Research on Monitoring System of Ocean Observation Buoy Based on Multi-sensor

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Abstract. With the continuous development of my country's marine three-dimensional monitoring business, it has put forward higher requirements for the stability and reliability of marine monitoring buoy communication equipment. In order to meet the above requirements, this study designed a multi-sensor-based marine observation buoy monitoring system. Optimize the system hardware structure by optimizing the multi-sensor function framework, and then improve the system software operation process to improve the system positioning accuracy and precision. Experimental results show that the multi-sensor-based marine observation buoy monitoring system is highly effective in practical applications and can provide a better reference for the three-dimensional monitoring business of my country's marine environment.

Keywords: Multi-sensor · Ocean observation · Buoy monitoring · Positioning accuracy · Precision

1 Introduction

With the development of economy, human activities on the sea are becoming more and more frequent, while marine environmental problems have become increasingly prominent. In addition to being affected by various marine environmental disasters such as marine pollution and marine red tides, my country's coastal areas are also affected by disasters caused by typhoons, ocean waves, storm surges, sea ice and other dynamic phenomena, making it a country with more serious marine disasters in the world one. Vigorously developing the cutting-edge technology of ocean monitoring can not only improve the original innovation ability of the national ocean monitoring technology, but also lay a solid technical foundation for the sustainable development of other ocean technologies [1].

Buoy monitoring is the main method of ocean observation and an important part of the marine environment three-dimensional monitoring network. It has the characteristics

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of strong resistance to harsh environments, large capacity, long in-place time and long life, and strong ability to resist man-made damage. During the process of severe weather such as storm surge and typhoon, it can obtain valuable hydrometeorological data and provide data support for the study of severe weather process. It has become the national marine monitoring, marine military rights protection, environmental protection, disaster reduction and prevention, petroleum and biological resources important carriers such as exploration and development, harbor construction, fishery fishing, and marine aquaculture projects cannot be replaced by other ocean observation methods [2]. Therefore, the design and analysis of the marine buoy monitoring system can better promote the development of marine monitoring technology, promote the development and utilization of the ocean, and contribute to economic development and social progress.

In the process of marine buoy monitoring, many projects require far-sea, long-term data monitoring, which requires a lot of manpower and material resources [3]. The data communication function of the multi-sensor can solve the problem of ocean monitoring data communication. Not only can the monitoring data be easily obtained through the ground station, but also the two-way communication function can be used to remotely control the equipment thousands of miles away.

Based on the above research background, this paper designs an ocean observation buoy monitoring system based on multi-sensor, in order to provide better help for Marine environment three-dimensional monitoring business in China.

2 Design of the Monitoring System of Ocean Observation Buoy

2.1 Hardware Configuration of Marine Observation Buoy Monitoring System

Ocean monitoring technology is a comprehensive high-tech formed by integrating computers, information and sensors, databases, remote communications and other disciplines. It integrates the development results of multiple disciplines and represents the frontier of high-tech development. It follows the development of related disciplines and technologies. Development and rapid development [4]. A monitoring system is designed for the multi-parameter ocean buoy, including the buoy system, the shore station receiving system and the upper computer, etc. The schematic diagram is shown in Fig. 1.

The buoy management unit is mainly divided into two parts: the data acquisition system and the buoy body [5]. The data acquisition system includes acquisition main control service module, acquisition array element, cable array and sensor communication terminal. The acquisition main control service module and battery are placed in the buoy body cabin, and its structure is shown in Fig. 2.

The traditional monitoring system refers to a computer system with data collection, monitoring, and control functions. The various production parameters collected in marine environment monitoring and common industrial monitoring systems are essentially the same, but the application environment is different. In the industrial production site, the monitoring system usually connects the monitoring hosts distributed geographically by wire [6]. In the marine environment monitoring system, since the monitoring values of hydrological elements, chemical elements, and algae density should be obtained directly

