
Time	1h

Table2.Test result ofinterior noise (simulation).

Baseline (m)	Times	Measured value(m)	Error (mm)
0	1	0.0003	0.3
	2	0.0006	0.6
	3	0.0002	0.2
	4	0.0004	0.4
	5	0.0008	0.8
6	1	6.0003	0.3
	2	6.0006	0.6
	3	6.0003	0.3
	4	6.0007	0.7
	5	6.0001	0.1

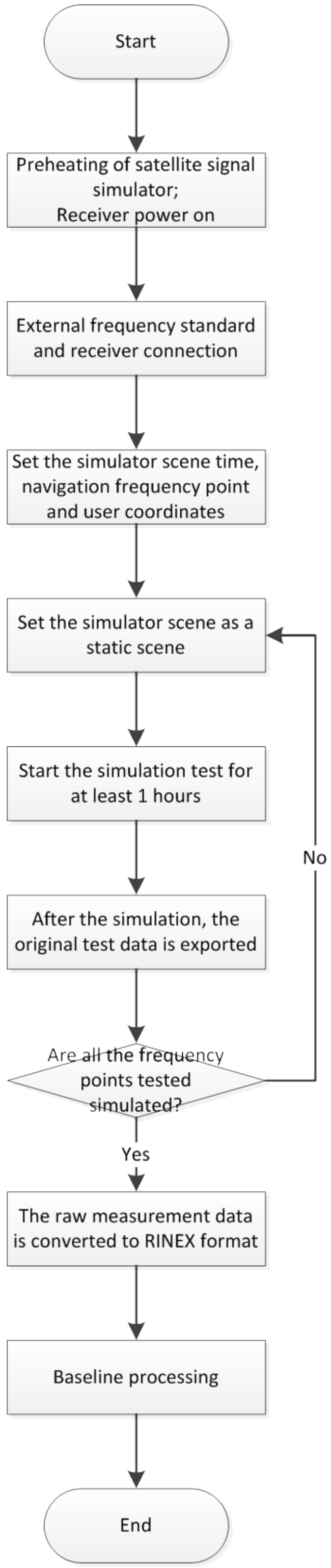

Fig. 4.Simulation flow chart

Based on the test method of the zero line of the real environment, the test time is 1 hours, and the continuous measurement of the time interval is 5 hours. The baseline results are shown in Table 4 and table 5.

Table3.Interiornoisestatistics(simulation).

Baseline (m)	Mean (mm)	Standard deviation	Variance	Skewd	Kurt
0	0.46	0.24	0.058	0.60	-0.95
6	0.40	0.24	0.060	0.17	-1.75

Table4.Test result of interior noise (real environment).

Times	dx m	dy m	dz m	ds m
1	-0.0004	-0.0002	0.0000	0.0005
2	-0.0002	-0.0004	0.0004	0.0007
3	-0.0002	-0.0004	0.0001	0.0005
4	-0.0002	-0.0002	0.0001	0.0003
5	-0.0001	0.0001	0.0001	0.0002

Table5.Interiornoisestatistics (real environment).

mean (m)	Standard deviation	Variance	Skewd	Kurt
0.00044	0.00020	0.000000038	0.08	-0.82

Based on the simulator test, the average value ofinterior noise is 0.5mm. Based on the real environment test, the average value of interior noise is 0.4mm. The measured values meet the design requirements of the receiver, and the interior noise is better than 1mm. The skewness is less than 0.60, indicating the measured GNSS receiver noise level in most of the error distribution in the mean left; kurtosis value is less than 3, indicating the measured noise level of GNSS receiver for flat distribution distribution. It can be seen from the above that the interior noise test based on the satellite signal simulator is consistent with the real environment test results.

Table6.Test result of baseline solution (simulation).

