Design and Implementation of Sonars for Underwater Inspection with ROV

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ABSTRACT

Two inspecting sonar-High Resolution Multi-beam Sonar (HRMS) and Profiling Sonar (PS) - mainly presented in this paper. The ROV which carries them will also be briefly described. Some experimental results have shown that the ROV equipped with the developed sonars under control of the movement programs can give accurate maps for either the surface shape or the internal structure of underwater objects, so it is applicable for many underwater engineering cases.

INTRODUCTION

For inspection of underwater constructions, especially, in turbid water, sonars are useful to map either the surface shape or the interior structure of objects, so that sonars with different frequencies and resolutions need to be used. High resolution multi-beam sonar (HRMS) is designed to image the surface shape of underwater objects. The profiling sonar (PS) is designed to inspect the inside of underwater structures or objects. The former obtains the detailed information of the surface, so as short as possible wavelength of signal and as narrow as possible beams should be used. Whereas, the latter needs to obtain the internal information of objects. In most sonar engineering applications, the resolution and detection range (depth) of sonars are contradictory specifications. The sonar designer must make an optimum compromise between these technical parameters or use different technical schemes.

In the last two decades, various underwater carrier techniques, such as ROV (Remote Operating Vehicle), UUV (Unmanned Underwater Vehicle) and AUV (Autonomous Underwater Vehicle), have been developed rapidly. These small platforms equipped with kinds of sensors and other instruments show powerful and flexible working capabilities, they can direct the instruments to wherever inspecting tasks are needed. In underwater inspecting tasks, like checking damages, faults, holes and so on inside structure, one must first get precise 3D maps of them. The inspection sonars are installed in a ROV, while the ROV moves in a programmed course and the sonar inspects the object continuously, so that a composite map of it can be formed.

Since 2000 we have developed a general purpose underwater inspecting ROV. The main instruments in this ROV are HRMS and PS.

Technical descriptions of these two sonars and the ROV carrier will be presented in following sections.

HIGH RESOLUTION MULTI-BEAM SONAR

The surface roughness is the most important feature of the inspected objects. The scale of roughness that can be measured depends on the wavelength-the shorter the wavelength, the finer the roughness scale. Considering the factors of resolution, coverage of inspection and computing time of a real-time digital beam-former, power consumption, and array size and weight, the specifications were chosen as follows:

Signal frequency: 1MHz

Beam width: Horizontal: 0.35°

Vertical: 0.5° (short transmitting array)
10° (long transmitting array)

Number of Beams: 107

Inspection coverage: 40°×0.5°(short transmitting array),
40°×10°(long transmitting array)

Number of receiving array elements: 128

The block diagram of the HRMS is shown in Figure 1.

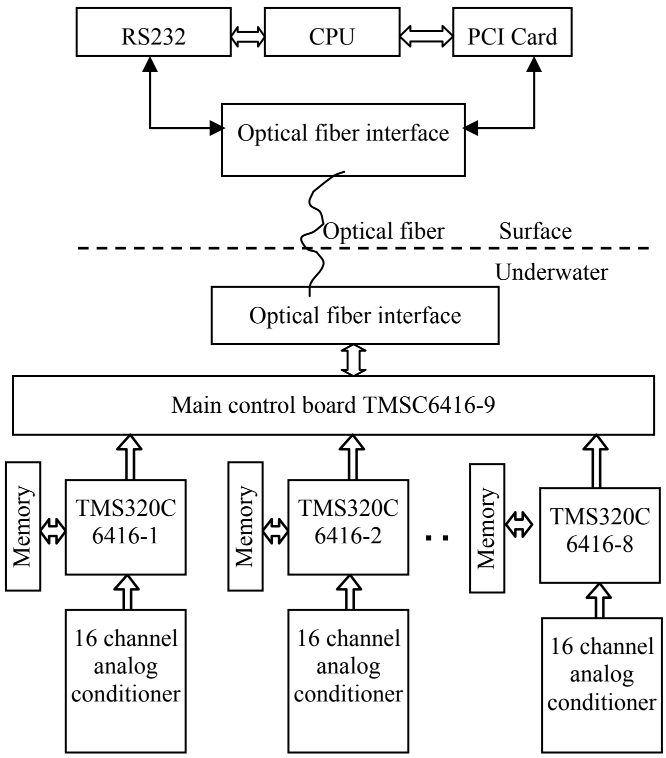

Figure 1 Block diagram of HRMS

The HRMS is a digital programmable system. Its underwater unit is composed of 128 signal conditioners, 128 parallel A/D converters, and 9 DSP for 2 stage parallel beam-forming, interface; The surface control and display unit use a general PC. Between the underwater and surface units, an optical fiber is used as the information link.