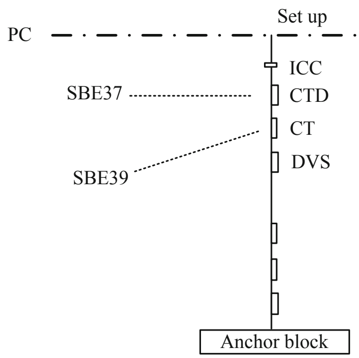

Fig. 1. Sensor detection structure of marine buoy monitoring system

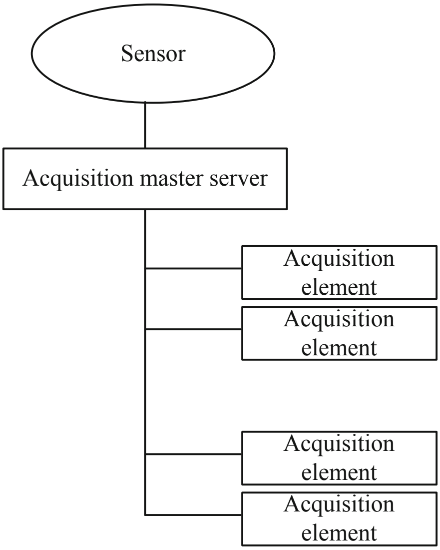

Fig. 2. Buoy unit structure

from seawater, the monitoring equipment must work in the seawater environment, and marine stations, as one of the monitoring equipment, are usually located on the coast.

In order to improve the scientificity and accuracy of the monitoring results, the monitoring coverage area of the marine monitoring system should be as large as possible, so the distance between the monitoring points is measured in kilometers. It is obviously impractical to connect buoys with a large distance in the ocean and to connect the buoys with the stations on the shore in a wired manner [7]. It can be seen that the wired connection method usually used in the monitoring system cannot meet the needs of the marine monitoring environment [8]. Therefore, this design will select the GPRS wireless communication method widely used in remote monitoring system equipment.

The configuration of the system hardware structure is shown in Fig. 3.

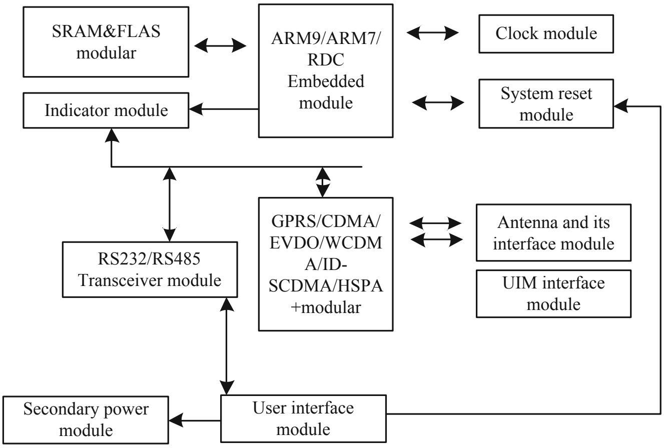

Fig. 3. System hardware structure configuration

In the system client/server, abbreviated as the C/S structure of the database system, the data processing task is divided into two parts: one part runs on the client side, and the other part runs on the server side [9]. There can be multiple division schemes. A commonly used scheme is: the client is responsible for application processing, and the database server performs the core functions of the DBMS. There are multiple hardware in the system, and the communication interface of each hardware is not the same. The specific interface between each module and the microprocessor STM32F407ZGT6 is shown in Table 1.

Table 1. Function description of each module

Modular	Model	Function description
Magnetic sensor	MicroMag3	Used to detect ships close to buoys
Infrared sensor	LH1778	It is used to detect human body near buoy
Stepper motor drive	THB7128	Used to drive stepping motor
Microprocessor	STM32F407ZGT6	Used for data acquisition, analysis and system control
TF Card		Used to store data
Electronic compass	HMC5883L	Used to output angle information and correct camera position
Camera	OV2640	It is used to collect the image around the buoy
Relay circuit	JZC-32F-012	Switch of sound light alarm
Power management circuit	TSPIH100	Used to detect output voltage and current of battery

In the C/S structure, client software and server software can run on one computer, but most of them run on different computers in the network. Client-side software generally runs on a PC, and server-side software can run on various types of computers from PCs to mainframes. The database server separates the data processing tasks to run on the client and the server, thus making full use of the server's high-performance database processing capabilities and the client's flexible data representation capabilities [10]. Usually, only query requests are sent from the client to the database server, and only the query results are sent back from the database server to the client. There is no need to transmit the entire file, which greatly reduces the amount of data transmission on the network [11]. It is given by the voltage of the CS pin. In this design, the CS pin is directly connected to the A/D mapping pin PA7 of the microprocessor, and the voltage value is obtained by sampling the voltage of the CS pin, and then calculating according to formula 1 to obtain the current of the power supply Value, the formula is as follows:

