An Acoustic Simulation Approach for Testing ADCP

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Abstract

The difficulty of calibrating ADCPs has long been known. This paper describes an acoustic simulation approach to accomplish the functional and accurate calibration of ADCP. By the acoustic approach, the simulation system monitors the ADCP transmitted pulse, simulates the actual backscatter signal that an ADCP would receive, provides wide scope of profiling range and current velocity simulation, thereby allow direct calibration. Application of the simulation system in functional and accurate calibrations and addressing system failures is also introduced.

1. Introduction

In recent years, acoustic Doppler current profilers (ADCPs) have been widely used in oceanographic research and marine application development.

In many cases, it is necessary to ensure that the function of an ADCP is normal before use. Currently, the main way of evaluating the performance of an ADCP is its self-calibration system and rubbing tests, but such calibrations are insufficient to cover the whole functionality and performance of ADCP, especially profiling range and the velocity calibrations. In most cases, the functionality and performance should be checked in the validation experiments in lake or the sea. These high-cost and long-time validation tests are not easily been established and more often are susceptible to the environment conditions (for instance, sea conditions and sea depth).

To solve this problem mentioned above, we developed an acoustic simulation approach, which provides direct calibrations of ADCP's functionality and performance under the laboratory conditions.

2. System composition and principle

In the simulation system, a transducer array, using the same number of transducers of an ADCP, is docked with the ADCP transducers face to face through coupling medium. By its transducer array, the simulation system transforms acoustic wave into electric pulse. In this way, simulation system monitors the ADCP transmitted pulse in real time. On the other hand, the simulation system produces simulated acoustic backscatter signal, the backscatter signal can be changed from electric signal to acoustic wave by the transducer array, and the backscatter signal simulates the acoustic backscatter of bottom and current when sonar works. According to the profiling range and current velocity information contained in the simulated backscatter signal, ADCP correspondingly feeds back the results of range and velocity. Thus the test environment of an ADCP for functionality and performance is established.

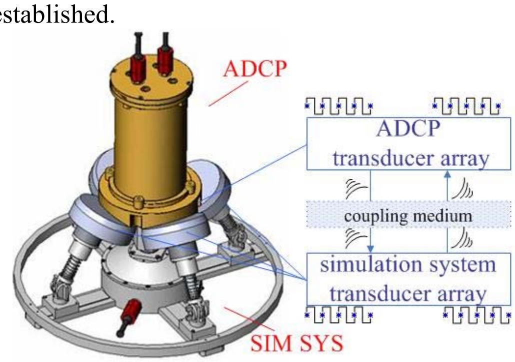


Figure 1 Schematic diagram of the simulation system dock structure

The basic principles of the simulation system are as follows:

(1) The simulation system acquires transmitted pulse of ADCP, and sets the signal benchmark, transmits the simulated backscatter signal at a designated time delay. The time delay of the simulated backscatter signal is generated as:

$$Td=2H/\left(C\bullet\cos\varphi\right)$$

Where H is the bottom depth, C is the sound speed, φ is the sonar beam angle.

(2) In accordance with the velocity profiles, the

simulation system calculates the Doppler frequency shift as:

$$f_1 = \frac{f_0}{C}(F_1(\varphi)V_x + F_2(\varphi)V_y + F_3(\varphi)V_z)$$

$$f_2 = \frac{f_0}{C}(-F_1(\varphi)V_x + F_2(\varphi)V_y + F_3(\varphi)V_z)$$

$$f_3 = \frac{f_0}{C}(-F_1(\varphi)V_x - F_2(\varphi)V_y + F_3(\varphi)V_z)$$

$$f_4 = \frac{f_0}{C}(F_1(\varphi)V_x - F_2(\varphi)V_y + F_3(\varphi)V_z)$$

f_1, f_2, f_3, f_4 are the Doppler frequency shifts of four channels, C is the sound speed, f_0 is the center frequency, $F_1(\varphi)$, $F_2(\varphi)$, $F_3(\varphi)$ are functions of the beam angle φ, V_x ,V_y ,V_z are velocity vectors in the orthogonal coordinate.

Simulation system changes frequency of the simulated backscatter signal by controlling the sampling rate.