The highest speed of the A/D converter is 15MW/s per channel, so that the computing load of beam-forming must be very high. The first beamforming stage uses 8 TMS3206416, each one of which processes 16 channel receiving signals and forms 107 beams. The eight sets of 107wide beams are composed into 107 narrow beams by the controlling TMS3206416 in the underwater unit. The beam-formed output passed through the PCI interface and the fiber to the surface unit for display. The surface PC also sends programming instructions to the underwater unit. The block deagram of the real HRMS is seen in Figure2.

PROFILING SONAR

Since an acoustic signal traveling through the underwater environment, and especially through composite or multilayer

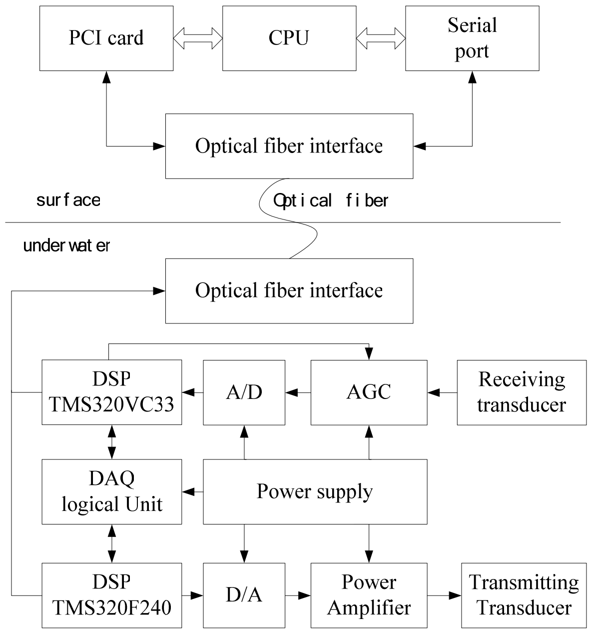

Figure 2 Block-diagram of PS

materials, will suffer severe loss of its energy, a profiling sonar(PS) to map the internal structure of underwater constructions must have detection capability over a large dynamic range. Another important design requirement for PS processor is to make the resolution as high as possible under the condition of sufficient penetrating depth of acoustic signals.

For the first design requirement, we choose 16 bit A/D as quantizer□AGC, low-noise circuits and PCB design for the analog part, so that 96 dB of dynamic range can be guaranteed. For the second design requirement, we use a wide band transmitting signal and pulse compression at the receiver to address the conflicting requirement of resolution and penetrating depth. In the underwater unit, DSPs are used for generating transmitter waveform and for receiver signal processing.

The specifications of the PS are:
Signal frequency: 11kHz-22KHz
Source level: 206dB
Inspecting angle: 6°× 30°
Compare to the present PS systems(Edgetech, Triton imaging, Tritech), our PS boasts some special features:

- High transmmition centra frequency making smaller size of the transducers suitable for mounting on ROV or AUV.
- High efficency of transmmiting and range resolution.

REMOTE OPERATING VEHICLE (ROV) UNIT

In order to carry out underwater inspection, a carrier of instruments must be equipped with the following navigation sensors: Ranging Sonar, Height Sonar, Depth Sensor, Magnetic Compass and dopler velocity log (DVL). In practice, these sensors can supply the position and track information of the ROV, but these can be inaccurate, especially in the case of an ROV moving with low speed in a current. So we have developed also a Long-base Positioning System, which can reach the position with accuracy of the order of a centimeter. The ROV can work in manually controlled mode by joystick, or in programmed mode.

The ROV is designed with a modularized and framed structure, so that it is flexible and changeable to fit different instruments and sensors. The block-diagram of the ROV is shown in Figure 3 and a graph is given in Figure4

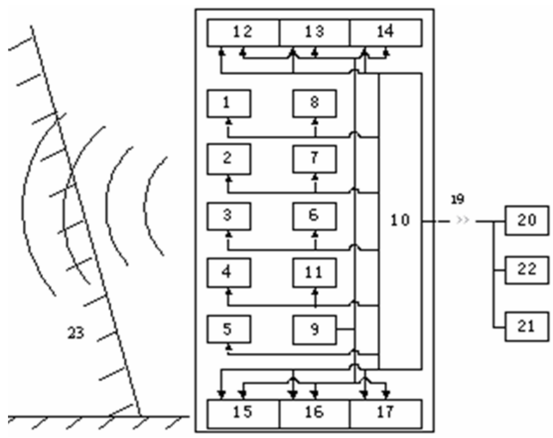

Figure 3 Block diagram of ROV system

Notes to Figure3:
1. HRMS. 2. PS
3. TV. 4. Ranging Sonar.
5. Height Measuring Sonar.
6. Magnetic Compass
7. DVL. 8. GPS (NA).
9. Movement Controller.
10. Electro-Optic Transformer.
11. Power supplier.
12.13.14.15.16.17. Thrusters.
18. Frame. 19. Composite Cable.
20. Surface PC. 21. Power Distributor.
22. Electro-Optic Transformer.
23. Object.