$$\text{Iout} = \frac{V_{\text{cs}} \times k}{R_{\text{cs}}} \tag{1}$$

Among them, k is the ratio of the output current to the sensing current, which is a fixed value, generally 500, and R_{cs} is the external resistor of the pin CS, that is, R34 in the circuit diagram. In order to achieve higher monitoring accuracy, R_{cs} needs to select a resistor with an accuracy of 1% or higher, and the value of V_{cs} ranges from 0 to 4 V. TPS1H100-Q1 also has a programmable current limit function. When the current exceeds the set value, the TPS1H100-Q1 will automatically disconnect the power supply. The current value setting can be calculated according to the formula, the formula is as follows:

$$R_{cl} = \frac{V_{cl} \times k_{cl}}{I_{\text{out}}} \tag{2}$$

The hardware structure mainly includes client and server. In this model, the client must install applications and tools, making the client too large and burdensome, and difficult to install, maintain, upgrade, and release the system, thereby affecting efficiency [12]. The signal generated by each sensor is automatically processed by the instrument. Its main contents include: the main body of the buoy, the mooring system, the protection device, the sensor, the data acquisition, storage and transmission module, the design and selection of the power supply and distribution module; Time is continuously recorded, unattended [13]. In view of the powerful features of LabVIEW software, flexible programming, and friendly man-machine interface, we choose it as a front-end development tool, while SQL Server has powerful data management functions. As a network database, the system functions that the monitoring system can achieve are shown in Fig. 4.

The marine environment monitoring buoy system requires the monitoring center to realize real-time connection with each data information collection buoy. Due to the large number of buoy placement points, the system requirements can meet the needs of burst data transmission, and GPRS technology can well meet the needs of burst data transmission; because the system adopts a mature TCP/IP communication architecture, it has a good With extended performance, a monitoring center can easily support the communication access of thousands of meteorological collection points [14, 15]. Although it

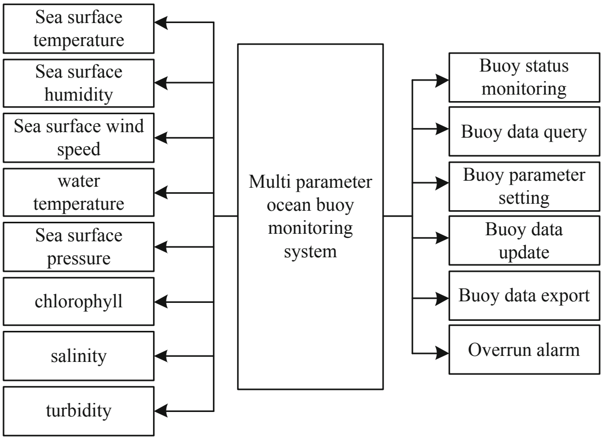

Fig. 4. Functional structure of marine buoy monitoring system

has two-way communication with a data center thousands of miles away, GPRS data transmission equipment only needs to communicate with nearby mobile base stations when it is working. Its overall power consumption is equivalent to that of an ordinary GSM mobile phone, with an average power consumption of only 200 ms. About watts, much smaller than traditional digital radio.

2.2 Software Process Optimization of Marine Buoy Monitoring System

Through the use of interrupt program design to control the operation of each subroutine, and then realize the function of each submodule. The main program of the system base station and the mobile station is basically the same. When the system starts to work, it will initialize the various hardware subsystems, and at the same time enter the waiting interrupt loop link. The interrupt request turns off the standby state, executes the interrupt program, and returns to the original standby low-power state after the interrupt program is executed. After the interrupt program is executed, the interrupt flag will be cleared, the interrupt will be exited, and the next interrupt will be entered after entering the low-power mode [16]. In summary, the main program completes data collection, communication, storage, remote transmission and other program operation functions by interrupting the work. The main program flow chart is shown as in Fig. 5.

