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Performance of Underwater Multi-Channel Communication Method Applying Frequency Diversity Technique in Underwater Fading Channel

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1. Introduction

Underwater acoustic communication channel is an environment dominant communication channel, especially multipath directly affects the performance of underwater acoustic communication systems. The multipath is caused by reflection on the boundary between sea surface and bottom, refraction by water temperature difference, and suspended solids.[1)]

The signal propagated through multipath is received with a time delay, and thus the received signal is delayed and spread. The signal received by delay spread affects the inter-symbol interference (ISI) and the bandwidth and frequency selectivity of the channel, which is a major factor that degrade the performance of the acoustic communication system. In addition, due to in-phase and out-of-phase interference between multipath received signals, a fluctuation of fast fading and frequency selectivity of a signal amplitude characteristic occurs.[2,3)]

In this paper, we evaluated the performance of frequency diversity technique considering frequency selectivity in underwater acoustic communication of multi-channel Frequency Shift Keying (FSK) method. By analyzing the correlation between fading and error for each frequency, we checked the performance improvement of the underwater acoustic communication applying frequency diversity technique.

2. Characteristics of Frequency Selective in Multipath Channel

The signal transmitted in underwater cause multipath phenomenon due to reflection by the sea surface and bottom, such as **Fig. 1**.

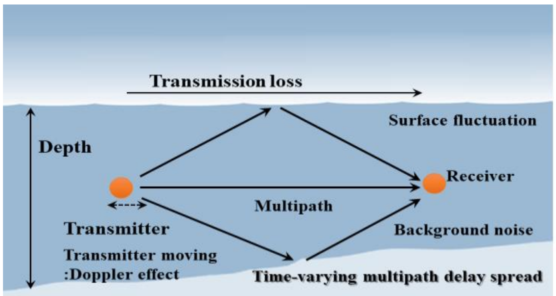

Fig. 1 Multipath in underwater acoustic channel.

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The transfer function equation of the multipath channel is as shown in Eq. (1).

$$\boldsymbol{H}(f) = \sum_p H_p\,(f) e^{-2\pi f \tau_p} \qquad (1)$$

Assuming that the transmitted signal is transmitted through two paths, the phase difference between the two signals is as shown in Eq. (2).

$$\Delta\emptyset = 2\pi f(\tau_2 - \tau_1) = \frac{2\pi f(l_2 - l_1)}{c} \qquad (2)$$

Signal distortion does not occur when $\Delta\emptyset$ is an even multiple of π, but distortion occurs when it is an odd multiple of π. The frequency at which distortion occurs is expressed by Eq. (3).

$$f = \frac{(2n-1)c}{2(l_2 - l_1)} = \frac{2\pi f(l_2 - l_1)}{2\Delta l} \qquad (3)$$

From Eq. (3), it can be seen that signal distortion occurs when the frequency is an odd multiple of $c/2\Delta l$. As such, the characteristic that the distortion of the signal occurs depending on the frequency is called frequency selectivity.

The frequency selective channel is characterized in that the delay spread is longer than the symbol period in the time domain, and the channel bandwidth is smaller than the signal bandwidth in the frequency domain.

3. Experiment and Results

The experiment was conducted by setting the depth of transmitter to 10m and receiver to 10m in

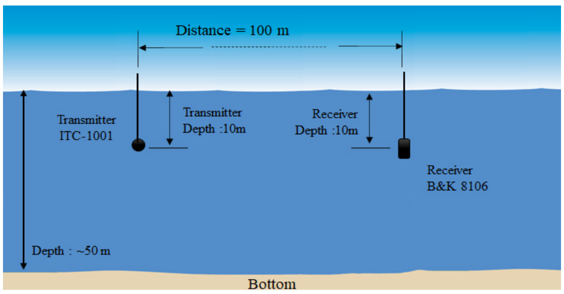

Fig. 2 The experimental configuration.

Table I Experiment parameters.

