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Weighted Time Reversal Combining in Snapping Shrimp Noise

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1. Introduction

Snapping shrimp produces loud broadband snapping sounds that disturbs underwater commuinications in the form of impulsive noise. The sound source level of the snapping shrimp is measured as high as 190 dB re 1 μPa above 2 kHz of frequency and the length of waveform is shorter than 100 μs [1], [2]. Thus, the underwater communication systems in area where a number of snapping shrimp inhabits need to mitigate the snapping shrimp noise.

Time reversal (TR) combining, one of robust underwater communication techniques, offers a potential application to the underwater communications [3], [4]. The TR process provides the eqaulization of the receved signals with low complexity. Since SNR in underwater environment is low, multiple hydrophones are utilized to obtain temporal and spatial diversity and reduce signal distortion from underwater communication channel and noise. As the number of hydrophone at receiver increases, the effect of impulsive noise also is suppressed. If the small number of hydrophone is used, however, the impulsive noise degrades bit error performance of underwater communication systems. Thus, when the small number of hydrophone is utilized in snapping shrimp habitat, robust communication method over the the impulsive noise is developed.

In this paper, we propose a novel time reversal combining method which mitigates the degradation by the snapping shrimp noise. The proposed method combines the TR method with multiple hydrophones with adaptive combining weights. Simulation results show that the proposed method obtains less bit error rate (BER) than that of the conventional time reversal combining.

2. Proposed method

The conventional time reversal combining technique filters the received communication signals with the time reversed version of the underwater channels at all hydrophones and combines the filtered signals. If the snapping shrimp noise is added to the communication signals at several hydrophones, the communication signals are severely distorted by the impulsive noise. In this case, the conventional combining technique with equal combining weight causes the degradation of BER performance.

Thus, the proposed method adaptively adjusts combining weights which are calculated from the amount of the snapping shrimp noise at each hydrophone. If a hydrophone receieves communication signal and snapping shrimp noise is added all of sudden, the signal at the hydrophone is combined with a small weight. Then, the combined signal is less affected by the snapping shimp noise, but collects information of communication signals even if it is small.

Fig. 1 depicts the receiver structure of the proposed method. In **Fig. 1**, the receievd signals at hydrophones are combined with adaptively calculated weights $\omega(t)$ after the TR processing. The combined signal $r(t)$ can be written by

$$r(t) = \sum_{n=1}^{N} \omega_n(t) \left[h_n(-t) * y_n(t) \right], \qquad (1)$$

where ω_n, h_n and y_n denote weight, channel impulse response and received signal at the n-th hydrophone, respectively, at a time t. The weighting factor $\omega_n(t)$ is defined as

$$\omega_n(t) = \frac{1}{\sqrt{\sigma_n^2 + \sigma_i^2(t)}}, \qquad (2)$$

where σ_n^2 denotes variance of ambient noise and $\sigma_i^2(t)$ denotes the instantaneous variance of snapping shrimp noise. When the snapping shrimp noise occurs largely at a hydrophone, the receved signal at the hydrophone contributes to the combining signals with a small weighting value which is inversely proportional to the snapping

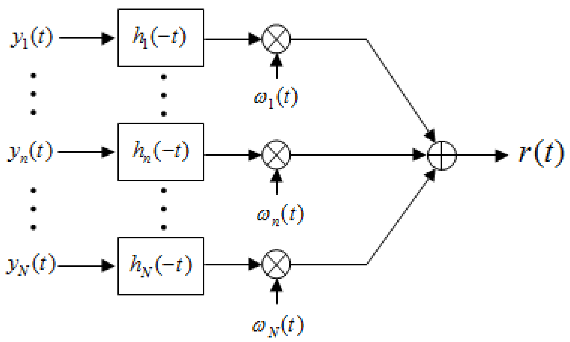

Fig. 1. the proposed receiver structure.

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shrimp noise. Note that the proposed scheme does not discard any received signal to collect communicaiton information, even though the signal is corrupted by the snapping shrimp noise. If $\omega_n(t)$ or $\sigma_i^2(t)$ is constant, the proposed method becomes the conventional TR scheme.

