**2P6-2**

# Band Reject Filter Characteristics of Acoustic Metamaterial in Underwater Multipath Channels

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## 1. Introduction

The shallow water multipath channel is very active area of underwater acoustics research, as the continental shelves and slopes have great economic, social, and military importance to humans, and all these areas interact with ocean sound.[1)] The underwater acoustic (UWA) digital communications in multipath channel has severe signal fluctuation and distortion, which is caused by multipath propagation by the dynamic variation of boundary and high temporal and spatial variability of the channel conditions. In particular, the phase coherent UWA communications are greatly influenced by amplitude, phase variation and frequency shift in time domain. Also, UWA channel shows a frequency selective fading in high speed transmission and this induces an inter symbol interference (ISI) resulting in bit error increase. [2-4)]

The Fabry-Perot resonance is a resonance filter that passes certain wavelengths and removes the rest. In underwater multipath channels, performance was evaluated by applying Perry-Perot resonance to reduce the effects of reflected waves.

In this study, we compare the performance for band reject filter characteristics of acoustic metamaterial and binary phase shift keying (BPSK) in underwater multipath channel.

## 2. Underwater Multipath channel and acoustic metamaterial

**Figure 1** show typical acoustic multipath channels. Physical and boundary conditions which characterize the acoustic channel parameters are temperature profile of medium, medium property, surface roughness and bottom property. Under these condition, transmitting acoustic wave will be spreaded, refracted, absorbed and scattered. The *i*th path coherent component $r_i$ is given as[3,4)]

$$r_i = \alpha_i e^{j2\pi f c \tau i} \qquad (1)$$

were, $f_c$ is a carrier frequency and $\alpha_i$ and $\tau_i$ denote a magnitude and a time delay. $\alpha_i$ depends on frequency and medium inhomogeneity for a direct path, but depends also on surface roughness, and grazing angle for a path reflected at surface.

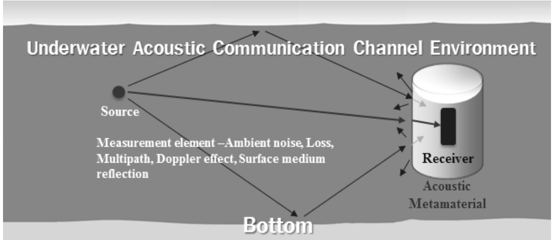

Fig. 1 Underwater multipath channel.

The Fabry-Perot resonance is two parallel mirrors with high reflectivity were placed facing each other to form a cavity, so that the light was reflected on the mirror it is like a light resonance filter that causes interference with the light wave so that only the light wave of a specific wavelength remains and the rest is canceled.[5)]

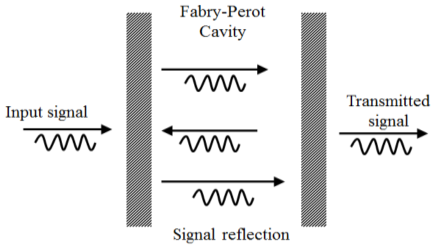

Fig. 2 The Composition and principle of acoustic metamaterial

The Fabry-Perot resonance wavelength determination condition equation (2) is as follows[5)].

$$L = m\lambda/2n \qquad (2)$$

where, $\lambda$ is wavelength in free space, $n$ is refractive index.

The Full width at half maximum (FWHM) bandwidth of Fabry-Perot resonance is inversely proportional to the finesse $F$ of the cavity[5)]

$$F \approxeq \pi\, \sqrt{R} / 1-R \qquad (3)$$

$$\Delta v_{FWHM\,(bandwidth)} = \Delta v_{FSR}/F \qquad (4)$$

where, $\Delta v_{FSR}$ is free spectral range, $F$ is finesse. In

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shallow UWA communication, the Fabry-Perot resonance is used to improve the performance by reducing the reflected wave effect of underwater acoustic communication.

## 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 0.35 m and 0.35 m, respectively.

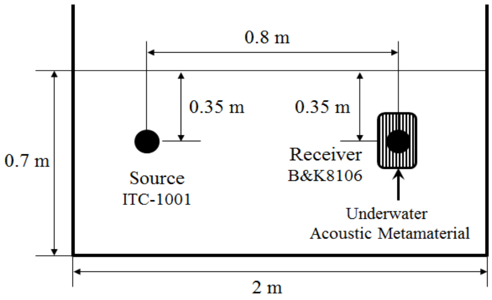

Fig. 3 The experimental configuration.

Table I. The experimental parameters.

| | |
|---|---|
| Modulation | BPSK |
| Mark Carrier frequency | 13 kHz |
| Bit rate (bps) | 200 |
| Transmission bit | 20000 bit |
| Distance | 0.8 m |
| Transmitter / receiver depth | 0.35 m/ 0.35 m |

**Figure 4** shows the frequency response of water tank using liner frequency modulation (LFM). LFM frequency range is 7 kHz ~ 20 kHz. **Fig. 5** shows the frequency response of water tank with underwater acoustic metamaterial applied.

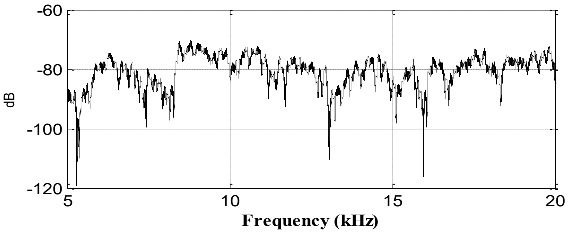

Fig. 4 The frequency response of water tank using LFM (without acoustic metamaterial).

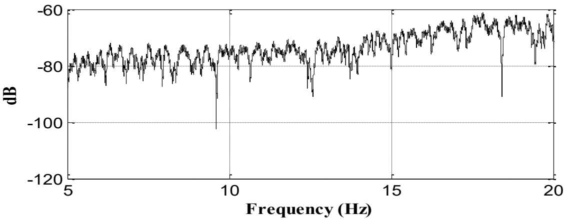

Fig. 5 The frequency response of water tank using LFM (with acoustic metamaterial).

The acoustic metamaterial reduces the fading and frequency selectivity by multipath channels and has an effect of increasing the received acoustic signal by 10 dB.

**Table II** is a performance evaluation of the effect of acoustic metamaterials and is the result of underwater image transmission performance by applying the BPSK modulation method.

Table II. The performance of underwater acoustic metamaterials.

| Source image | Without image | With image |
|---|---|---|
|  |  |  |
| Error number | 2246 | 256 |
| BER | 0.1123 | 0.0128 |

In the results of **Table 2**, the error bit is 2246 and the bit error rate is 0.1123 before application of underwater acoustic metamaterial. After applying, the error bit is 256, bit error rate was reduced to 0.0128.

## 4. Conclusions

In this study, we assessed the effect of underwater acoustic metamaterial on the reduction of multipath reflections. In Experimental results, it was confirmed that the underwater acoustic metamaterial was effective for improving the performance.

## Acknowledgment

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