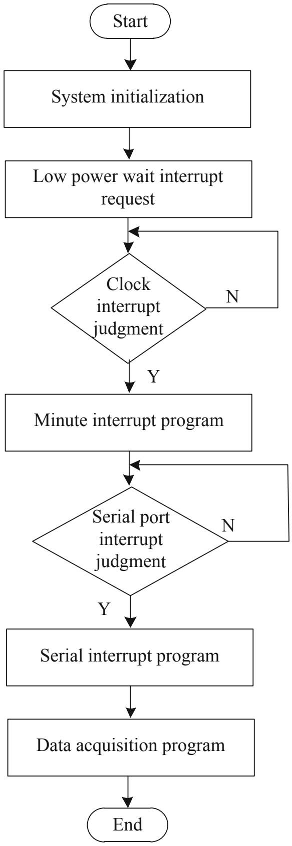

Fig. 5. Optimization of the running process of the main program of the system

According to the requirements of real-time automatic monitoring of the system, this paper proposes the following design schemes accordingly: It has the advantages of high degree of automatic integration, high positioning accuracy, safe and reliable data transmission, and improved operation efficiency. The system is mainly composed of three subsystem modules: buoy data acquisition module, data communication module and data processing analysis module. Its structure and operation principle are shown in Fig. 6.

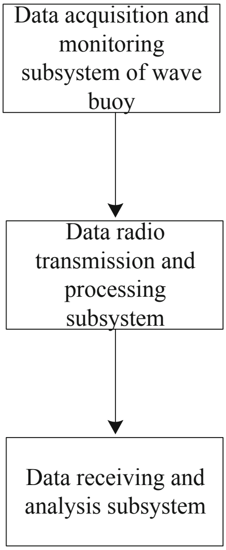

Fig. 6. Operating principle of the system structure

A data compression technology is proposed. As shown in the figure, the communication data is firstly compressed losslessly. In order to prevent data loss, the sender regularly queries the receiver and finds that the lost data is retransmitted in time to improve the reliability of data communication. Based on this, the buoy monitoring data compression process is further optimized, as shown in Fig. 7.

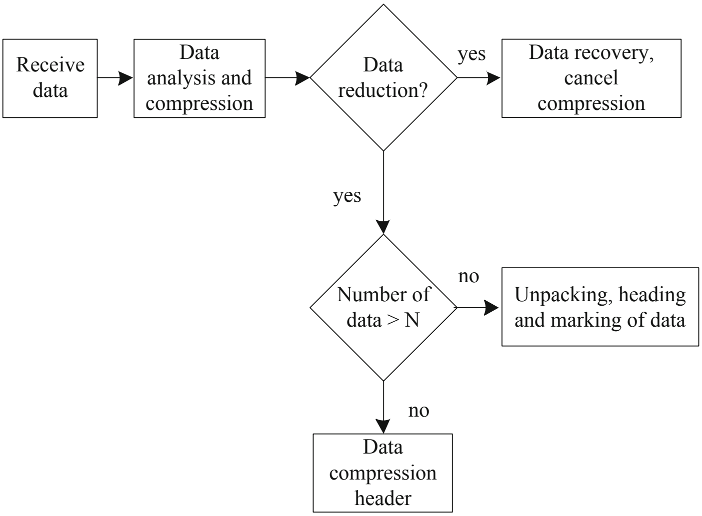

Fig. 7. Data compression process for buoy monitoring

The data conversion protocol is a protocol that converts collected data into data suitable for transmission by the sensor terminal. The conversion method is as follows: The collected data is divided into a group of 3 bytes in order, so that each group has 24 bits of data, and then each 6 bits of data is divided into 1 part in order, so that each group gets 4 parts, each part the value range of is 0 to 64. Add 48 to this value, and its range is: 48–112. This value range corresponds to the visible character part of the ASCII table, so that the collected data can ensure the correct transmission in the sensor communication terminal. The data conversion diagram is shown in Fig. 8.

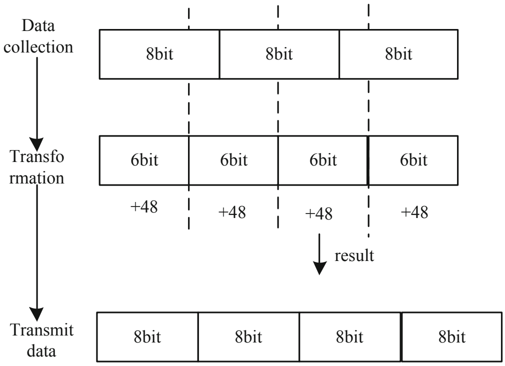

Fig. 8. Conversion of collected data to transmission data

The central station monitoring software needs to realize the functions of sending commands, receiving data, auditing data, storing data, displaying real-time data, querying historical data, generating messages, managing and monitoring the system, as shown in Fig. 9.

