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Effectiveness of Frequency Hopping/ Frequency Shift Keying in Shallow Water Multipath Interference Channel

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1. Introduction

To establish a reliable underwater acoustic communication in shallow waters, the most important task is that it can overcome a number of limitations[1]. The first dominant factors are spreading in time domain (multipath delay spread) and in frequency domain (Doppler spread). In the frequency domain, the multipath delay spread can make the frequency dependent destructive or constructive amplitude fluctuation[2,3].

In this paper, by analyzing the multipath delay spread in frequency domain for a given range of transmitter to receiver, and comparing the BERs of FSK and FH-FSK communication system, we try to figure out how the FH-FSK system works in multipath fading channel.

2. FH-FSK system

The spread spectrum techniques were originally developed for use in military systems on account of their low probability of interception (LPI) and resistance to jamming signals.

In FH/FSK communication system the available bandwidth is subdivided into large number of contiguous frequency slots. The transmitted signal occupies one or more of the available frequency slots. The selection of each frequency slot is made pseudo-randomly according to the output from a PN generator. A block diagram of the FH/FSK communication system is shown in **Fig.1**[4].

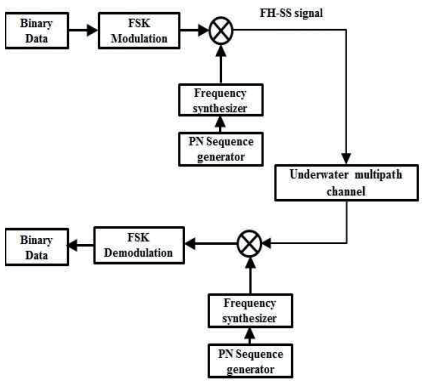

Fig. 1 Block diagram of FH/FSK system.

3. Experiment

As a preliminary experiment before a real ocean, the experiment was conducted in about 1 m depth water tank on Aug. 10, 2015. The experimental configuration and parameters are shown in **Fig.2** and **Table I**. The ranges between the transmitter and receiver are set to be about 0.2, 0.4, 0.6, 0.8 m and 1m, the depth of receiver and transmitter are both set to be 0.2 m, respectively. FH/4FSK system is applied.

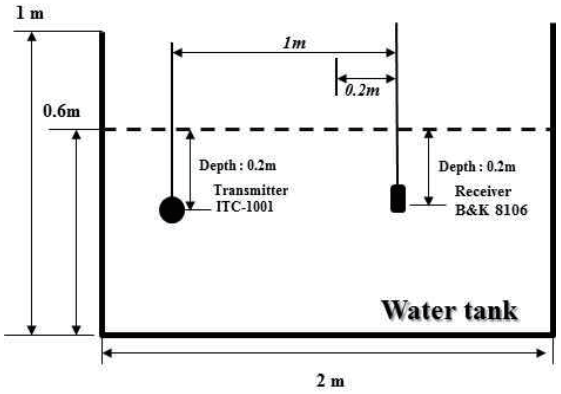

Fig. 2 The experimental configuration.

Table I. Experimental parameters.

Modulation	FH-4FSK
Tank depth(m)	0.6
Data rate(bps)	100
4FSK Carrier frequency(kHz)	1.1-1.4
PN frequency(kHz)	11-19
Hopping number	16
Distance(m)	0.2,0.4, 0.6, 0.8,1
Tx and Rx depth(m)	0.2
Information data(bit)	20000

The frequencies of 4FSK modulated signal are set to 1.1 to 1.4 kHz which the orthogonal frequency spacing is given by 100 Hz, the frequencies of PN sequence are set to be 11 to 19 kHz which the hopping interval is 500Hz. **Fig. 3** shows the spectrum of FH-4FSK signal.

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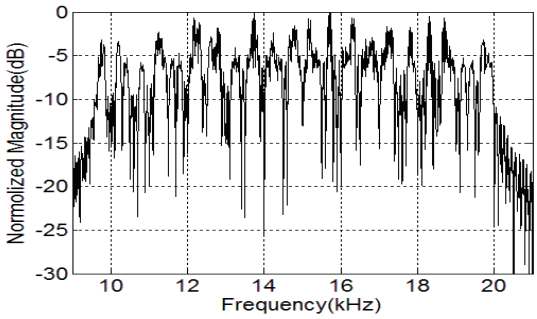

Fig. 3 Spectrum of FH-4FSK signal.

