

Design and Implementation of Multi-beam Transmitter

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Abstract. The multi-beam sounding technology has been carrying out a revolution in underwater survey. Compared with traditional equipment's, the multi-beam sounding system has a huge advantage in efficiency, accuracy and resolution. According to the beam-forming theory, the paper designs a phase-control signal formulation circuit based on FPGA (Field Programmable Gate Array), and the experiments show that the multi-beam transmitter has a high performance and can fully meet the needs.

1. Introduction

Nearly seventy percent of the earth's surface is covered by the ocean. Therefore, the strategic position and potential economic value of the ocean is attracting more and more attention. The topography and geomorphology of the seabed should be measured before the development of marine resources on the basis of historical experience [1]. On island, satellite remote sensing and infrared remote sensing can be used to obtain topography and landforms on the surface, but those methods are infeasible in the ocean because of electromagnetic wave attenuating too fast in water which caused electromagnetic waves to disappear before they reach the bottom of the sea [2, 3, 4]. Although there are many similar waves between acoustic and electromagnetic waves, the absorption coefficients of them are very different. The attenuation of acoustic waves in seawater is small and can be spread far away in the sea. The acoustic wave is a common tool for people to detect the seafloor topography. Multi-beam sounders are the important tools for detecting underwater topography using acoustic wave have the advantages of large coverage, high accuracy and high efficiency and etc. In order to effectively overcome the problems on the common multi-beam sounders of high price, large volume and complicated installation, we united Zhejiang Zhongyu Communication Technology Co. Ltd developed a domestic multi-beam sounders system, and this system can improve the exploration effect of the seabed terrain and promote the economic development. In this paper, we mainly focus on the multi-beam transmitter, which is an important part of the multi-beam sounding system and is also a system unit with the largest power consumption. According to the design requirements, the transmitter should form a plurality of directional transmitting beam, to achieve wide coverage and high resolution. The transmitter is working with high frequency and large power output, these are the key problems to be solved, but also an important guarantee for the accuracy of the test system.



2. The system design of multi-beam transmitter

2.1. The system structure multi-beam transmitter

The transmitter is mainly composed of signal source generation and control circuits, power amplifying circuits, matching networks and transducers, showed as Fig. 1. The output small amplitude voltage signal generated by the source generation is amplified by the power amplifying circuits, and then the output of a certain power signal is sent to the matching network, matching the small output impedance power amplifier circuit with the large input impedance of the load, so that the load can output the rated power. Finally, the transducer converts the electrical signal to the acoustic signal and radiates into the water. The scheme of the transmitter design and its indicators will affect the working mode and performance of the entire transmission system, so the principle of design of active sonar system such as parameter setting and reasonable calculation, selecting the appropriate device and circuit must be abided, at the same time the operating conditions, reliability and size of the transmitter ultimately must be considered to achieve the design effect. The performance index of the transmitter is the basis of the system design, which determines the working mode and structure of the whole transmitter as well as the difficulty of realizing the transmitter. The performance index of the transmitter is the basis of the system design, which determines the working mode and structure of the whole transmitter as well as the difficulty of realizing the transmitter. When the transmitter is working, it produces an electrical signal with a certain pulse power P_e , a certain repetition period T and a certain pulse width showed as Fig. 2. The value calculation method is shown in Formula 1, 2.

$$T = \frac{2l_{\max}}{v \cos(\theta)} \quad (1)$$

$$\zeta = \frac{2l_{\min}}{v} \quad (2)$$

Among of them, $l_{\max}$, $l_{\min}$ are maximum sounding distance and the minimum sounding distance, v shows the speed of sound wave propagation in water usually take 1500 meters per second, θ is the deflection angle of the transmitting beam.

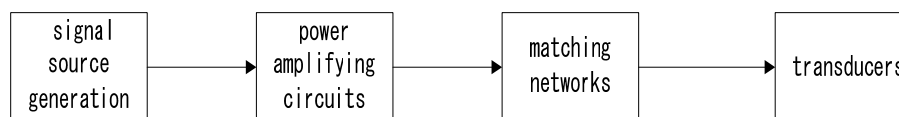


Figure 1. The transmitter framework

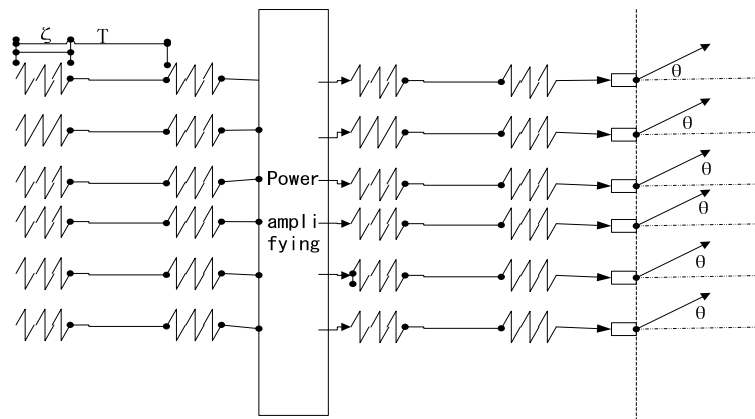


Figure 2. CW pulse signal transmission structure

2.2. Design of signal source control circuit for transmitter

The function of the transmitter signal source is a certain form of signal produced in the underwater acoustic channel. In this paper we have completed the system development by using FPGA which has very rich I/O resources, high integration, small size, high reliability and flexible design, and has a large number of soft cores [5]. FPGA not only compensate for the lack of custom circuits, but also solves the problem of programmable logic device gate number less, so it can be said that FPGA can achieve all the function done by any other digital device, it is used as a signal source circuit has also been more and more widely. The transmitting system adopts the way of digital waveform generation, which means that the internal ROM storage is designed by FPGA, and the waveform data is preprocessed. Then, the waveform data is read according to a certain beam selection and time sequence, and then through the digital to analog conversion, the CW pulse signal of the required frequency is generated.

