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Denoising of MEMS Vector Hydrophone Signal Based on Empirical Model Wavelet Method †

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Abstract: Underwater acoustic technology is a major method in current ocean research and exploration, which support the detection of seabed environment and marine life. However, the detection accuracy is directly affected by the quality of underwater acoustic signals collected by hydrophones. Hydrophones are efficient and important tools for collecting underwater acoustic signals. The collected signals of hydrophone often contain lots kinds of noise as the work environment is unknown and complex. Traditional signal denoising methods, such as wavelet analysis and empirical mode decomposition, product unsatisfied results of denoising. In this paper, a denoising method combining wavelet threshold processing and empirical mode decomposition is proposed, and correlation analysis is added in the signal reconstruction process. Finally, the experiment proves that the proposed denoising method has a better denoising performance. With the employment of the proposed method, the underwater acoustic signals turn smoothly and the signal drift of the collected hydroacoustic signal is improved. Comparing the signal spectrums of other methods, the spectral energy of the proposed denoising method is more concentrated, and almost no energy attenuation occurred.

Keywords: MEMS vector hydrophone; wavelet analysis; empirical mode decomposition (EMD); signal denoising

1. Introduction

Underwater acoustic technology is a major method in current ocean research and exploration, which support the detection of seabed environment and marine life [1]. However, the detection accuracy is directly affected by the quality of underwater acoustic signals collected by hydrophones. Many kinds of environment noises, such as wind sounds, sea waves, and ship navigation, are collected simultaneously when the hydrophones are collecting the useful signals. Before the information extraction of detected targets, the collected signals of hydrophones should be denoised firstly. Traditional denoising methods, such as wavelet analysis and empirical mode decomposition, usually fail to achieve satisfactory denoising results. Therefore, a denoising method combining with wavelet threshold processing and empirical mode decomposition is proposed in this paper, and the experiment data collected by MEMS vector hydrophone is processed. Compared with wavelet threshold denoising and empirical mode decomposition denoising method, the results show that the proposed denoising method has a better denoising performance [2–6].

2. Materials and Methods

2.1. MEMS Vector Hydrophone

The hydrophone used in the experiment is a MEMS vector hydrophone produced by North University of China [7]. The basic structure of the hydrophone is shown in Figure 1. The cilia vibration caused by sound wave propagation produces the stress, which deforms the root of the cross beam micro-structure. The resistance of the varistor integrated at the root of the cross beam is changed. Then the resistance change of X-axis, Y-axis are transferred to voltages, and measured by Wheatstone bridge. Following the principle, the underwater sound signal is converted into the electrical signal.

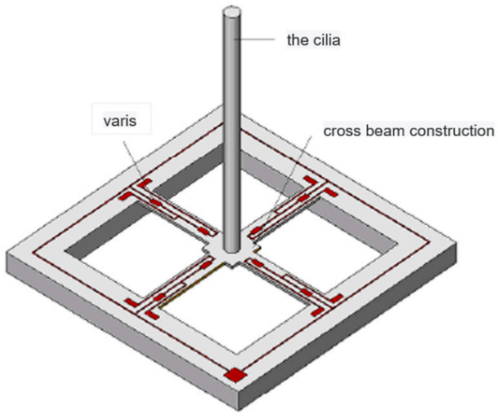

Figure 1. MEMS vector hydrophone microstructure.

2.2. Signal Acquisition

The procedure of collecting the underwater acoustic signal is shown in Figure 2. The frequency of the sound source was 331 Hz and the sampling rate of hydrophone was 10 kHz. Then, a random 500-sampling points were selected for the denoising experiments in this work.

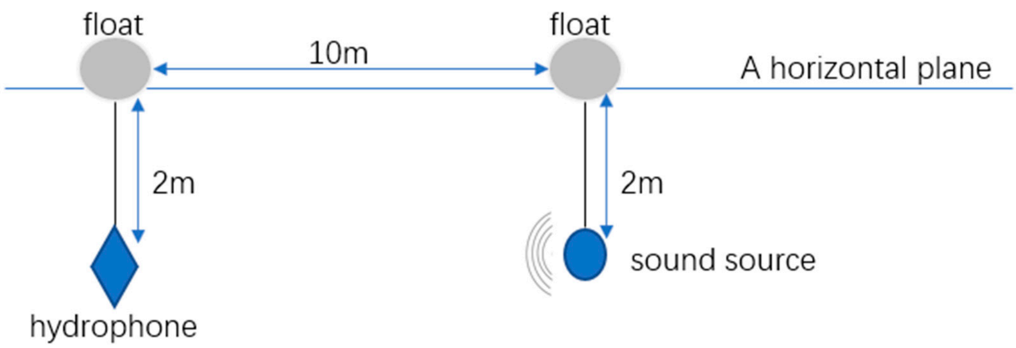

Figure 2. Signal acquisition process.

2.3. The Procedures of Proposed Method

The procedures of proposed signal denoising method in this work are as follow:

(1) Empirical mode decomposition (EMD) of underwater acoustic signals for eigenmode function (IMF) of the underwater acoustic signal.
(2) Correlating the underwater acoustic signal with the eigenmode function.
(3) Select the high-related IMF components, and perform image analysis on the selected IMF components.
(4) If the IMF component still contain much noise, wavelet threshold method is employed for a new IMF component with noise reduction; Otherwise, keep the IMF component without any action.

