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Research on Ocean Sounding System based on Multi-beam Sounding Technology

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Abstract

With the development of Marine resources and the deepening of Marine scientific research, the need for ocean sounding technology is becoming more and more urgent. As a high precision and high efficiency sounding method, multi-beam sounding technology has been widely concerned. This paper is based on multi-beam sounding technology. Firstly, the principle and composition of multi-beam sounding technology are introduced. Then, the hardware and software design of multi-beam sounding system are described in detail, including multi-beam transmitter, receiver, data processing unit, data acquisition and processing algorithm, etc. A set of ocean sounding system based on multi-beam sounding technology is designed and implemented.

Keywords

Multi-beam Sounding Technology; Marine Sounding System; Hardware Design; Software Design.

1. Introduction

Ocean sounding is an important link in ocean scientific research and ocean engineering construction. It is of great significance for understanding ocean topography, measuring water depth and developing and utilizing ocean resources. The traditional sounding technology mainly relies on the single beam sounding instrument, whose sounding precision is limited and the measuring speed is slow. With the continuous development of science and technology, multi-beam sounding technology is gradually applied in the field of ocean sounding. By transmitting multiple acoustic beams at the same time, the accuracy and efficiency of sounding can be greatly improved[1-2].

2. Overview of Multi-beam Sounding Technology

2.1 Principle of Multi-beam Sounding Technology

Multi-beam sounding technology is a high precision measurement method for ocean sounding. Its principle is based on the propagation and reflection characteristics of acoustic waves in water. This technology transmits multiple acoustic beams at the same time, receives and analyzes the reflected signals, and thus obtains the depth information of the ocean bottom[3].

The principle of multi-beam sounding technology can be divided into the following steps: First, multiple acoustic beams are emitted at the same time, and each beam has a different emission Angle and direction. These beams travel through the water and interact with the bottom of the ocean. Second, there is a reflection between the acoustic beam and the seafloor, and the reflected signal is picked up by the receiver. The signal received by the receiver contains information about the interaction between the sound wave and the ocean floor, including the intensity of reflection, time delay, and so on. The received signal is then processed and analyzed, and by calculating the time delay and strength

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of the reflected signal, the depth of the ocean floor can be determined. Finally, the measurement results of multiple acoustic beams are integrated to improve the accuracy and reliability of sounding.

The multi-beam sounding technology has obvious advantages over the traditional single-beam sounding technology[4]. First of all, multi-beam sounding technology can measure the depth of multiple points at the same time, which greatly improves the measurement efficiency. Secondly, multi-beam sounding technology can synthesize the measurement results of multiple beams, reduce the measurement error and improve the measurement accuracy. In addition, multi-beam sounding technology can adapt to different Marine environments and measurement needs by adjusting the beam launching Angle and direction.

In short, multi-beam sounding technology is a high-precision ocean sounding method, its principle is based on the propagation and reflection characteristics of sound waves in water. By transmitting multiple acoustic beams at the same time and analyzing the received reflected signals, depth information on the ocean floor can be obtained. This technology has the characteristics of high efficiency, accuracy and strong adaptability, and has been widely used in the fields of ocean exploration and seabed topography.

2.2 The Composition of Multi-beam Sounding System

Multi-beam sounding system is an advanced technology for ocean sounding, which consists of multi-beam transmitter, multi-beam receiver and data processing unit.

Multi-beam emitter is one of the core components of multi-beam sounding system. It usually consists of multiple emitters, each of which can work independently and emit sound beams in different directions. These sound beams can be controlled by the transmitter to form a network of sound beams covering a wide area. The design of the multi-beam transmitter needs to consider the parameters such as the frequency, power and direction of the emitted sound wave to ensure the adaptability and accuracy of the sounding system in different Marine environments[5-6].

The multi-beam receiver is another key component. It usually consists of multiple receivers, each corresponding to a transmitter, responsible for receiving the signal reflected back by the corresponding acoustic beam. The receiver needs to have a high sensitivity and a wide dynamic range in order to be able to receive weak reflected signals and make accurate measurements. At the same time, the receiver also needs to have high-speed data acquisition and processing capabilities to cope with the complex signal processing requirements in ocean sounding.

The data processing unit is the core processing part of the multi-beam sounding system. It is responsible for receiving and processing acoustic data acquired from the receiver, and performing depth calculations and the generation of measurement results. The data processing unit is usually composed of high-performance digital signal processor and related algorithms, which can process and analyze the received multi-beam data in real time. At the same time, the data processing unit also needs to have a user-friendly interface so that the operator can easily adjust the parameters and view the results.