(3) Getting the information of time delay and frequency shift in the simulated backscatter signal, the ADCP correspondingly works out results of range and velocity profiles. According to these statistical measuring results, simulation system tells if ADCP's performance is good in the calibration and what is the problem.

Moreover, proper algorithms (such as coordinate and sound speed real-time correction) are taken in the system, which make the simulation condition more close to the real acoustic propagation environment.

As mentioned above, the simulation system provides a functionality and performance calibration approach of an ADCP without changing the structure and the interface characteristics of the instrument.

3. Main fuctions description

A) Monitoring signals

By acoustic coupling of transducer array, acoustic signals can be converted to electrical signals, so the simulation system is possible to monitor the signals of ADCP directly.

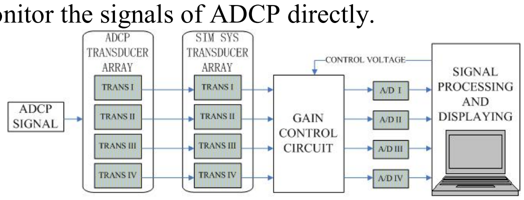


Figure 2 Data flow diagram of monitoring signals of ADCP

As the figure shows, the simulation system drives high speed acquisition device for acquiring signals of an ADCP, calculates the signal amplitudes of each channel, adjusts the signal amplitudes to target value by a gain control circuit, and monitors the ADCP signal on a software panel.

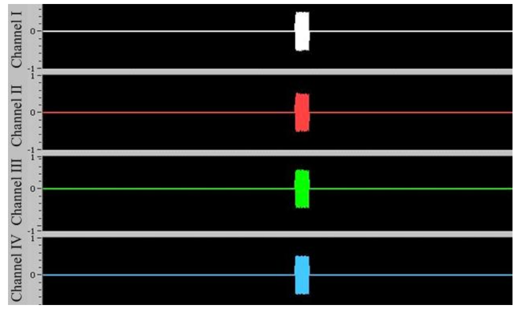


Figure 3 Simulation system monitors the ADCP signal on a software panel

B) The simulated backscatter signals

The simulation system produces simulated acoustic backscatter signal, the simulated backscatter signal can be changed from electric signal to acoustic wave by the transducer array, and the simulated backscatter signal simulates the acoustic backscatter of current.

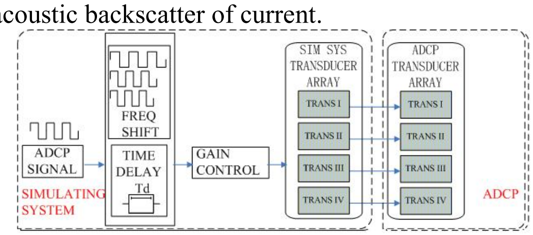
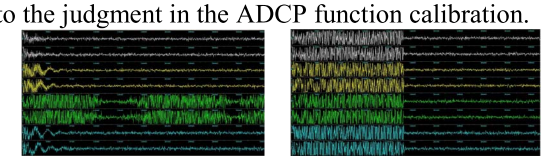


Figure 4 Data flow diagram of the simulated backscatter signals generation of simulation system

ADCP users may be familiar with the rubbing test, the test is designed to measure the relative noise in the environment and then let you apply more noise by rubbing the ceramics of ADCP transducer with your hand. By rubbing tests, ADCP shows the signal responses for one channel after another. Because the rubbing noise in the test is uncertain, ADCP can not output a valid result, so by this means it is impossible to tell the accuracy of ADCP velocity profiles.

While in the above-mentioned simulation system calibration, the valid velocity profiles' results of ADCP are acquired since simulation system synchronously provides four-channel simulated backscatter signals which simulate the actual backscatter signals that an ADCP would receive. The certainty of the signals will contribute to the judgment in the ADCP function calibration.



(a) (b)

Figure 5 Comparison of Rubbing test signal and the simulated backscatter signal

(a) Rubbing test signal (channel III), (b) The simulated backscatter signal

As the figure shows, according to the simulated backscatter signals, ADCP gets the information of time delay and frequency shift, and sends calibration results of range and velocity profiles.

C) Wide scope of profiling range and current velocity simulation.