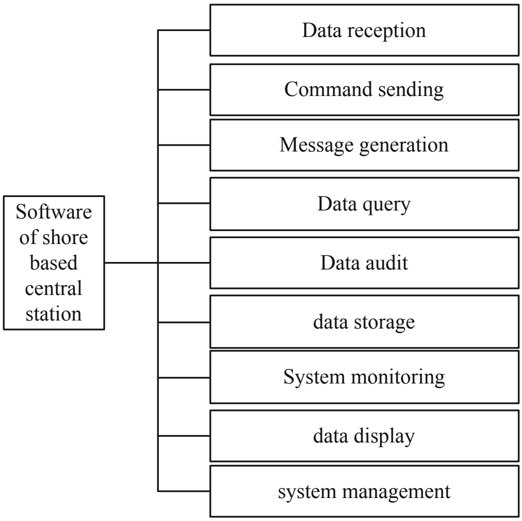

Fig. 9. System software function structure

The software needs to have the two most important functions. One is data communication, that is, sending commands to the hydrological monitoring buoy and reading data. The second is data storage, which stores all observation data in the database. Therefore, the shore-based central station software has two interfaces: communication interface and database interface. In addition to data communication and data storage, the software should also have functions such as data conversion, message generation, system management and monitoring. Data conversion is to convert and calculate the original data in accordance with relevant specifications to obtain the required result data; messages are data files generated in accordance with the specified format, used to send data to relevant application systems or relevant departments; system management and monitoring are for Centralize management and configuration of all on-site observation station equipment in the entire system, and monitor the operating status of the system. The overall structure of the shore-based central station monitoring software is shown in Fig. 10.

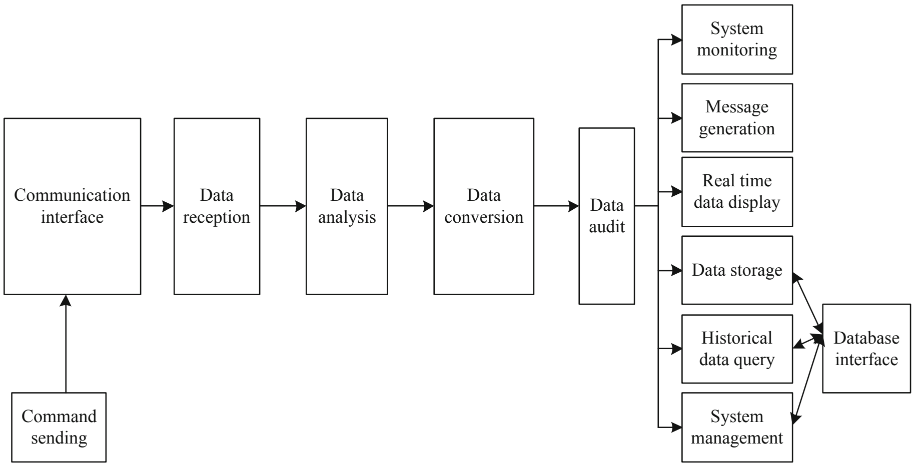

Fig. 10. The overall structure of the monitoring software

The BDS buoy wave measurement system is mainly composed of two parts: a reference station and a rover station. Relatively independent base station and mobile station make data intercommunication work through the radio, and the hardware circuit turns on the base station and mobile station power through the power control interface according to the predetermined sampling time interval. The mobile station performs differential processing between the carrier signal and observation data collected by the station and the carrier signal and data transmitted by the base station to obtain high-precision positioning coordinates of the mobile station in real time and store them in SRAM. The mobile station then sends the real-time high-precision vertical displacement of the mobile station to the shore station receiving system in the form of a message through the radio module. The fixed part of the whole week of the unknown number solution is the key to the whole process. As long as the observation value that satisfies the maintaining phase is tracked by more than four satellites and the unknown number is fixed, each epoch can be processed in real time. The mobile station can achieve centimeter-level positioning. The working data link network is shown in Fig. 11.

