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Experimental verification of bit error rate in fading underwater acoustic communication channel

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1. Introduction

Underwater Acoustic (UWA) channels are generally characterized as fading multipath channels especially in shallow littoral ocean. Multipath propagation in the highly-reverberant ocean channels results in severe degradation of the communication system performance by causing time and frequency spread of the transmitted signal.

Temporal coherence of acoustic signals in the ocean has an effect on the performance of underwater communication systems and it has been studied experimentally in the ocean [1]. Effects of ocean thermocline on BFSK(Binary Frequency Shift Keying) performance has been studied experimentally in ocean[2,3]. In this paper, BFSK performance is studied in highly reverberant water tank environment based on statistical characteristic of fading. The results of this study will be adopted in real ocean UWA channel.

2. Reverberant Water Tank Channel and Experimental Conditions

Figure 1 shows water tank dimension and coordinates of source and receiver. Water tank surface is fluctuated and receiver position to source is varied.

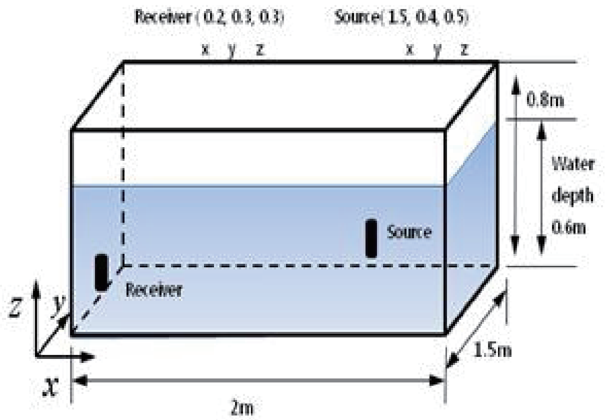

Fig.1 Schematic diagram of experimental configuration .

The received signal $r(t)$ in time variant multipath is given as[4]

$$r(t) = \mathrm{Re}[\{\sum_n \alpha_n(t) e^{-j2\pi f_c \tau_n(t)} s_l[t-\tau_n(t)] e^{j2\pi f_c t}\}], \quad (1)$$

where, $\alpha_n(t)$ and $\tau_n(t)$ are the attenuation factor and the propagation delay for the received signal of the n th path . The f_c and $s_l(t)$ are carrier frequency and the equivalent low-pass transmitting signal. Then the equivalent low-pass received signal $r_l(t)$ with white Gaussian noise $z(t)$ is given as

$$r_l(t) = \alpha(t) e^{-j\phi(t)} s_l(t) + z(t) \quad (2)$$

The processing and performance of BFSK depends on statistical nature of the envelope of $\alpha(t)$, and the phase $\theta(t)$. If there are a large number of time variant multipath, then the envelope of the received signal is Rayleigh distributed and the phase is uniformly distributed. These two statistical natures are experimentally quantified and the performance of BFSK is examined.

3. Experimental Results and Analysis

Figure 2 shows the measured waveform and statistical nature of the envelope. As shown, the envelope is faded due to the time variant multipath by surface fluctuation and the envelope is well approximated to Rayleigh fading. The phase is uniformly distributed in the interval -1.5~1.5 radian.

The coherence bandwidth B_c of the water tank channel, are also measured by cross-correlating the received signal of impulse. Figure 3 shows the measured multipath response and corresponding B_c which is about 40Hz.

Since the envelope $\alpha(t)$ and the phase is Rayleigh distributed and uniformly distributed, the error probability of non-coherent BFSK is given as

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$$P = \frac{1}{2+\bar{\gamma}_b} \tag{3}$$

where, $\bar{\gamma}_b$ is the average signal to noise ratio(ASNR), given as

$$\bar{\gamma}_b = \frac{\varepsilon_b}{N_0} E(\alpha^2) \tag{4}$$

The average value $E(\alpha^2)$ is about 5.7 from the result of Figure 2(b).

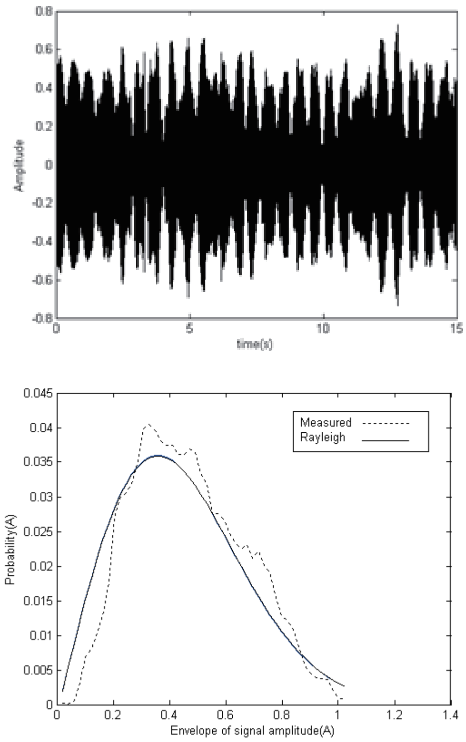

Fig. 2 Time variant fading waveform and the statistical nature of the envelope.

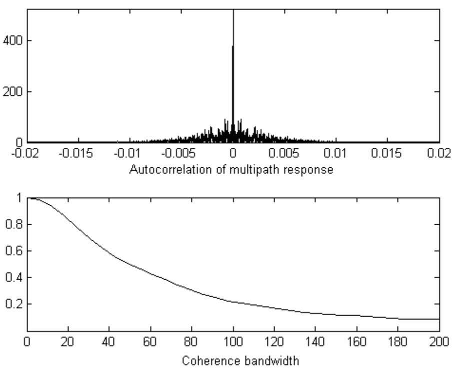

Fig. 3 Measured multipath response and corresponding coherence bandwidth.

The performance of the BFSK is examined in experimental condition. The noise power N_0 is assumed to be constant and transmission bit rate is confined to satisfy the coherence bandwidth such that less than about 100bps. The carrier frequencies are 20 kHz and 22 kHz. The SNR is changed by varying the bit rate. **Figure 4** shows the error probability with respect to ASNR. Predicted and measured results are well matched each other.

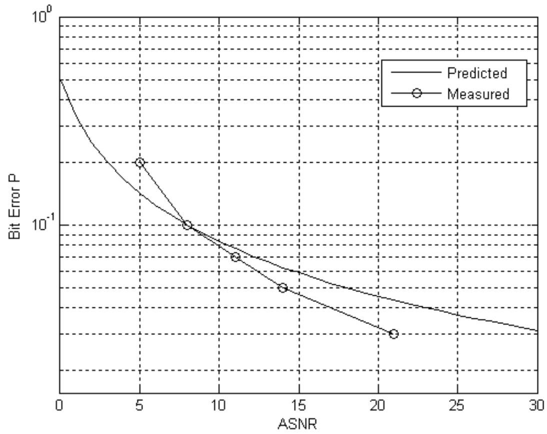

Fig. 4 Error probability with respect to ASNR.

4. Conclusions

BFSK performance is studied in highly reverberant water tank environment based on statistical characteristic of fading. The statistical nature of the water tank channel is well approximated to Rayleigh fading and the phase is uniformly distributed in the interval -1.5~1.5 radian. The coherence bandwidth B_c of the water tank channel is about 40 Hz. Predicted and measured bit error rate are well matched each other.

Acknowledgment

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