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# Target Echo Signal Separation from Underwater Active Sonar Data Using ICA

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## 1. Introduction

It is getting more difficult to detect underwater targets using target radiated noises due to the evolution of ship building technology. For this reason, a low-frequency active sonar system that uses the benefit of low absorption loss has attracted recently. To cope with this new threat, various studies such as anechoic coating material and active echo cancellation technique development are actively underway to get a better stealth performance against active sonar. When a new underwater acoustic stealth technology was developed, that one should be verified through real measurements. However, the target echo signal is dependent on the shape and aspect of the target, and it is very weak at the bow and stern aspect of a submarine where the target cross section is small[1]. In this situation, target reflected signal measurements are difficult and inaccurate due to the poor signal to noise ratio (SNR) of the received signals.

In this study, we propose an effective method to discriminate a genuine target echo signal from mixture of various disruptive noises that always reside in an underwater environment. We use an independent component analysis (ICA) as a basis for a new method. But the conventional ICA has two limitations. The first one is that it cannot determine exact signal amplitudes of the independent components because of the whitening matrix in ICA algorithm. The second one is that it cannot determine the order of the independent components. To resolve the first problem, we propose a signal amplitude reconstruction process using an amplitude compensation matrix. And to overcome the ordering problem, we used a signal arrangement process using a priori signal characteristics and the FFT results of ICA outputs.

Using artificial and real ocean recorded data, we demonstrated that the proposed method can perform better than the conventional beamforming method which is widely used in underwater applications.

## 2. Experimental Setup

The system configuration of ocean experiments was shown in **Fig. 1**. The sound source was operated at the first ship and a 10-channel receiving sensor array was installed just beneath it

And an echo repeater (ER) which is used to emulate an underwater target was operated at the second ship located about 1km apart from the source. The receiving sensor array and an ER were installed at the same depth to minimize interference of bottom and surface reflection waves.

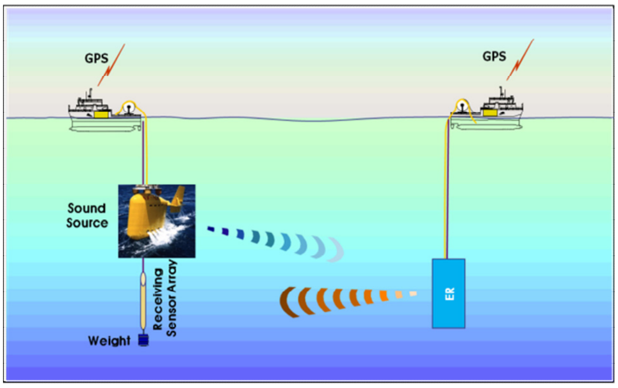


**Fig. 1** System configuration of ocean experiments

During the experiments, the sound source transmitted a series of 7 kHz ping signals at every 6 seconds. And, the retransmitted signal by the ER was recorded using a receiving sensor array.

## 3. Proposed Method

The proposed method is composed of three steps. First, 1 second of target echo signals were selected for the signal processing and band-pass filtered to reject noises. Second, ill-posed data was removed using the principal component analysis (PCA) and then carried out the Fast-ICA processing to separate source signals from its mixture [2,3]. Finally, the target echo signal was extracted from the noise mixture through the previous processes, however the amplitude of source signals are not maintained. Therefore, it is necessary to reconstruct the source signal amplitudes which have changed by whitening process in Fast-ICA. This can be solved by multiplying an amplitude compensation matrix given in **Fig. 2**.

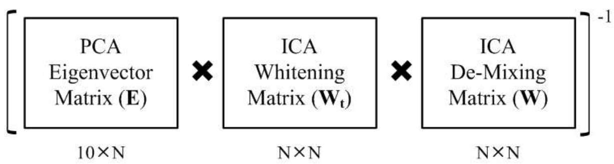


**Fig. 2** Amplitude compensation matrix calculation.

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Where, $N$ is the dimension which is reduced after the PCA.

## 4. Results and Discussion

As we can see from the ocean recorded data shown in **Fig. 3**, it is very difficult to distinguish the true target echo without echo arrival time information due to the reverberation, bottom and surface reflection waves. For this reason, we calculated a signal arrival time at the array using signal reception time and set delay time at ER which is synchronized with an array system using GPS.

