Design and implementation of a GNSS navigation terminal automation test system

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Abstract: In order to solve the problem that it is impossible to carry out multi-scene and multi-station tests for satellite navigation terminal in the market, an automatic test system is developed. By integrating multiple test scenes and multiple test sources, multiple navigation terminals can be tested simultaneously. The test system is classified and constructed according to hardware and software, and the data flow and control command flow among subsystems are introduced. Based on the concept of functional modular design, the test system uses Qt to develop the test software. Finally, a commercial navigation terminal is taken as an example to verify the test system. The satellite navigation terminal test system constructed by multi-source and multi-scene test method has high test efficiency and the test results prove that the test system is reliable.

Key words: Satellite Navigation; Navigation terminal; Automated testing; System design; System implementation

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1 INTRODUCTION

With the completion of the Beidou navigation satellite system, the application of satellite navigation terminals (hereinafter referred to as navigation terminals) is being further expanded. At present, the test system of navigation terminal in the market has some disadvantages such as low integration, single test source, low test efficiency. For the weakness of the existing test system, this paper develops a navigation terminal automation which is based on BD 420005-2015 second-generation navigation satellite System major special standard of China "Performance requirements and test methods for BeiDou Global Navigation Satellite System (GNSS) navigation unit". This system provides a multi-scenario and multi-source automated test platform by integrating multiple test sources in multiple scenarios, and it can realize multi-terminal simultaneous testing. This paper first introduces the composition of the test system. Additionally, it illustrates the working mode of the test system by using the data flow and control flow of the system respectively. Finally, the reliability of the system is verified through experiments aiming at the specific performance of the test system.

2 System architecture

The test system is composed of hardware system and software system, in which the hardware system provides the material basis for the operation of the test system and it is the prerequisite for the effective operation of the test system. Software systems are used to connect and control hardware systems for process control and to generate the data needed to test the process. The test system composition is shown in Figure 1.

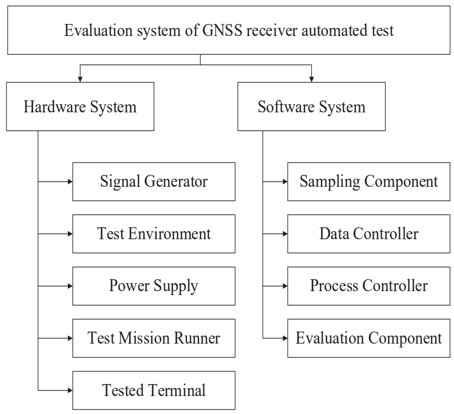

Fig.1 Test system composition diagram

Hardware system includes test signal generation system, test environment system, power system, test task running system and navigation terminal. The test signal generation system is used to generate the reference data required by the test. The test environment system is used to meet different test requirements of the navigation terminal test environment; The power system consists of a program-controlled DC power supply, which is used to supply power to the navigation terminal. The test task running system is used to run the control software and control the cooperative work of all hardware systems. It is also used to collect, evaluate and store data.

The software system consists of data acquisition module, data management module, process control module and evaluation module. The data acquisition module is used to collect the data and status information generated during the test. The data management module is used to display and store the intermediate data generated during the operation of the system. The process control module is used to realize various test processes in the test specification and complete the test according to the specified time sequence control system hardware equipment; The evaluation module uses the reference data obtained in the test process and the output data of the navigation terminal to calculate and evaluate the performance indicators of the navigation terminal and determine whether the navigation terminal is qualified.

3 System design and implementation

According to the test standard, the test system is designed. The composition of each subsystem is further analyzed, and the hardware system and software system are designed and implemented respectively. The design and implementation methods of each system are as follows.

3.1 Hardware system design and implementation

The hardware system consists of the test signal generation system, the navigation terminal and the auxiliary system needed to support the normal operation of the test system. The specific design and implementation methods of each hardware system are as follows.

3.1.1 Test signal generation system

In order to meet the requirements of the test specification and realize multi-source test, the test signal generation system includes GNSS signal source simulator, satellite signal acquisition and playback system, signal repeater and high-precision integrated navigation system.