(5) Signal reconstruction from the smooth IMF components obtained from step (4).

3. Results and Discussions

To evaluate the performance of the proposed signal denoising method, the conventional wavelet threshold method, empirical mode decomposition, and the proposed method were employed for denoising the collected underwater acoustic signals. The spectrum analysis of original signal and three denoised signals were also conducted. The results are shown in Figure 3. Figure 3a shows that there is a signal drift in the original collected signal by hydrophone. And the signal drift effect is not reduced by wavelet threshold method, as shown in Figure 3c. However, the signal drift effect is reduced after the employment of empirical mode decomposition method, as shown in Figure 3e. With employing the proposed method, the underwater acoustic signals turn smoothly, and the amplitude is concentrated between −0.1 and 0.1. The signal drift of the collected hydroacoustic signal is improved obviously, as shown in Figure 3g. Comparing the signal spectrums in Figure 3, the spectral energy of the proposed denoising method is more concentrated, and almost no energy attenuation occurred.

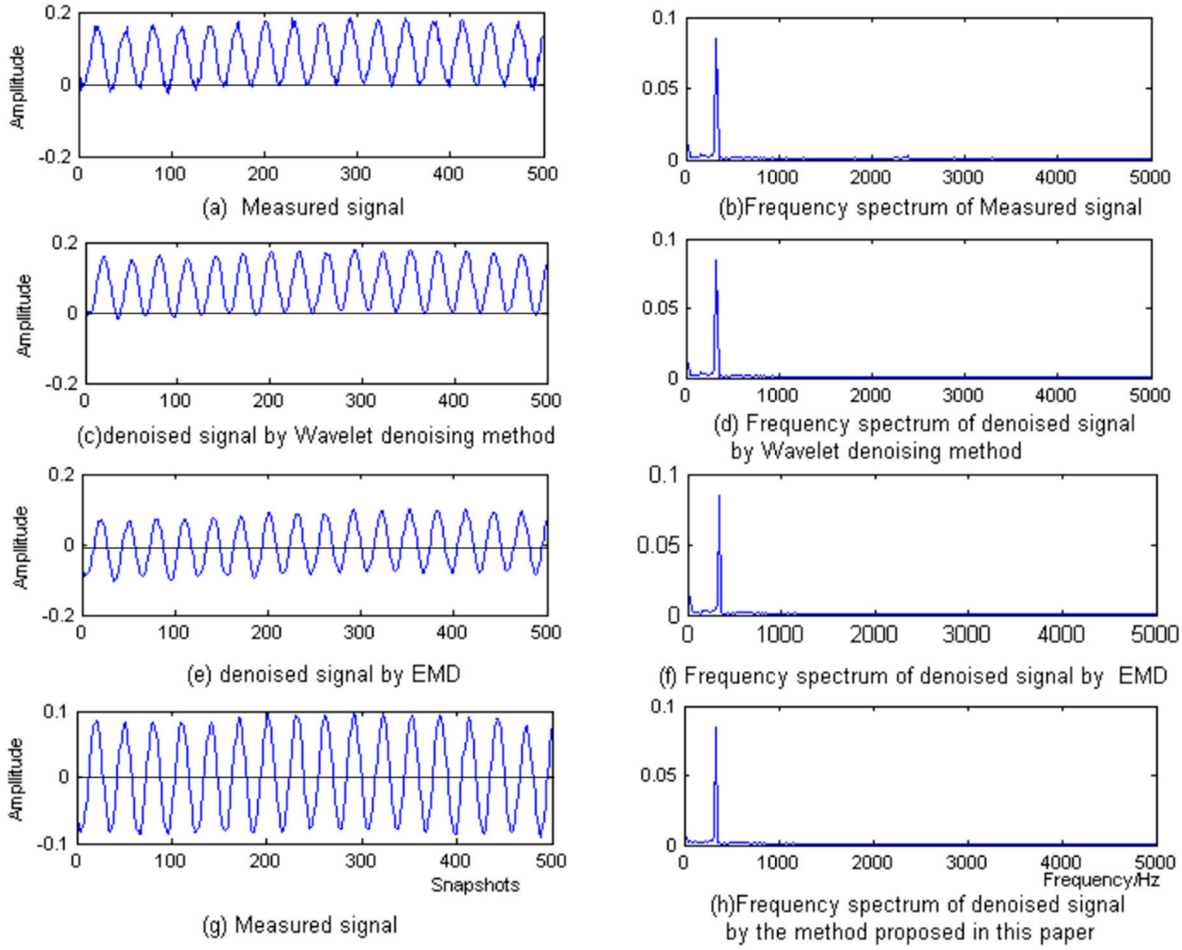

Figure 3. Signal denoising contrast result. (**a**) The measured hydroacoustic signal. (**c**) The denoised signal from wavelet threshold method. denoising result, (**e**) The denoised signal from empirical mode decomposition. (**g**) The denoised signal from the proposed method. (**b**,**d**,**f**,**h**) are the spectrum analysis for (**a**,**c**,**e**,**g**), respectively.

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