Effect of Acoustic Metamaterials on Frequency Selective and Underwater Communication Performance in Underwater Multipath Channel

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1. Introduction

An underwater frequency selective channel is a rapid time-varying channel. The time variation of the channel is caused mainly by the boundary and the propagation medium property fluctuation with time.[1,2] In the underwater communications (UWC), the phase coherent UWC are greatly influenced by amplitude, phase variation and frequency shift in time domain. Also, underwater frequency selective channel shows a frequency selective fading in high speed transmission and this induces an inter symbol interference (ISI) resulting in bit error increase.[3,4]

In this study, we assessed the underwater communication performance of underwater acoustic metamaterial in frequency selective channel.

2. Underwater frequency selective channel and acoustic metamaterial

Figure 1 shows underater multipath and frequency selective. Physical and boundary conditions of underwater frequency selecitve channel are temperature profile of medium, surface roughness and bottom property.

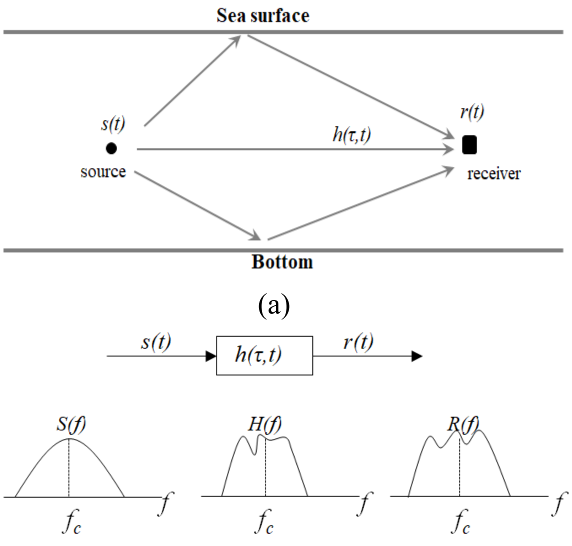

Fig. 1 (a) Underwater multipath, (b) Frequency selective characteristic in multipath.

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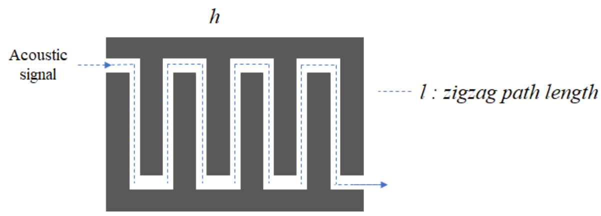


Fig. 2 Underwater acoustic metamaterials

The acoustic metamaterials were applied to reduce frequency selectivity. **Fig. 2** shows the composition of the acoustic metamaterials, the reflection R and transmission T coefficients for a plane wave normally incident on a slab with the mass density ρ_2 and the sound speed c_2 placed between two identical media with ρ_2 and c_1[5)]

$$R = \frac{Z_2^2 - Z_1^2}{Z_1^2 + Z_2^2 - 2iZ_1Z_2\cot\theta} \quad (1)$$

$$T = \frac{1+R}{\cos\theta + \frac{Z_2 i\sin\theta}{Z_1}} \quad (2)$$

were, $Z_i = \rho_i c_i$ is the acoustic impedance, $\theta = 2\pi f h / c_2$, f is frequency of the acoustic wave, and h is slab thickness.

3. Experimental Results

The experimental parameters and configuration are shown in **Fig. 3** and **Table I**, respectively. The source and the receiver are located at depth of 0.2 m and distance 0.5, 0.7m, respectively.