3. Design and Implementation of Multi-beam Sounding System

3.1 System Hardware Design

3.1.1. Multi-beam Emitter Design

Multi-beam emitter is an important part of multi-beam sounding system, its design and performance directly affect the accuracy and effect of sounding system. In this section, the design of multi-beam emitter will be discussed in detail.

The following key factors should be taken into account in the design of multi-beam emitter: transmitting Angle, transmitting frequency, transmitting power and transmitting array layout.

Firstly, the transmitting Angle refers to the Angle between the transmitting beam and the horizontal direction. The proper launching Angle can make the coverage of the sounding system wider and

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improve the measurement efficiency. Generally speaking, a smaller launch Angle can provide better resolution, but the coverage is smaller; The larger transmission Angle can cover a wider area, but the resolution is relatively low. Therefore, it is necessary to make a reasonable choice according to the specific application requirements when designing the transmitter.

Secondly, the choice of transmission frequency is also key. Sound waves of different frequencies have different propagation characteristics in seawater and are affected by factors such as absorption and scattering. Higher frequency sound waves have better resolution, but travel shorter distances in seawater. Lower frequency sound waves travel longer distances but have lower resolution. Therefore, when designing the transmitter, it is necessary to consider the measurement depth and resolution requirements of the system, and choose the appropriate transmission frequency.

In addition, the transmitting power is also a factor to be considered in the design of the transmitter. The higher transmitting power can increase the propagation distance of the sound wave, improve the strength of the signal, and thus improve the sounding accuracy. However, too high transmitting power may cause disturbance to Marine organisms, so it is necessary to control transmitting power reasonably on the premise of ensuring the accuracy of sounding.

Finally, the layout of the transmitting array also affects the performance of the system. A reasonable arrangement of transmitting array elements can improve the beam coverage and resolution. The common layout of transmitting array elements includes linear array, circular array, etc. The appropriate layout mode is selected according to the specific application requirements.

To sum up, the design of multi-beam emitter needs to consider the transmitting Angle, transmitting frequency, transmitting power and the layout of transmitting array. Reasonable design of transmitter can improve the accuracy and effect of multi-beam sounding system, and provide strong support for ocean mapping and survey.

3.1.2. Multi-beam Receiver Design

The multi-beam receiver is a key component of the multi-beam sounding system, and its design and performance directly affect the measurement accuracy and effect of the system[7]. The main function of a multi-beam receiver is to receive acoustic signals from multiple transmitters and convert them into electrical signals for processing and analysis.

In the design of multi-beam receiver, the first thing to consider is the sensitivity and bandwidth of the receiver. Sensitivity refers to the sensitivity of the receiver to the acoustic signal, which can be improved by selecting the appropriate receiver components and circuit design. Bandwidth refers to the frequency range that the receiver can receive, which needs to be set reasonably according to the needs of the sounding system.

Multi-beam receivers also need to consider the array design of the receiver. The design of the array can adopt the form of linear array or surface array, and the multi-beam receiving can be realized through reasonable layout and spacing. Each receiving element in the array needs to be characterized by high sensitivity and low noise to ensure accurate reception and conversion of acoustic signals.

Multi-beam receivers also need to consider the amplification and filtering of the received signal. Through the appropriate amplifier design, the intensity of the received signal can be enhanced, and the signal-to-noise ratio of the system can be improved. The design of the filter can remove unnecessary stray signals and ensure the quality of the received signal.

Multi-beam receivers also need to consider the processing and analysis of the received signal. The received signal needs to go through a series of digital signal processing algorithms, such as beamforming, beamforming, Doppler shift compensation, etc., to extract the required sounding information.

3.1.3. Data Processing Unit Design

The data processing unit is the key component of the multi-beam sounding system, which is designed to realize the efficient processing and analysis of the sounding data. The data processing unit mainly includes three main modules: data acquisition, data processing algorithm and data output.

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The data acquisition module is responsible for acquiring the raw sounding data from the multi-beam receiver. Through high-speed sampling technology, the module can obtain the echo signal of multiple beams in real time, and convert it into digital signal for storage and subsequent processing. In order to improve the accuracy and stability of data acquisition, high precision analog digital converter and clock synchronization technology can be used.