Dynamic adjustment technique is applied to a wide scope of profiling range and current velocity simulation in the simulation system, the scope of the current velocity can be up to ± 10m/s or wider, and the profiling range can be up to the maximum range of ADCP, parameters can be easily set on a software panel, the simulation system automatically calculates the related parameters, and adjusts the simulation signals.

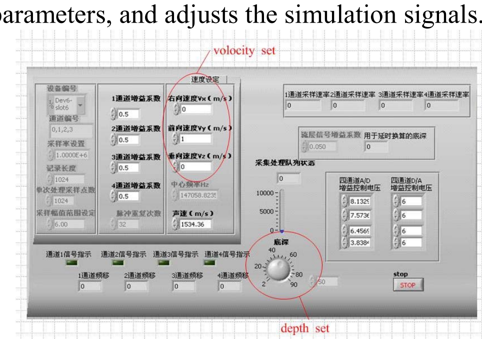


Figure 6 The simulation system soft panel for setting calibration signal parameters

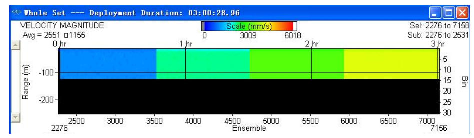
4. Coupling loss compensation and adaptive gain control techniques in the simulation system

The simulation system uses an Automatic Coupling Loss Compensation method to countervail the influence on the simulation signals by transducer, and adaptively adjusts the signal strength. Based on the sound propagation attenuation model, the simulation system adjusts signal strength and ensures consistency of the simulated backscatter signal strength of each channel.

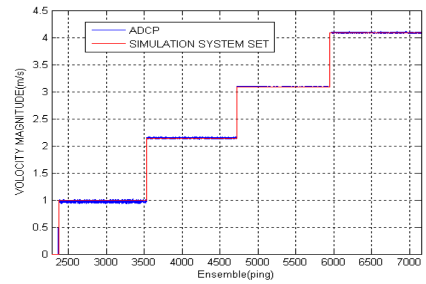
Since the coupling loss process from ADCP to the simulation system and the simulation system to ADCP is a reciprocal process, the simulation system calculates the compensation value of receiving process and used it to compensate the coupling loss in the sending process to make sure that backscatter signals amplitudes are consistent of each channel, According to the simulation system coupling loss compensation strategy of each channel, the simulated backscatter signals of each channels are consistent and certain.

5. Calibration result and conclusion

Based on the acoustic simulation approach, we calibrated an ADCP using the simulation system, here is the result:



(a)



(b)

Figure 7 Calibration result of ADCP:(a) ADCP velocity magnitude color map in multi-layers (the depth 0~120 m) shown on the WinADCP software panel, (b) Velocity magnitude of simulation system sets and ADCP results

Investigating the simulated backscatter signal quality of the simulation system and the ADCP signal also helps to find out the reasons of system failure. Following figures show the results of single channel hardware failure of an ADCP.

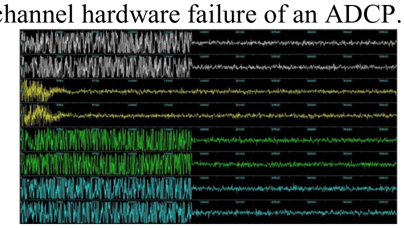


Figure 8 The ADCP processing waveform when the second receive channel disabled

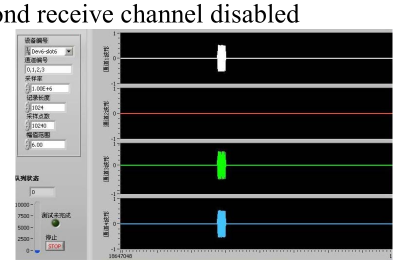


Figure 9 The simulation system waveform when the second transmit channel of ADCP is disabled

The acoustic simulation system and acoustic simulation method solve the problem of present calibration limitation of ADCP, and the simulation system provides a functional and accuracy calibration platform of ADCP under the laboratory conditions. Using the coupling loss compensation and automatic gain compensation approach, the calibration precision is improved.

As the simulation system uses ideal simulation signal, there are still differences with the actual conditions, and the calibrations are not comprehensive or incomplete. With the data accumulation of lake and sea tests, we are trying to apply more simulation models, and develop more functional calibration functions into the simulation system in the near future.

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