Figure4 ROV Outline

EXPERIMENTS

Some experimental results are shown in Figure 5-8, which have been obtained in the water tank of campus and in a real dam in Yangzi River. Figure5 is the ROV fulfilling a field inspection of a dam in Yangzi River. Figure6 is a map obtained by the HRMS. Figure7 is the structure of a relief tank floor in Yangzi River gained by the HRMS. Figure8 is the internal structure of a a relief tank in Yangzi River obtained by the PS.

Figure 5 ROV working in site of dam

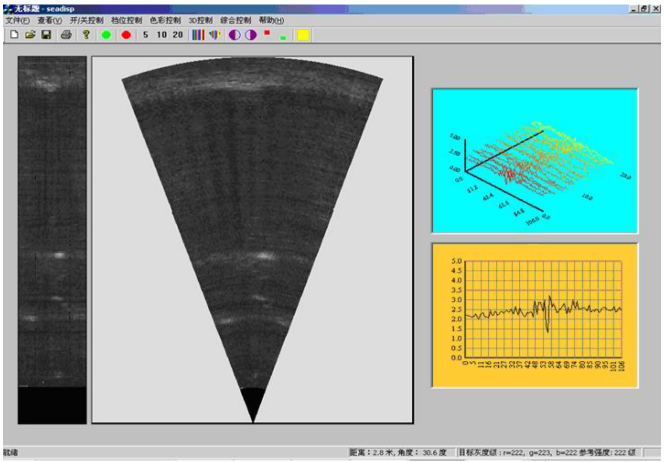

Figure 6 HRMS imaging for crevice

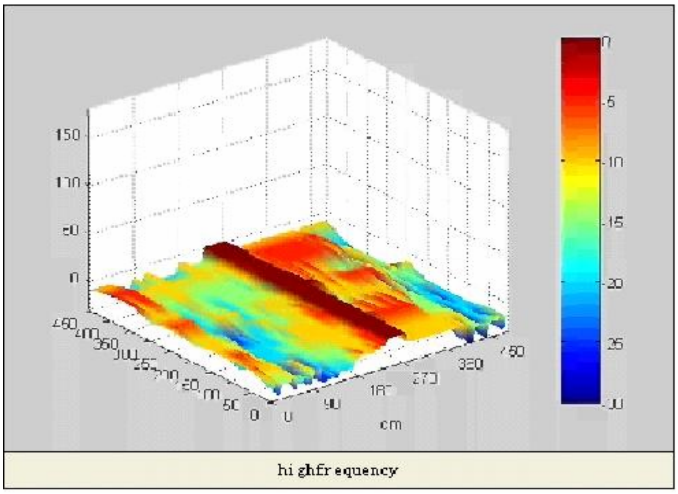

Figure 7 HRMS imaging for object surface

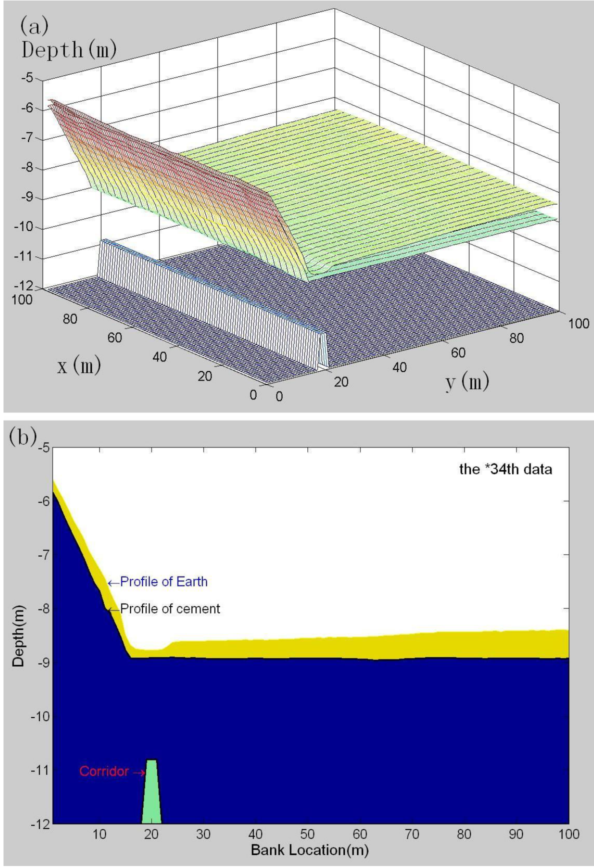

Figure 8 (a)3D profiling images of PS in test site
(b) 2D profiling images of PS in test site

CONCLUSIONS

The sonars developed are suitable for small platforms, such as ROVs, UUVs, AUVs and other underwater vehicles, which carry out underwater inspecting tasks. The presented design specifications of these sonars are mainly focused on inspection of dams. But they are useful also for other underwater exploration applications, for instance, pipeline inspection, object detection, etc.

Reference

1. Sang Enfang, " A Modularized Inspecting ROV Design", IWAET 2002, Harbin, China, 25-26 August, 2002.