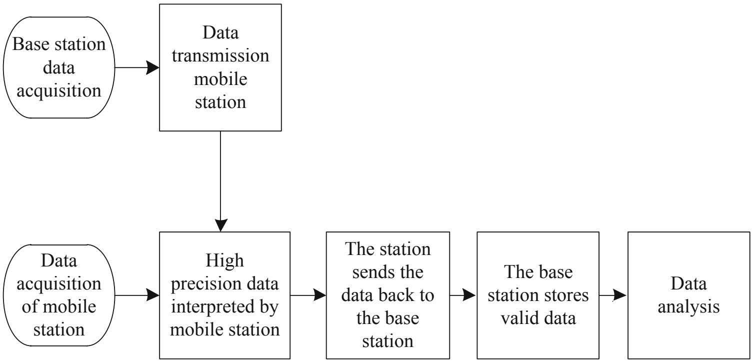

Fig. 11. System information management process optimization

When the buoy works offshore, the buoy communicates with the base station through the radio, and the communication module transmits the collected raw data through the serial port. The data processing module is the core of the program, which is responsible for filtering and correcting the original data collected by the buoy. Draw a two-dimensional graph of the wave surface movement, which is convenient for users to understand and analyze the wave graph. This software can save relevant data in the background and store it in the form of an array. Buoy data processing and ocean wave inversion programs can read relevant data in the background respectively. The signal is processed to obtain the vertical displacement of the wave, and the high-precision wave surface recording data is fitted to improve the operating efficiency of the system.

2.3 Realization of Marine Observation Buoy Monitoring

Combining the expected sea surface monitoring environment and actual conditions, in order to limit the influence of the normal operation of the system, creatively proposed the following basic requirements for the hardware: First, the floating buoy model on the sea must withstand unfavorable factors such as tsunamis, strong winds and waves, and low temperature., And strictly guarantee the tightness of the model at the same time. Secondly, the buoy will be used in the offshore waters, and it will monitor the fluctuation of sea waves for a long time in the area where it is put into use. Therefore, the system has strict requirements for low power consumption and long-term operation of the power supply. Real-time reception of buoy monitoring data, so the independently designed communication module must be stable. The satellite positioning buoy uses carrier phase difference. The principle of carrier phase difference is composed of a reference station and one or more mobile stations. The reference station transmits the three-dimensional raw data of the measured base station to the mobile station. The observation data of the mobile station and the reference station form at least four double-difference unknown equations; the unknown error amount can be eliminated in the solution process, which can reduce the orbit error and the atmosphere Errors and so on can then accurately measure the three-dimensional coordinates of the mobile station.

$$\varphi_j^p = \frac{\sqrt{\left(X^p - X_j\right)^2 + (Y^\rho - Y_i)^2 + \left(Z^p - Z_j\right)^2}}{cV_{t,} + cV_t - N_j^p \lambda - (V_{iw})_j^p - \left(V_{tap}\right)_i^p} \tag{3}$$

According to the signal of the infrared sensor, the microprocessor judges whether a person is approaching by driving the camera to the place where the person and the ship are approaching. After detecting that someone is approaching, the system will start the stepping motor. After reaching the designated position, the system will start the camera to take pictures. After completion, the image data will be sent to the shore receiving system through the wireless data transmission radio. After the data is sent, it becomes an automatic alarm. Process, automatically enter the start position. Suppose the geometric distance from the satellite p to the receiver is:

$$\rho_j^\rho = \sqrt{\left(X^p - X_j\right)^2 + \left(Y^\rho - Y_j\right)^2 + \left(Z^p - Z_j\right)^2} \tag{4}$$

Therefore, the vector direction cosine from the satellite to the receiver i is:

$$\frac{\partial \rho_j'}{\partial X^\rho} = \frac{X'' - X_{j0}}{\rho_{j0}'} = l_p' \tag{5}$$

$$\frac{\partial \rho_j''}{\partial Y^\rho} = \frac{Y'' - Y_{j0}}{\rho_{j0}^P} = m_\rho^j \tag{6}$$

$$\frac{\partial \rho_j^P}{\partial Z^\rho} = \frac{Z^p - Z_{j0}}{\rho_{j0}^P} = n_{\mathrm{p}}^j \tag{7}$$

The carrier phase observation equation is linearly expressed as:

$$\varphi_j' \lambda = \rho_{j0}^p - cV_t + cV_{tp} - N_i^p \lambda - (V_{imA})_j^p - \left(V_{to\rho}\right)_i^p \tag{8}$$

Therefore, in the case of the same frequency carrier, the observation equations of the base station and the mobile station are:

$$\varphi_i^P \lambda = \rho_{i0}^P - cV_{t_t} + cV_{tp} - N_i^P \lambda - (V_{ion})_i^P - \left(V_{trop}\right)_i^p \tag{9}$$

$$\varphi_i' \lambda = \rho_{i0}^p - cV_t, +cV_t, -N_j^p \lambda - (V_{ian})_i^p - \left(V_{to\rho}\right)_j^m \tag{10}$$