Modulation	4FSK
Channel number	5
Depth(m)	~50
Tx-Rx depth(m)	20
Tx-Rx distance(m)	100
Bottom property	Mud, Sand
Carrier frequency(kHz)	14~17
Data rate(sps)	200
Information data(bit)	20000

the environment shown in **Fig. 2**. The distance between the transmitter and the receiver is 100m, and the experimental parameters are shown in **Table 1**. The guard band was set at 200 Hz.

Figure 3 shows the multi-channel FSK method applied in the paper, and the 4FSK method per channel is applied.[4-6]

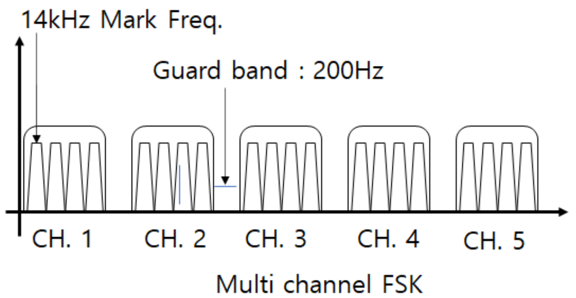

Fig. 3 Multi channel FSK.

Fig. 4 is the Intensity Profile of the underwater multipath channel. **Fig. 5** shows the frequency response characteristics of a multipath channel using an LFM signal, and frequency selectivity can be confirmed.

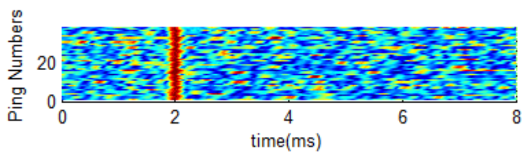

Fig. 4 Intensity profile of multipath channel.

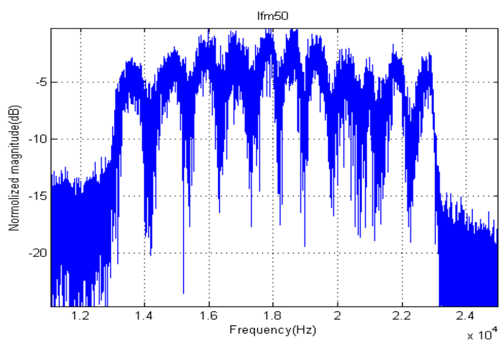

Fig. 5 Frequency response characteristics of multipath channel.

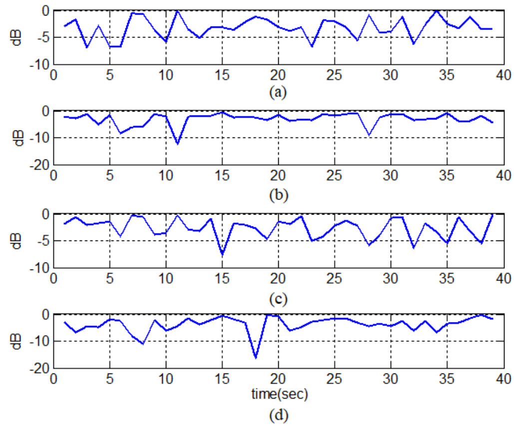

Fig. 6 Fading characteristics in multipath channel.

We checked the frequency selectivity through LFM analysis in the multipath environment of underwater multipath channel. From **Fig. 6**, we confirmed that relatively stable transmission is possible at carrier frequency 15 kHz in the fading characteristics of each frequency.

4. Conclusion

We analyzed the frequency selectivity and fading characteristics in the multipath environment of underwater multipath channel. In the analysis using LFM, we confirmed the band-limiting characteristics by frequency selectivity. Based on this, we analyzed the fading characteristics of the carrier frequency of each multi-channel and confirmed the correlation between fading and communication performance. By estimating the change in fading in the underwater acoustic communication, it may be possible to solve the transmission limitation of the underwater acoustic communication.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Education) NO. NRF-2019R1I1A1A01063575).

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