GNSS signal simulator can simulate real satellite signals by setting parameters and transmit them to the device under test, so as to evaluate and test the navigation terminal under test by using the test system[5]In this paper, Sparron GSS7000 signal simulator is adopted, which can simulate satellite signals of GPS, BEIDOU and GLONASS. The acquisition and playback system is used to collect the navigation signals of the actual outdoor scene, and repeat the replay for many times in the laboratory to construct the real indoor signal testing scene[6,7], Spirent GSS6450 satellite signal acquisition and playback instrument was used in this paper. The signal repeater locks the satellite signal through the receiving antenna, and introduces the received satellite signal from the outdoor to the indoor, and receives the satellite signal through the indoor navigation terminal, and provides the adjustable test signal for the navigation terminal. The high precision integrated navigation system can receive the real satellite signal in the open air and the positioning accuracy is high, so the positioning results can be used as the reference data for testing and evaluation. Since the test signal generation system contains multiple test sources, in order to realize the random switch of test sources, the system also includes a signal distribution device for selecting input signals.

3.1.2 Test environment system

In order to realize multi-scene test of the test system, the test environment of the system is divided into indoor wired environment, indoor wireless environment and outdoor environment.

In indoor wired environment, the navigation terminal is connected with the test signal generation system through cables to realize the wired signal transmission test. The indoor wireless environment is composed of anechoic chamber and rotating pedestal. The navigation terminal is fixed on rotating pedestal in the anechoic chamber. The indoor test signal generation system transmits wireless navigation signals in the anechoic chamber through the transmitting antenna, which can effectively isolate external electromagnetic interference to test the antenna performance of navigation terminal. The outdoor environment is composed of the high-precision integrated navigation system, power system and other supporting hardware, all of which are placed in the test vehicle. When the test vehicle is driving outdoors, the navigation terminal and the high-precision integrated navigation system receive actual satellite signals respectively, and the positioning results obtained are compared and tested. In particular , the systems can run in three test environments which have different hardware but share a single software system.

3.1.3 Power system

The power system is used to power the navigation terminal. In order to realize the automation of the system, the programmed power supply is used to supply power to the navigation terminal. The test task operation system can send instructions to the programmed power supply to open and shut down the control and set the electric current and voltage. Two sets of 4-port programmable power supply of N6701C are used, which can supply power to 8 navigation terminals at the same time.

3.1.4 Test the task running system

Based on a test server, the test task running system can be divided into three modules according to functional classification: test running, performance evaluation and system management. The test run module is used to support the system operation, the performance evaluation module evaluates the test data through the evaluation algorithm, and the system management module is used to manage the process parameters and various intermediate data of the test process.

The specific realization of each hardware system model and specification in this paper is shown in Table 1.

Table 1 Part of the test equipment specifications

Test equipments	Models and specifications
GNSS signal simulator	Spirent GSS7000
Signal sample playback	Spirent GSS6450
Signal transponder	LT10238
Integrated navigation	NovAtel ProPak6
Signal distributor	Huaxiang SHX-0.8/2.7-8S
Power supply	Keysight N6701C

All hardware devices are assembled and connected to build the indoor hardware system. The physical picture is shown in Figure 2.

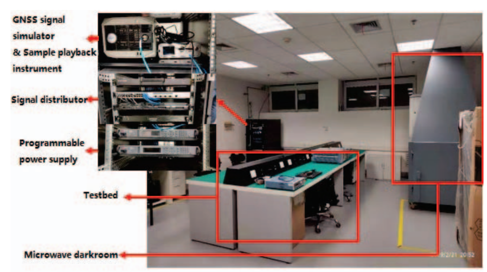

Fig.2 Physical picture of indoor test system

3.2 Software system design and implementation

The software system is used to integrate and control the operation of the hardware system to generate relevant test data, and the evaluation algorithm is used to compare and evaluate the test and reference data, and the final evaluation result is output. For this test system, the software takes Qt as the development platform and is decomposed according to the interface layer, logic layer and data layer. The interface layer is used to display configuration parameters, test status, test information and system information. The logical layer includes test engineering configuration, test process control, external equipment management and monitoring. The data layer includes user information, process parameters and evaluation results, etc.