The detection distances of the reference station and the mobile station relative to the buoy can be differentiated respectively, and the double difference observation equation of the two satellites can be obtained:

$$\Delta \varphi_{ij}^{A_i} \lambda = \left(l_i^p - l_i^o, m_i^p - m_i^o, n_i^p - n_i^o\right)(\partial x_j, \delta Y_j, j - \Delta N_i^{po} \lambda) \tag{11}$$

The least squares method of ambiguity floating point solution, rewrite the formula as follows:

$$y = Aa + Bb = \begin{bmatrix} A \ B \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \tag{12}$$

According to the demand analysis and research goals of the system, the overall design of the system is carried out. The overall structure of the system is divided into a buoy unit and a shore station monitoring unit. The buoy unit includes a sensor group, data acquisition and data processing modules, and the shore station monitoring unit includes a shore-based monitoring center and a buoy remote monitoring system. According to the overall design analysis of the buoy unit, the overall composition of the buoy unit is divided into two parts: the data acquisition system and the buoy body. The data acquisition system is composed of acquisition main control service module, acquisition array element terminal, acquisition system cable array and sensor communication terminal. Among them, the acquisition main control service module mainly includes the main control CPU, RS232 interface circuit, CAN bus interface circuit, power supply module and so on. The acquisition array element terminal mainly includes cabin structure design and electronic system design. Secondly, the design index analysis and the structure design of the buoy body are carried out. According to the overall design analysis of the shore-based unit, the overall composition of the shore-based unit is divided into the shore-based unit hardware system and the shore-based unit software system. First of all, the hardware system is mainly composed of database server, data acquisition terminal and sensor communication terminal. Secondly, the shore-based unit software system mainly includes the shore-based unit software system architecture, function overview, functional module composition, database tables, and the design of various functional modules to ensure the quality of system operation.

3 Analysis of Results

In order to verify the practical application effect of the multi-sensor-based ocean observation buoy monitoring system, the following experimental tests were carried out.

The acquisition array terminal is placed in the sealed pressure tank, the sealed pressure tank is connected with a test port of the manual water pressure source through the connecting pipe, and the other test port is connected with the precision pressure gauge, and then the manual water pressure source is injected into the tap water. After pressurizing by manual pressure valve and micro pressure valve of water pressure source, the data of precision digital pressure gauge and the data collected by acquisition array terminal are read out and compared. This collection array terminal pressure collection and testing experiment started from SOKPa pressure points, with a collection point every SOKPa. A total of 40 pressure collection points were collected, and 200 sets of data were collected at each collection point.

A buoy is placed in a small scale wave tank, and the anchor chain link plate on the underside of the buoy is connected with the small scale tank. The purpose is to record the vertical displacement change of the water quality point at the fixed position measured by the buoy in the wave tank.

The frequency of the experimental sampled data is 5 Hz, and a buoy is placed 30 m away from the wave building plate. Comparable to test results, verify the accuracy of RTK technology buoy wave and the stability of the system, the selection model BG-1 high resistive wave sensor calibration, the measurement of the depth of the water for 3 m, the range of measurement of A resistive sensor resolution size was mainly affected by A/D converter circuit, the resistance sensor measurement accuracy theoretically to 1 mm.

RTK differential technique is used to measure the time series of buoy vertical displacement. The measured wave displacement signal series mainly includes wave signal and observation noise signal. A series of vertical displacement data of the wave surface obtained by the buoy is compared with the wave height and period of the resistive wave height sensor using the power period method. The comparison results are shown in Table 2 and Table 3.

Table 2. Resistive sensors and buoy regular waves

Wave measurement method	$H_{1/100}$/cm	H_{mean}/cm	$H_{1/3}$/cm	Tmean
RTK buoy wave measurement	83.4983	51.2202	83.4983	4.9673
Wave measurement with resistance sensor	82.6652	49.4253	82.6652	4.0227

Table 3. Irregular waves of resistive sensors and buoys

Wave measurement method	$H_{1/100}$/cm	H_{mean}/cm	$H_{1/3}$/cm	Tmean
RTK buoy wave measurement	110.7536	48.9234	78.6325	4.9683
Wave measurement with resistance sensor	108.5286	46.7288	76.4257	4.7864

Based on the results of the above table, a comparative analysis was performed, the standard deviation of the sensor terminal test was standardized, and the collected data of the collection element terminal was compared with the data calculated by the output curve of the collection element terminal, and the standard deviation was calculated as shown in Fig. 12.