4. Results

Figure 4 shows measured channel spectrum using LFM received signal. For different transmission range, the multipath delay spread of each range gives a different fading characteristic in frequency domain.

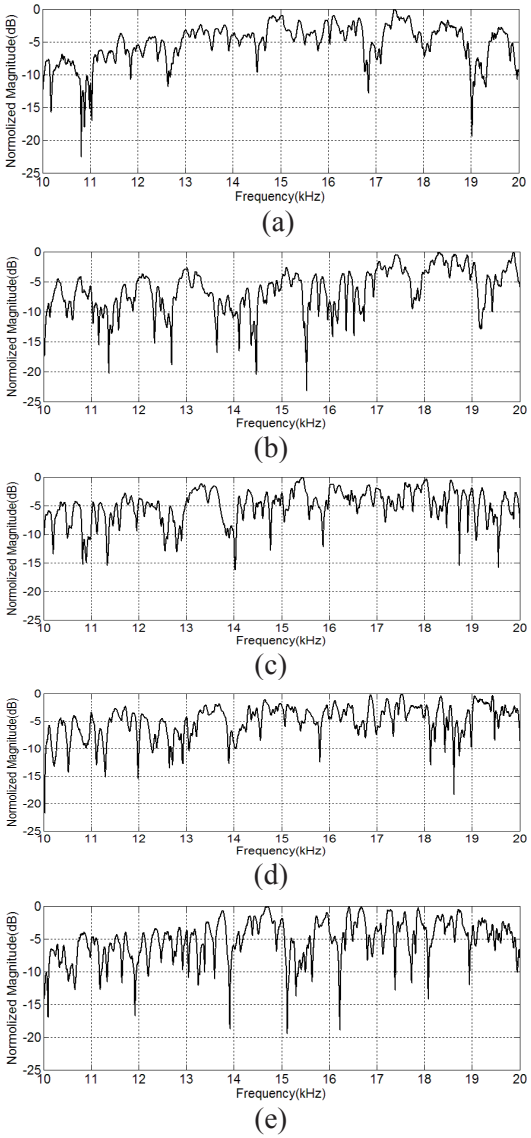

Fig. 3 Measured spectrum of LFM received signal: (a) 0.2 m; (b) 0.4 m; (c) 0.6 m; (d) 0.8 m. (e) 1 m.

Table II shows the received images and BERs of five different ranges. The errors of FH-4FSK system at 0.6, 0.8 and 1m are larger than those of 4FSK because its frequency bandwidth is wider than that of 4FSK and it has more chance to meet a fading signal. Considering overall BER range of FH-4FSK and 4FSK, the former is less than the latter since the error of FH-4FSK is mitigated in wide fading frequency range. This will give a more uniform error distribution to each user than 4FSK multiple access scheme using different frequency bands.

Table II. Received images and BERs.

Range	0.2m	0.4m	0.6m	0.8m	1m
FH/FSK Image					
BER	0	0	0.008	0.068	0.022
FSK Image					
BER	0.278	0	0	0.001	0

5. Conclusions

The BERs of FH-4FSK system for five different Tx-Rx ranges are examined. The influence of multipath fading in frequency domain on the FH-4FSK system is analyzed. Overall BER range of FH-4FSK is less than that of 4FSK since the error of FH-4FSK is mitigated in wide fading frequency range. In the future, the FH-16FSK which has 16 hopping will be studied based on 16FSK system.

Acknowledgment

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References

1. R. J. Urick: *Principles of Underwater Sound* (McGraw-Hill, New York, 1983) 3rd ed., p. 129.
2. M. Chitre, S. Shahabudeen, and M. Stojanovic: Mar. Tech. Soc. J. 42 (2008) 103.
3. Z. Zou, X. Xu, Z. Zhu, X. TU: OCEANS 2012, IEEE (2012) 1.
4. J. G. Proakis: *Digital Communication* (McGraw -Hill, New York, 2001) 4rd ed., p. 772.