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Limit of Convolutional Code in Multipath Underwater Acoustic Channel

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1. Introduction

In underwater acoustic channel, the source signal is subject to multipath propation whose characteristics depends on the boundary and the location of the source and receiver [1,2].

Therefore, multipath propagation causes intersymbol interference (ISI) and multipath is an important factor that limits the coherence bandwidth.

In this study, we have analyzed that coherence band-limit effect to convolutional code performance at multipath underwater acoustic channel. Coherence bandwidth is calculated through channel response of water tank, and bit error rate (BER) is examined through quadrature phase shift keying (QPSK) transmission.

2. Coherence Bandwidth by Underwater Multipath

In underwater acoustic communication channel, the multipath reflection is a factor that varies with physical parameters of the underwater environment and the position of the transmitter and the receiver. Therefore, Transmitted signals experience delayed spread due to the time delay, and this greatly limits the coherence bandwidth [3].

The coherence bandwidth due to the discrete multipath in the multipath channel is evaluated based on the effective delay spread $\tau_{\mathrm{rm\,s}}$ in relations to τ_n (nth multipath), and is given as [4]

$$\tau_{rm\,s} = \sqrt{\overline{\tau^2} - (\bar{\tau})^2} \tag{1}$$

Here, the average delay $\overline{\tau^2}$ and $\bar{\tau}$ given as

$$\overline{\tau^2} = \frac{\sum_k P(\tau_k)\tau_k{}^2}{\sum_k P(\tau_k)},\ \bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \tag{2}$$

Here, $p(\tau_k)$is a power density of kth path. The relationship between the effective delay spread $\tau_{\mathrm{rm\,s}}$ and the channel's coherence bandwidth B_c is given as

$$B_c = \frac{1}{5\tau_{rm\,s}} \tag{3}$$

If the channel's coherence bandwidth B_c is less than the transmitting signal bandwidth B_s, a distortion occurs within the signal bandwidth and prevents an error-free signal transmission[5]. In addition, convolutional code in adopted to increase the performance the performance under additive white gaussian noise. Therefore, the convolutional code under the coherence band-limited channel will be reduced.

3. Experimental Results

The experimental configuration and parameters are shown in **Fig. 1** and **Table I,** respectively. The source and the receiver are located at depth of 0.3 m and 0.2 m, respectively. **Fig. 2** shows the delay spread in the water tank. The effective delay spread is 1 ms, The corresponding coherence bandwidth is 200 Hz. Therefore, the signal that can be transmitted without error is at a rate of less than 200 bps under high signal to noise ratio.

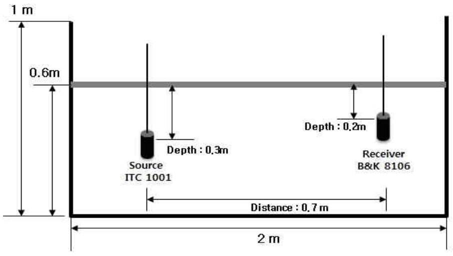

Fig. 1 Experiment configuration.

Table I. Experimental parameters.

Modulation	QPSK
Depth(m)	0.6m
Bit rate(bps)	200, 400, 1000, 2000
Distance	0.7m
Tx and Rx depth	0.3m and 0.2m
Transmission data	Image(50x50) 8bit (20000bit)
Channel Coding	Convolutional Code
Code rate	2/3, 1/2, 1/3, 1/4

Figures 3 show the received images in water tank. The BER of the transmission rate is shown in **Fig. 4.** As shown in **Figs. 3** and **Fig. 4**, the error-free

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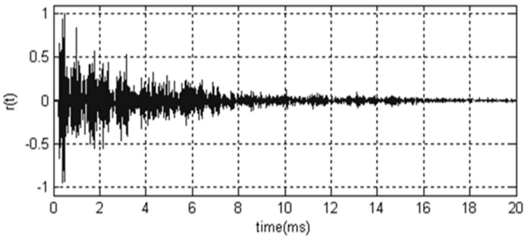

Fig. 2 Channel response in water tank.

image of 100bps well matches the coherence bandwidth. Also the convolutional code shows better performance as shown in the **Figs. 3**. However, the convolutional code in the 2000 bps is hard to expect reduced performance of the error. From these results, convolutional code gives better performance when the signal bandwidth is less than 10 times of the channel coherence bandwidth.

200bps	400bps	1000bps	2000bps
BER: 0	0.0011	0.0509	0.2906

(a) without convolutional code

200bps	400bps	1000bps	2000bps
BER: 0	0	0.009	0.38125

(b) with convolutional code

Fig. 3 Received images with respect to transmission bit rate in water tank : (a) without code, (b) with code.

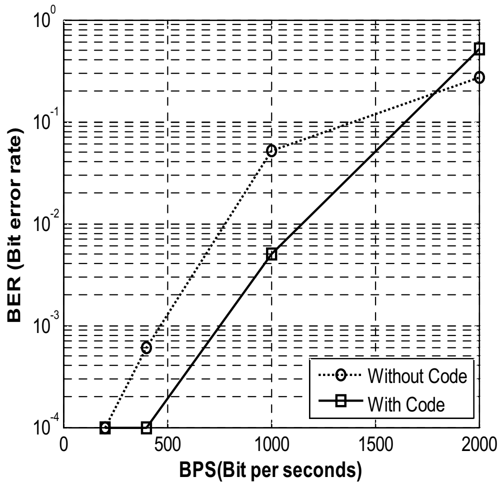

Fig. 4 BER of transmission rate (without code and with code).

code rate: 2/3	1/2	1/3	1/4
BER:0.1463	0.0037	0.0008	0.00085

Fig. 5 Received images for convolutional code rate (transmission rate = 1000bps).

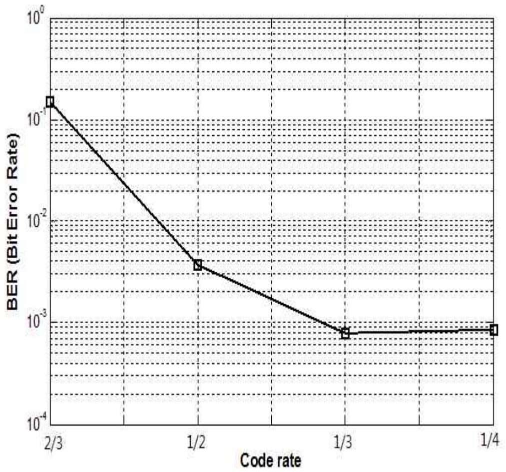

Fig. 6 BER of convolutional code rate (transmission rate = 1000bps).

Figures 5 and **Fig. 6** is convolutional code performance by code rate. In **Figs. 5**, 1/4 code rate is better than any code rate at 1000bps and BER is 0.0085. Relatively, the lowest performance is shown 2/3 code rate.

4. Conclusions

In this study, the effect of the channel coherence bandwidth to convolutional code is examined in multipath acoustic channel convolutional code is found to be effective when the transmission signal bandwidth is less than 5 times of the channel coherence bandwidth.

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