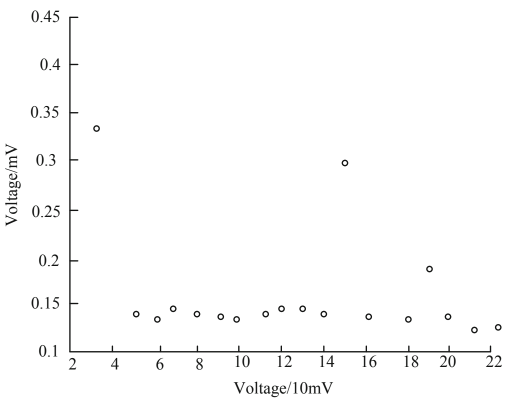

Fig. 12. The standard deviation of the sensor terminal test

Further compared with the traditional detection system, the detection data were adjusted down with an interval of 0.1 degree. After collecting the data, the data curve is obtained by fitting the data. On this basis, the collected data and quasi and curve contrast, with horizontal resistance, arrays of collection terminal to conduct stress tests, and contrast arrays arrays acquisition terminal and the data acquisition terminal output curve to calculate the data, calculate the standard deviation between them, to verify the correctness of the whole process from data collection to data warehousing and reliability, the specific test results are shown in Fig. 13.

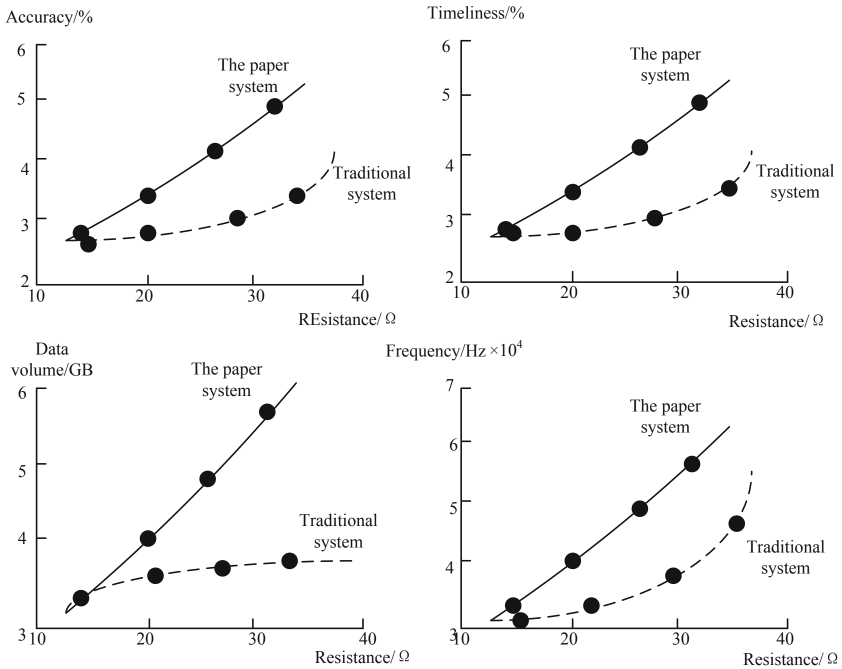

Fig. 13. System performance test results

Based on the comparative analysis of the detection results shown in Fig. 13, it can be seen that compared with the traditional sea breeze buoy detection system, the system performance in this paper is significantly better in the actual application process, which fully meets the research requirements.

4 Conclusion and Outlook

As a satellite navigation system with independent intellectual property rights in my country, multi-sensor has the characteristics of small investment, simple and cheap user equipment, high reliability, and strong confidentiality. Its appearance provides a way for the application of satellite communication and positioning systems in marine monitoring buoys. The new choice lays a technical foundation for the use of multiple sensors for ocean observation data transmission. Therefore, this research combines the characteristics of marine buoys and multi-sensors to design a multi-sensor-based marine monitoring buoy communication system.

Although the system has achieved some achievements, it still has some shortcomings, such as little communication data and data loss. Therefore, targeted measures should be taken to apply multi-sensor to Marine monitoring system in future research.

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