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The Performance of Underwater Frequency Diversity Communication Applying FFT-based Threshold Estimation

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1. Introduction

Underwater multipath is an important environmental factor that determines the performance of underwater acoustic communication. In particular, the performance of underwater acoustic communication is degraded due to the time-varying characteristics of multipath according to changes in the boundary between sea surface and bottom. In these underwater multipath channels, the transmission signals are received with time delay. Delay and spread increase Inter-Symbol Interference(ISI) and frequency selectivity of signal, which degrade the performance of underwater acoustic communication.[1)]

The underwater multipath channel has rapidly changing fading characterisics with time, and the frequency selectivity is changed according to the change of the boundary. Diversity is being applied as a method of improving the performance of underwater communication according to the change of frequency selectivity.[2,3)]

In this paper, we apply Fast Fourier Transform(FFT)-based threshold estimation of the signals received from each channels to counteract time-varying frequency selectivity of underwater acoustic communication channel. This is a diversity technique that reduces errors in underwater acoustic communication by selecting channels with high energy above threshold to secure the reliability of the channel according to the frequency selectivity. Frequency diversity underwater acoustic communication with FFT-based threshold estimation reduced error by about 0.4% compared to before application, and we checked that it is applicable as a method to improve underwater acoustic communication performance.

2. Frequency diversity and FFT-based threshold estimation

The signal transmitted in underwater cause multipath phenomenon due to reflection by the sea surface and bottom, and signal transmitted through the multipath are received with a time delay. The signal received with a time delay is shown in Eq. (1).

$$\mathrm{r(t) = As(t) + As(t - \tau)} \tag{1}$$

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The Fourier transform of Eq. (1) is shown in Ep. (2).

$$\begin{aligned} R(f) &= AS(f) + AS(f)e^{-j2\pi f\tau} \\ &= AS(f)\left[1 + e^{-j2\pi f\tau}\right] = AS(f)H(f) \end{aligned} \tag{2}$$

where $H(f)$ is a transfer function of the communication channel, and the influence of the channel bandwidth and the frequency selective channel according to fading is added to the received signal. Due to the these characteristics of channels, the FFT-based threshold estimation algorithm is applied for reliable channel selection.

The FFT-based threshold estimation is based on Mean Squared Error(MSE), as shown in Eq. (3).

$$MSE = \frac{1}{n}\sum_{k=1}^{n}(y_k - \widehat{y_k})^2 \tag{3}$$

where y_k is the received signal as the actual value, and $\widehat{y_k}$ is the transmitted signal as the predicted value. The FFT-based Threshold estimation algorithm is shown in **Fig. 1**, and it is a process of selecting and demodulating a channel that satisfied the FFT-based threshold based on the MSE output value of the received signal of each channel. [4)]

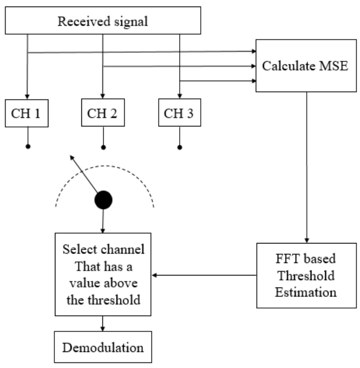


Fig. 1 Algorithm for estimating FFT-based threshold using MSE.

3. Experiment and Results

The experiment was conducted in the environment shown in **Fig. 2**. The distance between the transmitter and the receiver is 10m, and the experimental parameters are shown in **Table I**.

Figure 3 shows the 3CH frequency diversity used in this paper, and 4-Frequency Shift Keying(FSK) modulation is applied for each channel.

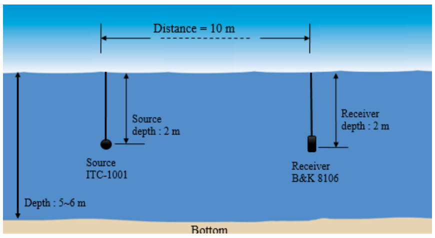


Fig. 2 The experimental configuration.

Table I Experiment parameters.

Modulation	4FSK
Channel number	3
Depth(m)	5~6
Tx-Rx depth(m)	2
Tx-Rx distance(m)	10
Bottom property	Mud
Mark carrier frequency(kHz)	17, 18, 19
Gard band(Hz)	100
Data rate(bps)	100
Information data(bit)	20000

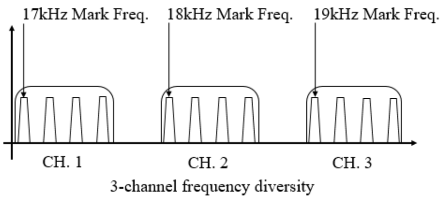


Fig. 3 3CH frequency diversity used 4FSK.

Figure 4 shows the energy variation characteristics of each channel for 200 seconds using PN signal for FFT-based threshold estimation. The estimated FFT threshold is set above –3dB to select a reliable channel to demodulate information.

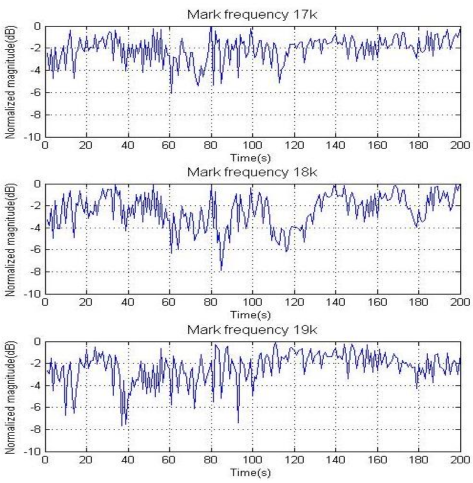


Fig. 4 Energy variation characteristics of 3 channels using FFT techniques.

Table II The underwater communication performance using FFT-based threshold estimation.

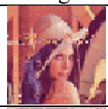
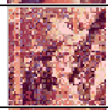
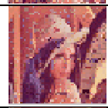
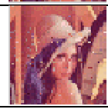
Frequency channel	The demodulated image	BER
Mark frequency 17kHz		0.01
Mark frequency 18kHz		0.24
Mark frequency 19kHz		0.05
Frequency Diversity with FFT-based Threshold Estimation		0.01

Table II shows the communication performance of the frequency diversity technique applying FFT-based threshold estimation. When the algorithm presented in this study was applied, the BER was reduced compared to other single channels.

4. Conclusion

We analyzed the underwater communication performance of the frequency diversity technique applying the FFT-based threshold estimation to ensure the reliability of the performance variation according to the change in frequency selectivity in the underwater acoustic channel. When the algorithm presented in this study was applied, the BER decreased by about 0.004, and the error decreased by 0.4% compared to CH1 which had relatively superior performance in a single channel. We confirmed that communication performance can be improved by maintaining the reliability of information in an underwater acoustic channel with strong time-varying characteristics through the algorithm presented in this study.

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