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Research on Test Method of Satellite Navigation Signal Simulator

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Abstract. The method of the current acceleration range navigation satellite signal simulator detection theoretically analyzed, but in the actual test work, how to set the satellite navigation signal simulator motion scenes and satellite receivers, a smaller level of the RF test signal navigation As well as implementing automated testing, there is a lack of practical and feasible testing methods. This paper simulates the RF signals received by receivers in different dynamic environments in real time, builds a dynamic range test staging, forms a specific test plan, and carries out the validity, practicability and effectiveness of the test verification test method. This test method is simple and reliable. The dynamic range of the satellite navigation signal simulator in the simulation environment can be accurately detected by this method.

1. Introduction

With this construction of this Beidou satellite navigation system, the emerging technology of satellite navigation was increasingly favored by all walks of life[1], and satellite navigation receivers are also widely used. Since satellite navigation receivers are mainly used in aeronautical speed, high-precision measurements and other fields, the accuracy and reliability of output measurement data is very important [2-4]. The Satellite navigation signals and generating simulator and runs a variety of different simulation scenarios according to specific test requirements.The performance of the satellite navigation signal simulator (SNSS) analog output RF signal directly affects test results of the satellite navigation receiver[5].For guarantee the needs of satellite navigation receiver test and evaluation, it is extremely important to establish a standard and perfect satellite navigation signal simulator key indicator measurement and calibration method [6].

2. Test Principle

2.1. Working principle

The GNSS satellite signal simulator system usually adopts the main structure scheme of "DSP+FPGA+host computer", which mainly includes the host computer digital simulation control module, DSP information processing module, FPGA signal processing module, RF module and DA digital-to-analog conversion module. Among them, the host computer is mainly responsible for setting the carrier motion trajectory, ephemeris, almanac, error and other parameters; DSP is responsible for the core calculation work in the process of analog signal generation, including calculating user trajectory, generating navigation message, calculating visible satellite position information in real time, and calculating navigation Signal propagation delay, etc.; FPGA is mainly responsible for receiving carrier control words, code control words and navigation messages sent from the DSP to generate modulated RF signals. The working principle of the simulator system is shown in Figure 1.

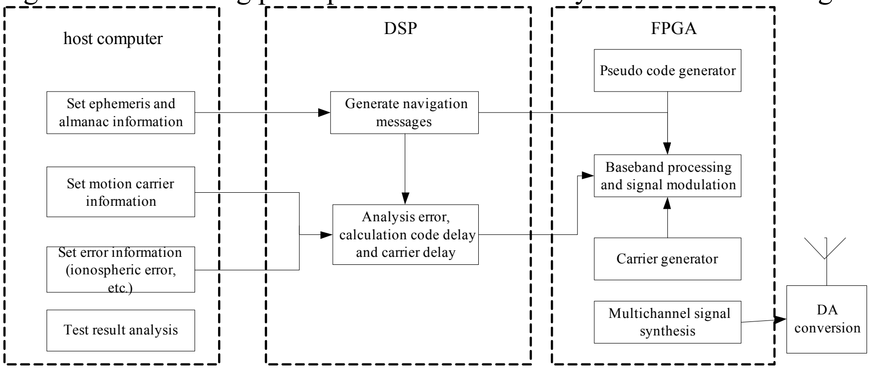


Figure 1. work principle of satellite navigation signal simulator

2.2. *Doppler effect*

Doppler effect is a phenomenon when there is a relationship between the transmitter and the receiver, the frequency of the transmitting information received by the receiving body is different from the frequency of the transmitting information of the transmitting source. When the source is close to the receiver, the received frequency rises and decreases when it leaves [7]. At present, the Doppler effect has been widely used in airborne early warning, navigation, missile guidance, satellite tracking, battlefield reconnaissance, range measurement, weapon fire control and meteorological detection [8]. The doppler effect working principle is shown in Figure 2.

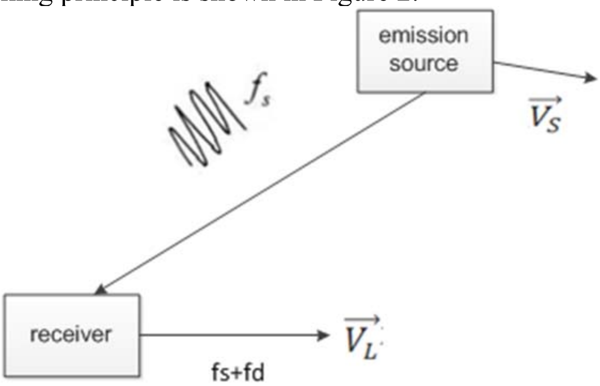


Figure 2. Doppler effect diagram

The Doppler shifted frequency received by the receiver can be calculated by:

$$f_d = \frac{(\overrightarrow{V_L} - \overrightarrow{V_S}) \bullet \vec{r}}{v} f_s \quad (1)$$