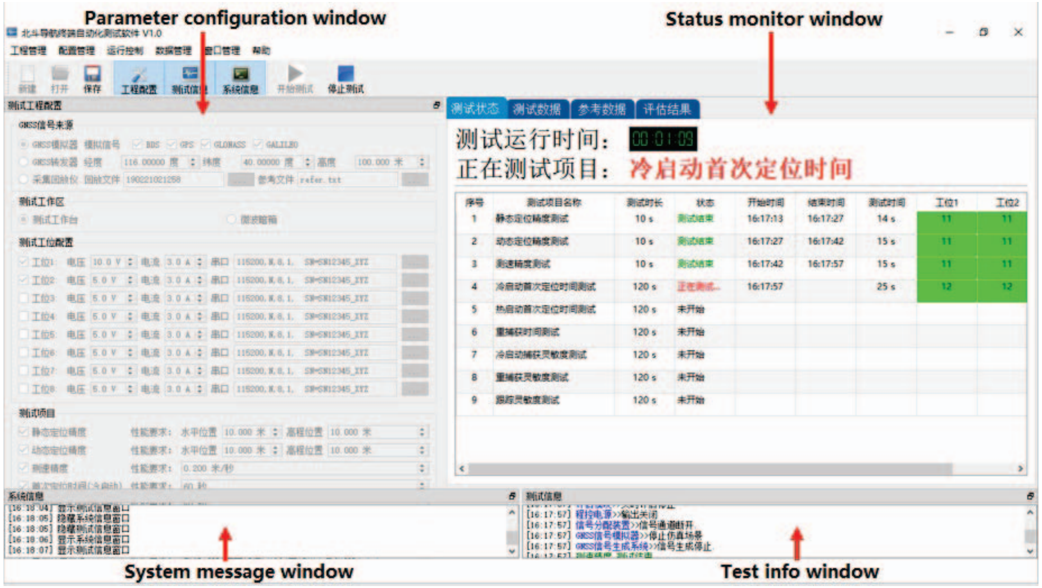

Fig.3 Main interface diagram of software

The software interface is shown in Figure 3. The left side of the interface is the parameter configuration window, which can configure the parameters of 8 navigation terminals under test at the same time, mainly including serial port parameters, test current and voltage and manufacturer information, etc. On the right is the status monitoring window. There are four sub-windows, which can display the current test items, test intermediate data and test results of 8 navigation terminals respectively. The system information window is used to record user actions, and the test information window is used to display the specific process of the test[8].

3.3 Working mode of the system

3.3.1 Test system data flow

The data flow between each subsystem within the test system and the navigation terminal is shown in Figure 4.

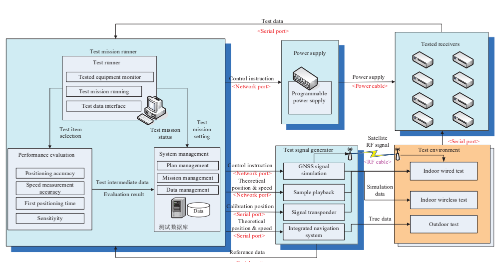

Fig.4 The test system data flow

Specific testing process is as follows: new testing tasks running system or from the test tasks running data in the system management module to read in advance design complete testing tasks, the task of scene files needed to set up the test process in advance, test signal generation system according to the scene file generated reference data and broadcast to the system test environment, at the same time the theory of simulation with reference data sent to the testing tasks running system, the reference value for evaluating theory. The test environment system broadcasts the reference data to the navigation terminal, and the navigation terminal starts to work after receiving the reference data and outputs the test data. The performance evaluation module USES test signals to generate theoretical reference data such as position and speed output by the system, as well as measured data such as position and speed output by the navigation terminal under test. The evaluation module calculates the mean error of each data during the test period, outputs the test results and stores them in the data management system.

3.3.2 Test system control flow

The operation control commands of test evaluation system include: start test, stop test, and initialize navigation terminal; The health states are: initializing, initialized and running. All operation control instructions are issued by the test task running system. After receiving the command, other subsystems will perform startup, stop and other operations, and then feedback the current running status to the test task running system. The control flow is shown in Figure 5.