3. Simulation

To verify BER performance of the proposed method, Monte Carlo simulation is performed. **Fig. 2** shows snapping shrimp noise measured in SAVEX15 which was conducted in shallow water (~100m deep) in the Northern East China Sea, ~100 km southwest of Jeju Island, South Korea, over the period 14-28 May, 2015. The snapping shrimp noise has impulsive noise shapes and propagates from bottom to surface.

In this paper, to evaluate the performance of the proposed method, the snapping shrimp noise captured from the practical experiments is added to the communication signals with a similar pattern of the practically measurements as seen in Fig. 2. A receiver is equipped with four hydrophones. A single path Rayleigh fading channel is adopted and binary phase shift keying signal with 16.5 kHz carrier frequency and 2 kHz bandwidth is utilized as communication signals.

Simulation results are shown in **Fig. 3**. X-axis denotes signal-to-noise ratio (SNR) in dB and y-axis denotes BER. Blue and red lines denote BERs of three and four hydrophones without snapping shrimp noise, respectively. When the snapping shrimp noise exists, BER of the conventional TR technique (triangle-green line) has an error floor since the snapping shrimp noise becomes dominant for larger than 6dB SNR region. Even though the conventional TR method is equipped with four hydrophones, the BER performance is lower than that of the three hydrophone system without snapping shrimp noise. But, BER (black line) of the proposed method with four hydrophones with the snapping shrimp noise is lower than that of the conventional TR, and close to the without snapping shrimp case (red line).

Thus, the simulation results exhibit that the proposed method mitigates the snapping shrimp noise and collects the communication information from all hydrophones.

4. Conclusion

An adaptive weighting scheme with TR combining is proposed to overcome the snapping shrimp noise. The proposed method reduces BER degradation from the snapping shrimp noise since the weighting values to the hydrophones are adjusted by the amount of the snapping shrimp noise. Simulation results show that the proposed method obtains improved BER performance in the snapping shrimp noise compared with the conventional TR method.

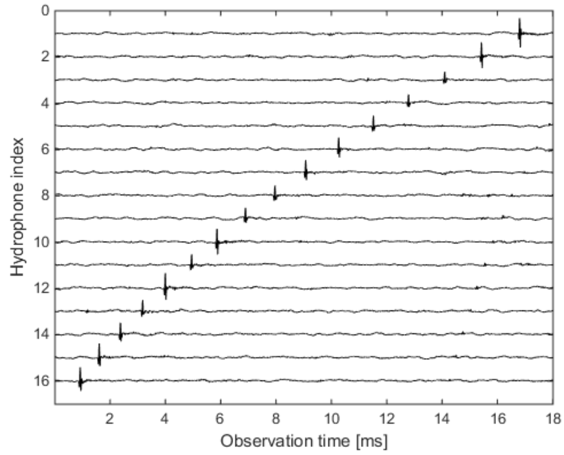

Fig. 2. Observed snapping shrimp noise.

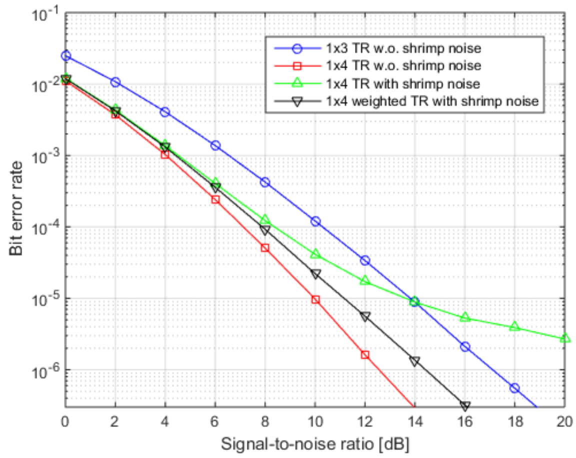

Fig. 3. Bit error rate of conventional and proposed time reversal method.

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