Baseline (m)	Times	Measured value (m)	Error (mm)
10	1	10.0011	1.1
	2	10.0013	1.3
	3	10.0010	1.0
	4	10.0009	0.9
	5	10.0011	1.1
24	1	24.0022	2.2
	2	24.0033	3.3
	3	24.0027	2.7
	4	24.0019	1.9
	5	24.0022	2.2
500	1	500.0882	88.2
	2	500.0938	93.8
	3	500.0837	83.7
	4	500.0889	88.9
	5	500.0932	93.2
1000	1	1000.0349	34.9
	2	1000.0409	40.9
	3	1000.0448	44.8
	4	1000.0357	35.7
	5	1000.0344	34.4
2000	1	2000.0293	29.3
	2	2000.0252	25.2
	3	2000.0278	27.8
	4	2000.0315	31.5
	5	2000.0245	24.5

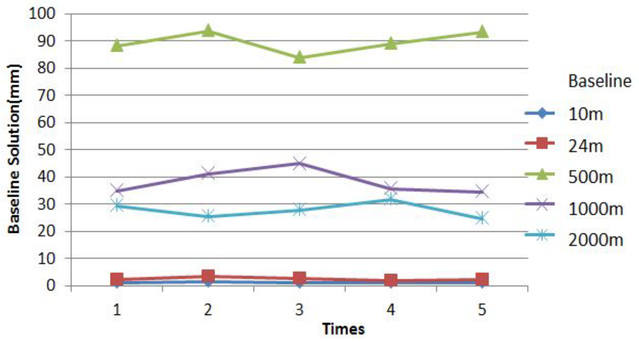

Fig. 5Test result of baselinesolution

The test results show that the test results based on zero baseline are feasible. However, the baseline error increases with the increase of baseline length(Table 6,Fig. 5). When the baseline length is greater than or equal to 10m, the baseline error exceeds the design requirements of the receiver nominal 1mm.

V. CONCLUSIONS

On the basis of the principle of the original zero baseline test, the test method is feasible and the test results are stable and reliable. The test of interior noise receiver of GNSS satellite signal simulator based on the simulation environment can be directly carried out repeated and controlled, interior noise test of GNSS receiver, convenient and effective or not need to refer to the GNSS receiver configuration; in addition, tested in the laboratory, is not affected by weather conditions, the test is more accurate.

VI. ACKNOWLEDGMENT

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REFERENCES

[1] Dai Shuicai,*GPS Receiver Detection Technology Research* [D], Hunan: Master degree thesis of Central South University,2004.

[2] You Zhendong,*Research on InteriorPerformance Testing Method of GNSS Receiver*[D],Hubei: Master degree thesis of Wuhan University,2005.

[3] Liu Junqing,Ding Guang,Zhang Chenxia,Zhang Yu.*The Application of Measurement Techniques about the GPS Receiver Noise and Phase Center Variation*[J],Journal of Disaster Prevention and Reduction,2012,vol.28,No.3,pp.77-81.

[4] Du Juan,Zhang Hui,Liu Xing,Gong Shaishuai,*Precision Detection Method of GPS/BD2 Compatible Receivers Based on Zero-baseline[J]*,Ship Electronic Engineering,2013,vol.33,No.7,pp.121-123.

[5] GJB 6564-2008, *Verification regulation for Global Positioning System (GPS) receiver[S]*,General Armament Department of the people's Liberation Army,2008.

[6] JJF 1118-2004,*Specifications for Check off and Test of GPS Receiver (Surveying and Navigating Model) [S]*, General Administration of Quality Supervision, Inspection and Quarantine of PRC.

[7] Dai Shuicai, Zhu Jianjun,Zhang XuezHuang,Tang Limin, *The Evaluation and Test on Interior Noise Level of GPS Receiver[J]* Beijing Surveying and Mapping,2007,No.1,pp.14-18.

[8] Zhang Rui,Cai Yanhui,Zhai Qingbin, InteriorNoise Level Evaluation of Modern GNSS Receiver[J], China Metrology,2010,12,pp.97- 99.

[9] Amiri-SimkooeiA R,Tiberius CCJM, *Assessing Receiver Noise Using GPS Short Baseline Time Series[J]*, GPS Solutions,2007,vol.11,No.1,pp.21-35.

[10] Langley R B, *GPS Receiver System Noise*[J], GPSWorld,1997,vol.8,No.7,pp.40-45.

[11] Luo Haiying,Liu Guangjun,Liu Xudong,*Resrarch on the evalution methods of testing on interior noise level of GNSS receiver*[J],Electronic Measurement Technology,2015,vol.38,No.1,pp.34-37.