4 Test system verification

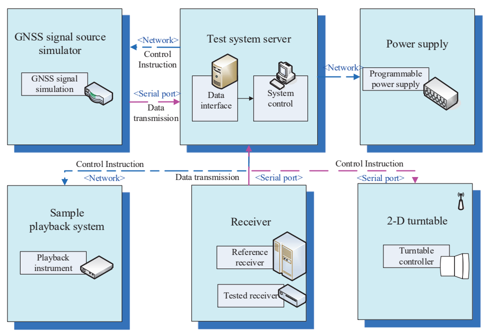

Fig.5 The test system control flow

The commercial navigation terminal is used to test the navigation terminal in the indoor and outdoor environment of the test system, and the test results are compared with the calibration results of the navigation terminal manufacturer to verify the correctness of the test system's functional performance [9,10].

4.1 Verification of laboratory test system

In the indoor test system, GNSS signal simulator is used to generate simulated satellite signals for the verification of the indoor test system, because the signal simulator can flexibly set the motion track, signal on-off and signal power of the carrier.

Spirent GSS7000 signal simulator is used as the test signal input source for this test. The test results under indoor wired environment are shown in Table 2.

Table 2 Indoor verification results

Test items	Measured results/Nominal indexes
Static horizontal positioning accuracy	1.316m/1.5m
Static vertical positioning accuracy	1.952m/3m
Dynamic horizontal positioning accuracy	1.576m/10m
Dynamic vertical positioning accuracy	2.588m/10m
Velocity measurement accuracy	$0.043 m \bullet s^{-1}$ / $0.050 m \bullet s^{-1}$
First positioning time(cold start)	46.9s/50s
First positioning time(hot start)	2.4s/15s
Recapture time	1.3s/2s
Capture sensitivity	-145dBm/-144dBm
Recapture sensitivity	-158dBm/-144dBm
Tracking sensitivity	-160dBm/-144dBm

It can be seen from the test results that all the test results are smaller than the nominal indicators of navigation terminals, indicating that the indoor test results of the test system are reliable.

4.2 Outdoor test system test verification

The outdoor test system is placed on a test vehicle. During the test, the outfield navigation satellite signal is used as the input signal of navigation terminal to ensure that the test result of navigation terminal is more consistent with its actual performance. The outdoor test system is equipped with a NovAtel ProPak6 high-precision integrated navigation system, whose horizontal positioning accuracy is 1.5m, vertical positioning accuracy is 1.5m, and speed accuracy is 0.03m/s. The positioning accuracy of this system is much higher than that of the navigation terminal, and its output data can be used as the reference data for the performance evaluation of navigation terminal. During the test, when the test vehicle travels at a certain speed, the positioning error of the navigation terminal can be obtained by comparing the positioning results of the combined navigation system and the navigation terminal.

In order to ensure the intuition of outdoor test location, the software displays the geographical location of the test vehicle in real time utilizing map display. Figure 6 shows the real-time display of the map during the test, in which red is the track of the navigation terminal under test and blue is the track output by the integrated navigation system. It can be seen from the trajectory that the positioning state of the navigation terminal is relatively stable during the test, and the synchronization rate with the reference position remains high.

Fig.6 Track display of outdoor performance test

The test results are shown in Table 3. The error of horizontal positioning accuracy and vertical positioning accuracy of the navigation terminal are both within 10m. The test results are consistent with the factory parameters of the navigation terminal, indicating that the outdoor test results of the test system are reliable.

Table 3.Outdoor test result

Accuracy	Measured results / Nominal indexes
Horizontal	2.456m/10m
Vertical	7.712m/10m
Horizontal velocity	$0.030 m \cdot s^{-1}$ / $0.050 m \cdot s^{-1}$

5 The conclusion

The automatic testing software for navigation terminals can be used for signal input by GNSS simulator, acquisition and playback instrument and GNSS repeater, and can also be utilized to receive actual signals for testing outdoors by road test vehicles. 8 navigation terminals can be navigation at the output end at the same time, realizing multi-scene, multi-source and multi-station testing. The software interface of the test system can display test items, test status, test data and test results in real time to reflect the current test status. After the end of the test, the intermediate data of the test will be saved for later analysis. The system will judge whether the current test product is qualified according to the test results and generate the test report. In the whole test process, the system works normally, and the test results show that the test system is reliable.

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