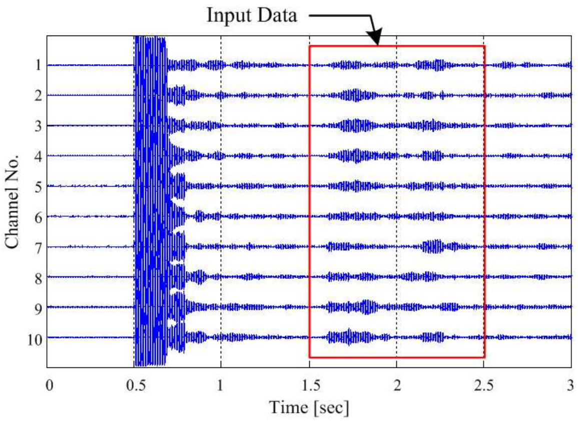


**Fig. 3** Real ocean recorded data after filtering.

In ocean data analysis the reference signal is not available, so the only way to evaluate the performance of the proposed method was to compare its SNR results to those of the beamforming technique [4].

**Fig. 4**(a) shows the signal reconstruction results by the proposed ICA method and Fig. 4(b) shows the results of the beamforming method. The SNR of reconstructed signals by the proposed method was 15.41 dB and this is about 3 dB better compared to the beamforming method. **Table 1** shows the SNR results from 5 typical ping data which were recorded in the real ocean. As we can see in the Table 1, the proposed method shows the better performance at every ping. So, the noises from the recorded data could be sufficiently reduced and more accurate estimation of source signal energy could be made.

**Table 1** The SNR output of each method with measured data.

| Ping No. | Beamforming Method SNR [dB] | Proposed Method SNR [dB] |
|---|---|---|
| 1 | 10.060 | 12.352 |
| 2 | 11.226 | 13.786 |
| 3 | 9.374 | 12.205 |
| 4 | 10.627 | 12.238 |
| 5 | 12.154 | 15.407 |

To make a better measurement through increasing the SNR, this paper proposed a new method based on ICA. However, whitening process in ICA algorithm changes the signal amplitude and makes it difficult to calculate the signal amplitude directly. To overcome this limitation, this paper suggested an amplitude compensation matrix which is composed of weights those are used during the calculation for the signal extraction.

Through the computer simulation and ocean experiments, we confirmed that the proposed method can preserve the amplitude of the original signal. Also we showed that a SNR enhancement over the conventional beamforming technique was achieved.

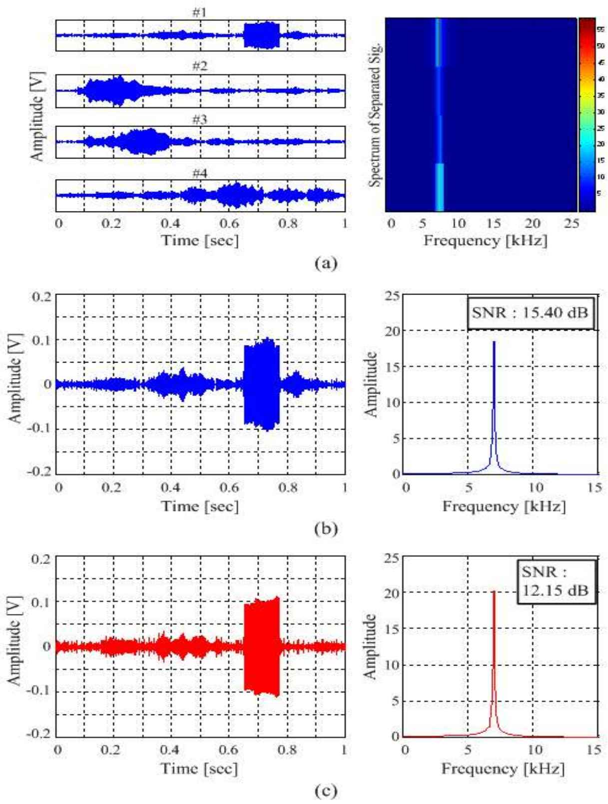


**Fig. 4** The signal separation results of real ocean recorded data: (a) Source separation and FFT result (b) Proposed method and (c) Beamforming method.


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