2.3. *Main test steps*

The test method includes the following steps:

(1) Turn on the satellite navigation signal simulator and warm up for more than 30 minutes;

a) turn off the atmospheric delay;

b) selecting a satellite positioning system and setting satellite signal frequency points;

c) Simulator simulation scene Select a single visible satellite, edit the satellite orbital parameters to make it in the geostationary orbit, and set the longitude value B of the intersection of the satellite and the Earth's center at the spherical point (called the sub-satellite point). If the simulator supports the BDS system, since there are five geostationary orbit satellites in the BDS system, one of the visible satellites can be selected;

d) turning off the visible satellite spreading code and navigation data so that only a single carrier modulated signal is transmitted;

e) setting the visible satellite signal power to a maximum value;

f) setting the initial position of the receiver to a longitude value of B, a latitude value of 0, and a height value greater than 0;
g) Set the receiver motion model: the receiver is stationary for 10s, and the receiver accelerates motion after 10s, wherein the initial speed is 0m/s, the acceleration is the upper limit of the simulator acceleration index range, and the final speed is the upper limit of the simulator speed range indicator.
(2) Run the scene to start simulation, the frequency automatic acquisition device collects the frequency value of the frequency meter output in real time, and the acceleration range analysis and calculation software is based on the Doppler frequency shift principle, and uses the formula 1) to calculate the acceleration value:

$$\alpha = \frac{f_d}{\Delta T} \cdot \frac{c}{f_s} \tag{2}$$

Where c is the speed of light, f_d is the Doppler shift, and ΔT is the time elapsed from the lowest end to the highest end, and fs is the frequency of the RF signal received when the receiver is stationary.

3. Test Frame

The satellite navigation signal simulator acceleration performance testing staging (in Figure 3) is built. The testing staging comprise a navigation signal control unit , a satellite navigation signal simulator, an amplifier, an automatic frequency acquisition device, and an acceleration performance analysis calculation software. The navigation signal control module was connected to the satellite navigation signal simulator for controlling the satellite navigation signal simulator to freely configure the detection scene; the satellite navigation signal simulator was generate the satellite navigation signal; the amplifier, for example, The lowest noise amplifiers, is connected to the satellite navigation Between the signal simulator and the frequencies meter, whether it is required to test the signal with less intensity, the amplifier needs to amplify the satellite navigation signal for the frequency meter to receive; the frequency automatic acquisition device is based on the LABVIEW software development frequency automatic acquisition program to measure the frequency meter. The frequency value of the radio frequency navigation signal is automatically collected inside the computer check; the acceleration performance analysis calculation software calculates the acceleration result according to the Doppler frequency shift acquired through the automatic frequency acquisition device.

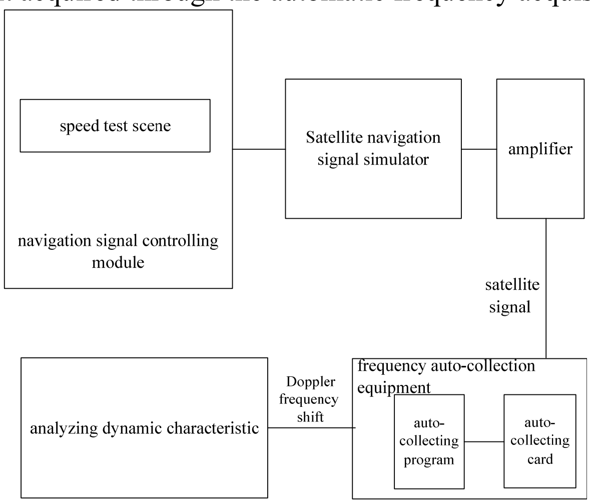
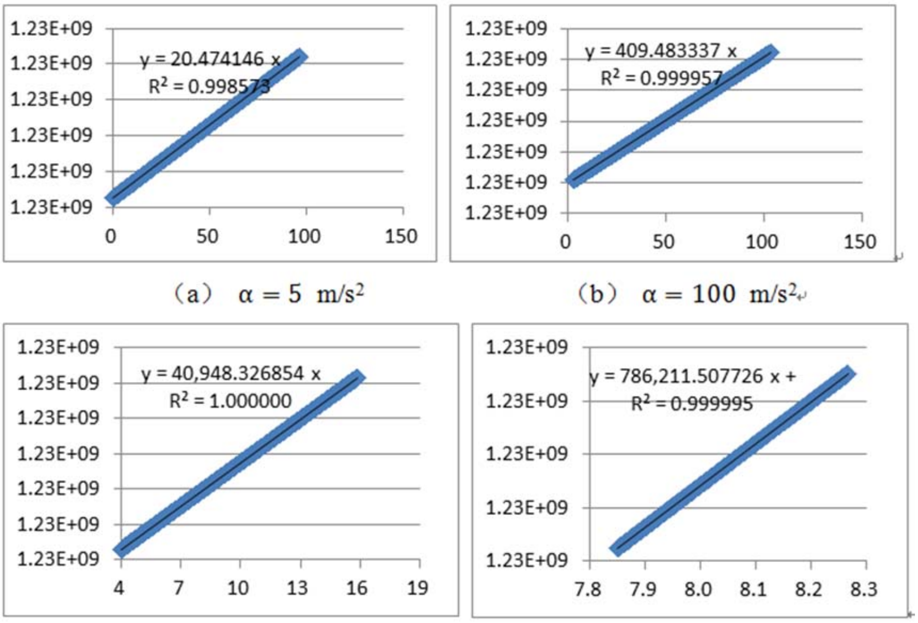


