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The performance of channel adaptive full duplex OFDM using PN pilot signal in underwater frequency selective channel

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1. Introduction

The reflection of boundary and medium in underwater acoustic multipath channel will affect the amplitude and phase of the transmitted signal.[1)] In addition, the interference of the interface reflected wave causes a selective increase in frequency and ISI (Inter-Symbol Interference), which degrades the performance of underwater acoustic communication.

The underwater acoustic communication channel is a fast fading channel. In such a channel, the energy fluctuation of the carrier frequency directly affects the communication performance. Therefore, the OFDM (Orthogonal Frequency Division Multiplexing) scheme in consideration of the narrow correlation bandwidth is effective. [2)]

In this paper, the PN pilot signal and OFDM are used as a method to improve the performance according to the frequency selectivity of the underwater acoustic channel. For channel analysis, the time series characteristics of the PN pilot signal inserted during full duplex transmission are analyzed. In addition, the image is reconstructed through QPSK (Quadrature Phase Shift Keying) demodulation by selecting an OFDM channel to which a frequency diversity matching technique is applied.

2. The underwater frequency selective channel and OFDM method

In an underwater multipath channel, the multipath propagation signal is delay spread and bandwidth limited [3,4)]. In addition, frequency selectivity is generated due to interference of signals along the propagation path, thereby limiting carrier selection.

As shown in **Fig. 1**, OFDM is an efficient transmission method in a band-limited underwater communication channel.

In OFDM modulation, the FFT size is N and the time length of one OFDM symbol is T. the OFDM signal can be expressed as[2)]

$$s(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} C_k \exp(j2\pi f_k t) \qquad (1)$$

where k is the index of subcarriers, and $f_k = k/T$ is the frequency of the k_{th} subcarrier.

In 4-subcarrier scheme, the N and T of one OFDM symbol are both 4 when only 4-subcarrier is used in OFDM modulation and demodulation, and the expression can be simplified as

$$s(t) = \frac{1}{2}(C_0 + C_1 \exp(j2\pi f_k t/4) + C_2 \exp(j2\pi f_k t/2) + C_3 \exp(j2\pi f_k t/2) + C_4 \exp(j2\pi f_k 3t/4) \qquad (2)$$

where $c_0, c_1, c_2,$ and c_3 represent the QPSK symbols modulated onto 4-subcarrier, respectively.

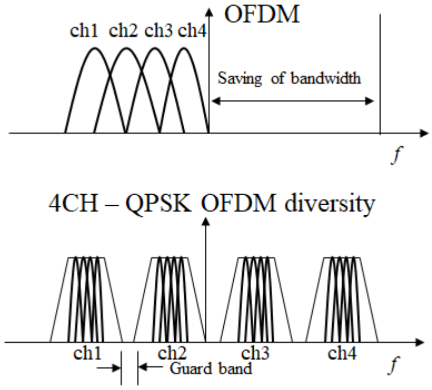

Fig. 1 The bandwidth characteristics of OFDM.

3. Experimental and Results

The experimental parameters and configuration are shown in **Fig. 2** and **Table I,** respectively. The source and the receiver are located at depth of 0.3 m and distance 0.6m, respectively. **Fig. 3** shows the uplink frequency mark frequency of 18 kHz and the downlink frequency mark frequency of 30 kHz as the receiving carrier frequency used in full duplex communication. **Fig. 4** shows the frame structure of the transmission signal.

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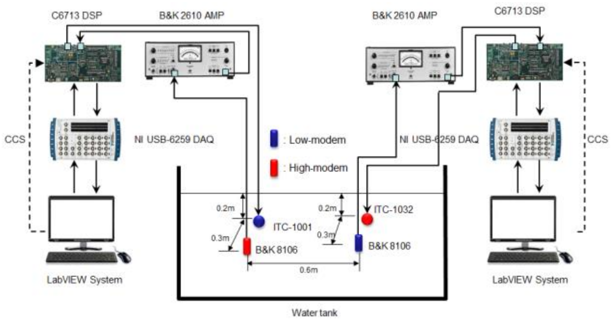

Fig. 2 The experimental configuration.

Table I. The experimental parameters.

Modulation	QPSK-OFDM
Mark Carrier frequency	18kHz, 30kHz
CH. number	2 CH
Bit rate (sps)	200,500 symbol per second
Transmission bit	20000 bit
Distance	0.6 m
Transmitter / receiver depth	0.3 m/ 0.3 m

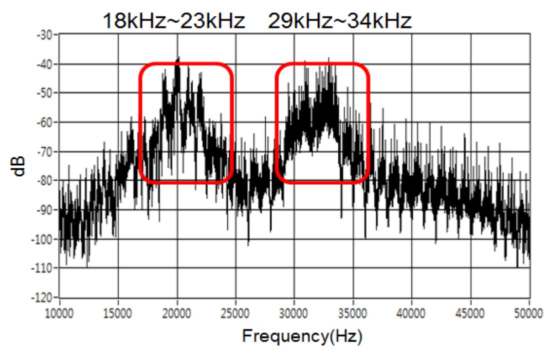

Fig. 3 Frequency response of water tank.

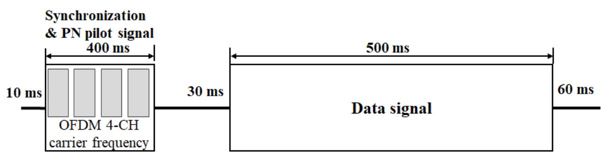

Fig. 4 Full duplex OFDM frame structure.

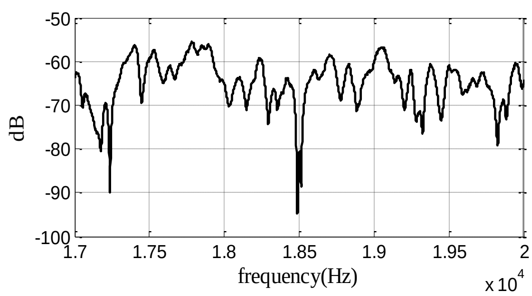

Fig. 5 Frequency response of water tank.

Figure 5 shows that the frequency response characteristics of the water tank show that the frequency selectivity is high in the down link frequency band.

Table 1 shows the image transmission performance of frequency diversity using two channels of OFDM according to the transmission rate. 200 sps was transmitted by configuring a channel having a bandwidth of 500 Hz. Transmission performance showed an error of less than 0.004 in both uplink and downlink. However, in the 500 sps transmission using the 1 kHz band, an error of 0.04 or more appeared. Due to the bandwidth limitation of the underwater acoustic channel, performance limitations occurred in the OFDM method as well.

Table II. OFDM image transmission performance.

sub carrier frequency	down link		up link	
	CH1 18kHz	CH2 18.5kHz	CH1 30kHz	CH2 30.5kHz
200 sps				
BER	0.0016	0.0005	0.004	0.002
sub carrier frequency	CH1 18kHz	CH2 18.5kHz	CH1 30kHz	CH2 30.5kHz
500 sps				
BER	0.056	0.04	0.04	0.06

4. Conclusions

In this paper, the PN pilot signal and OFDM are used as a method to improve the performance according to the frequency selectivity of the underwater acoustic channel. The full duplex communication performance was confirmed using the musk link and the downlink using 2 channels. Band limitation by the underwater multipath channel influenced the OFDM scheme. As a result, it was confirmed that the transmission rate of 200 sps was 10 times higher than that of 500 sps.

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