Data processing algorithm module is the core part of multi-beam sounding technology. Through signal processing and analysis of the original bathymetric data, the module can measure and reconstruct the seabed topography. Common data processing algorithms include beamforming, Doppler compensation, beamforming, etc. The beamforming algorithm can improve the sounder precision and resolution by weighted superposition of echo signals from multiple beams. The Doppler compensation algorithm can eliminate the influence of Doppler effect on the sounding result by correcting the frequency deviation of echo signal. The beam synthesis algorithm combines the echo signals of multiple beams to obtain a more accurate image of the seabed topography.

The data output module is responsible for the output of the processed sounding data to the user. The bathymetric data can be presented to the user in a visual form through the display, printer or network interface. In addition, you can save the data as a file for subsequent analysis and processing.

3.2 System Software Design

3.2.1. Design of Data Acquisition and Processing Algorithm

Data acquisition and processing algorithm is the key link in multi-beam sounding system, which directly affects the accuracy and efficiency of the system. This section introduces the design principles and implementation of data acquisition and processing algorithms.

In the multi-beam sounding system, the data acquisition is to receive and record the acoustic signal returned from the seabed through the simultaneous operation of multiple transmitters and receivers. In order to improve the efficiency and accuracy of data acquisition, the following design principles need to be considered.

First, you need to choose the layout of the transmitter and receiver. According to the characteristics of the sounding area and measurement requirements, determine the number and location of transmitters and receivers. A triangular or matrix layout is usually used to ensure the uniformity of the sounder coverage.

Secondly, it is necessary to consider the time interval and sampling rate of data collection. According to the speed of sound wave propagation and the range of sounding, the time interval of data collection is determined to ensure the accuracy and coverage of the measurement. At the same time, according to the signal frequency and bandwidth requirements, the sampling rate is determined to ensure that enough signal information is collected.

Then, it is necessary to design an appropriate signal processing algorithm to process and analyze the collected data. Common algorithms include beamforming, Doppler processing, seabed reflection intensity calculation and so on. Through the beamforming algorithm, the data from multiple receivers can be combined into a beam to improve the accuracy and resolution of the sounding. Through the Doppler processing algorithm, we can analyze the frequency of the received signal and get the velocity information of the seabed. The reflection characteristics of the seafloor can be evaluated by calculating the reflection intensity of the seafloor, which can provide reference for the study of the seafloor geomorphology.

Finally, data correction and error correction are required. Because there are some errors in the multi-beam sounding system, the collected data need to be corrected and corrected. Common correction methods include sound velocity correction and water depth correction. Through sound velocity correction, the sound velocity can be corrected according to the parameters of seawater temperature, salinity and pressure. Through the depth correction, the sounding data can be corrected according to the installation height and tilt Angle of the sounding instrument.

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3.2.2. Interface Design and Human-computer Interaction

In multi-beam sounding system, interface design and human-computer interaction are the most important parts of system design. An intuitive, easy-to-use interface and good human-computer interaction can improve the efficiency of the operator and reduce errors, thereby improving the overall performance of the sounding system.

First, in terms of interface design, we should pay attention to the simplicity, clarity and legibility of the interface. The interface should include the necessary information, such as depth data, location information, and so on, while avoiding too much irrelevant information interference. The use of appropriate fonts, colors and typography, so that the overall interface looks comfortable and beautiful. In addition, the interface should be adaptive and able to adapt to devices with different screen sizes and resolutions in order to be used in different working environments.

Second, in terms of human-computer interaction, we should pay attention to the simplicity and intuitiveness of the operation. The user interface should be designed to be easy to understand and use, reducing the cognitive burden on the user. For example, intuitive operation elements such as ICONS and buttons are used to provide clear operation guidance and feedback. At the same time, appropriate help documents or tips should be provided to answer the problems encountered by users in the process of use.

Third, the individual needs of users should also be taken into account. For example, the personalization option is provided to allow users to adjust the interface layout, color theme, etc., according to their preferences. In addition, you can also consider adding shortcut keys, gesture operation and other functions to improve the user's operation efficiency and convenience.

In a word, interface design and human-computer interaction are an important part of multi-beam sounding system design. Through simple and clear interface design and intuitive and easy-to-use human-computer interaction, the system can improve the ease of use and efficiency of the system, provide better user experience for the operator, and improve the overall performance of the sounding system.

4. Peroration

Multi-beam sounding technology is an advanced ocean sounding technology, which can achieve high precision ocean bottom measurement by transmitting and receiving multiple beams. In this paper, a set of ocean sounding system based on multi-beam sounding technology is designed and implemented. Based on the introduction of the principle and system composition of multi-beam sounding technology, the design and implementation process of the system are described in detail.

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