Figure 3. Acceleration Performance Test Staging

4. Experiments

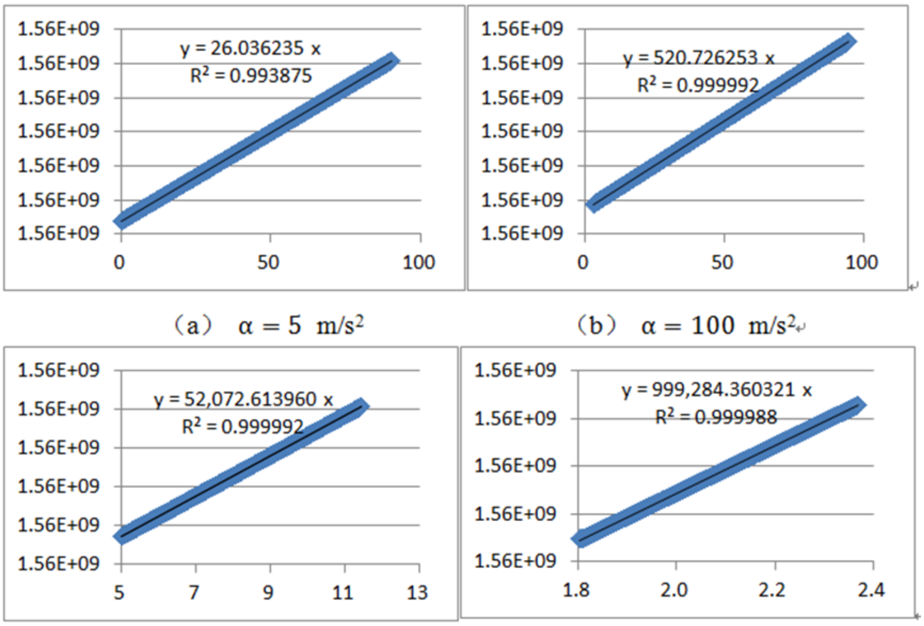
Under the GPS L2 and BDS B1 frequency points, the acceleration values are $5m/s^2$、$100m/s^2$、$10000m/s^2$、$192000m/s^2$ espectively. The test results are shown in Figure 4-5. According to equation (4), The slope value is $\alpha \bullet \frac{f_s}{c}$. According to the test results, the measurement results of the test methods studied in this paper reach $1mm/s^2$.



(a) α = 5 m/s² (b) α = 100 m/s²

(c) α = 10000 m/s² (d) α = 192000 m/s²

Figure 4. GPS L2frequency point



(a) α = 5 m/s² (b) α = 100 m/s²

(c) α = 10000 m/s² (d) α = 192000 m/s²

Figure 5. BDS B1frequency point

5. Conclusion

In this paper, the acceleration performance test method of satellite navigation signal simulator is proposed. Based on the principle of Doppler shift generation, a set of SNSS acceleration performance testing platform is built, and the specific detection method of acceleration performance is formed. The RF signal of the analog output is automatically acquired, and the acceleration performance analysis calculation software is developed to calculate the acceleration performance result by the least squares fitting method for the acquired Doppler frequency shift. It is verified by experiments that the test method is feasible, the test result is stable and reliable, and it can provide technical basis for the detection of the acceleration performance of the SNSS.

Acknowledgments
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