The hardware design of the system is mainly based on the FPGA system, and realizes the system clock input, digital to analog conversion circuit design, power circuit design and other corresponding modules, so as to realize the output of the pulse signal. The system clock consists of two parts: the design of the outer clock and the internal clock. There is no internal oscillation circuit in FPGA, so the chip clock is set up by using the active crystal oscillator with 40MHz frequency, and using the input of the PLL as external clock signal, after frequency doubled to 92MHz as the signal generation and control module of the global clock, and frequency to 23MHz as analog clock signal conversion module. Thus, the time cycle control is completed.

In the DAC module, the 40MHz crystal signal is also divided into 23MHz by using the phase-locked loop, which is the clock signal of the digital to analog conversion module, that is to say, the time interval of reading two adjacent data from memory is 48.43ns. AD9709 has a eight bit resolution that just interfaces with the FPGA, and does not need FPGA to configure it. It only needs to provide a conversion clock and work on power. Each piece of AD can convert the two signals, and the N signal requires a total of $n/2$ slices. The power of the whole system includes: the I/O port voltage of FPGA is 3.3V, and the core voltage is 1.2V. In the power circuit, the 5V can be obtained by external power, then LM1117 and PJ1085 are used as the power conversion chip in the power circuit, and the 5V voltage will be converted to 3.3V and 1.2V voltage.

2.3. Product parameters

The parameters of the multi-beam emitter developed by the system are shown in Table 1. From this parameter, it can be seen that the system can basically meet the needs of the actual engineering in the eastern coast of China.

Table 1. Product parameters

Frequency	180kHz
Bandwidth	10kHz
Beam width	4°×4°@180kHz
Swath Sector	10°to 90°
Number of Beams	43
Maximum Slant Range	200 m
MaximumPing Rate	20Hz
Pulse Length	50us-1000us
Pulse Type	CW
Multibeam Accuracy	0.05m± 1H%
Operating Temperature	-10° C to 50° C
Power Consumption	50W
Date Interface	10/100/1000 Base-T Ethernet

3. Experiments

The performance experiments of the transmitter are mainly carried out in the towing tank laboratory including anechoic pool, precision 3D coordinate rotary lifting device, as showed in Fig. 3. Experiment results showed that the resonance point at 180.6kHz meeting the requirement of working frequency =180 kHz + 10 kHz as showed in Fig. 4, the sensitivity at -192.5 dB@180kHz meeting the sensitivity than -200dB@180kHz requirements as showed in Fig. 5, and the natural point of 3.4 DEG @180kHz, meeting the natural directivity is smaller than 4 DEG @180kHz requirements as showed in Fig. 6.

**Figure 3.** The towing tank laboratory

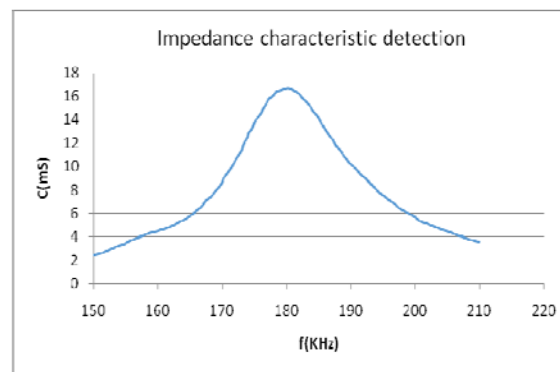


Figure 4. The resonance points

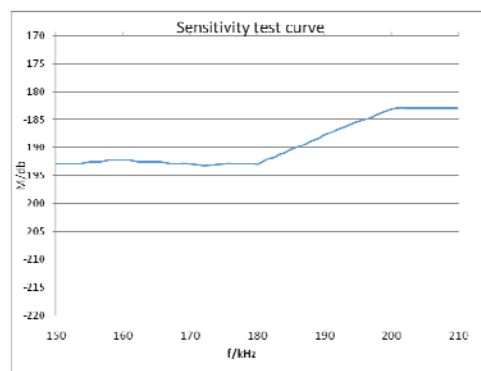


Figure 5. The frequency sensitivity

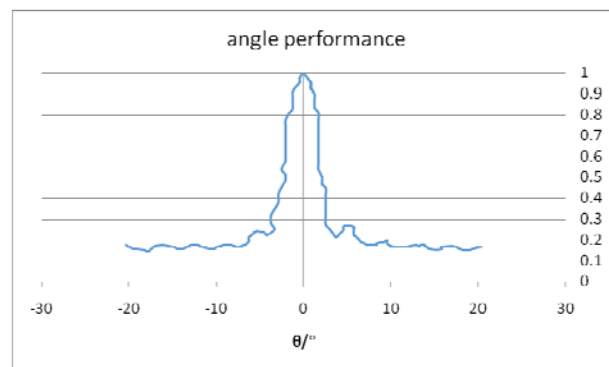


Figure 6. The angle performance

4. Conclusion

From these results of the towing tank laboratory experiment, it can be seen that the multi-beam transmitter has a high performance and can meet all the designs.

Acknowledgments

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