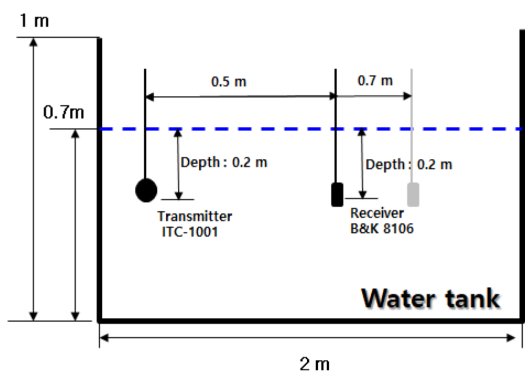
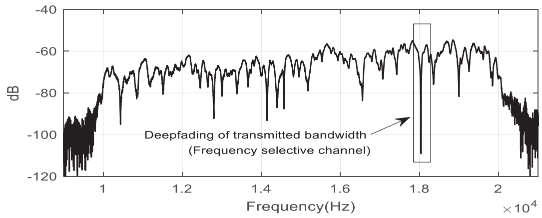


Fig. 3 The experimental configuration.

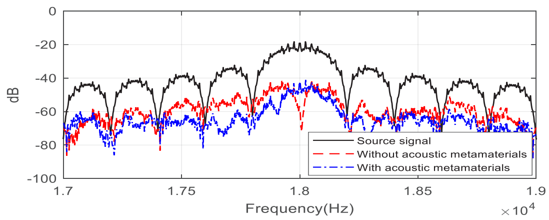
Table I. The experimental parameters.

Modulation	BPSK
Carrier frequency	18 kHz
Bit rate	200 bps
Transmission bit	20000 bit
Distance	0.5 m, 0.7 m
Transmitter / receiver depth	0.2 m, 0.2 m

Figure 4 and **Fig. 5** shows the frequency response of water tank using liner frequency modulation (LFM) and received signal spectrum in distance 0.5 m, 0.7 m. LFM frequency range is 10 kHz ~ 20 kHz

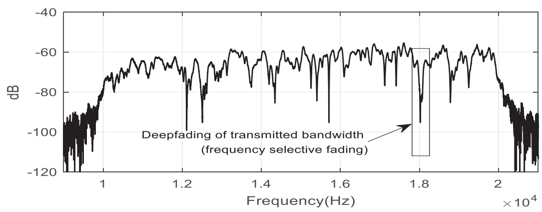


(a)

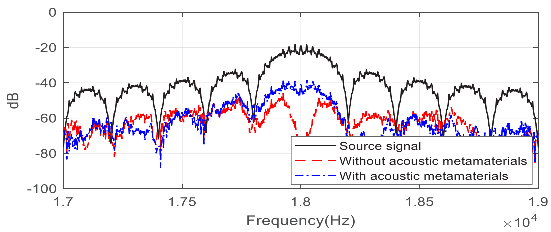


(b)

Fig. 4 (a) frequency response, (b) received signal spectrum of without and with acoustic metamaterial (distance 0.5 m).



(a)



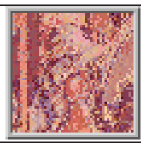
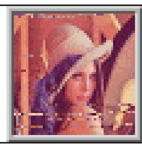
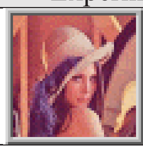
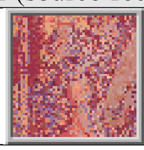
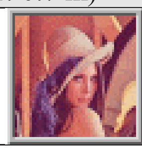
(b)

Fig. 5 (a) frequency response, (b) received signal spectrum of without and with acoustic metamaterial (distance 0.7 m).

The application of the acoustic metamaterial reduces the frequency selectivity in the spectrum of the received signal.

Table II, the error bit is 4603, 4065 and the bit error rate is 0.23, 0.2 before application of underwater acoustic metamaterial. After applying, the error bit is 504, 0 bit error rate was reduced to 0.02, 0.

Table II. The performance of underwater communication using acoustic metamaterials.

Experiment 1 (source-receiver: 0.5 m)		
Source	Without	With
		
Error number	4603	504
BER	0.23	0.02
Experiment 2 (source-receiver: 0.7 m)		
		
Error number	4065	0
BER	0.2	0

4. Conclusions

In this study, we assessed the underwater communication performance of underwater acoustic metamaterial in frequency selective channel. In experimental results, it was confirmed that the acoustic metamaterial was effective for improving the underwater communication performance.

Acknowledgment

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