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Performance of Carrier Frequency Variations on the Demodulation in Underwater Communication System

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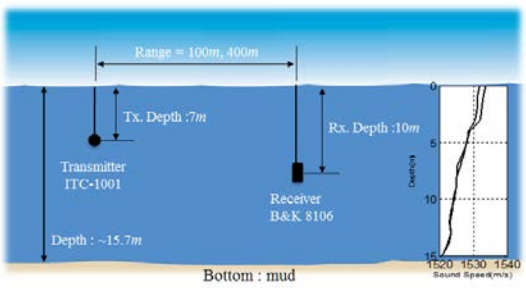
1. Introduction

An underwater acoustic communication channel in the shallow water is known to represent a multipath fading channel.[1-2)] This causes the amplitude variation, the phase change, and the intersymbol interference (ISI)[3-4)] in a transmitted signal. So the performance of the underwater acoustic communication system degrades owing to these channel distortions. To compensate for this, several techniques have been adopted like as a phase locked loop, the acoustic equalizers and so on. In this study, for the performance improvement, we evaluated the effect of carrier frequency variations at the QPSK demodulation system in the water.

2. Experimental Conditions

Figure 1 shows (a) the configuration of a sea experiment, (b) impulse response at 100 m and m (c) their frequency responses for the simulation in a very shallow multipath channel located in Geoje Island, Korea. The range between the transmitter and the receiver was set to be 100 m and 400 m, and the depths of the receiver and the transmitter are set to be 7 and 10 m, respectively. We assumed that the channel response had only 5 delayed impulse signals for the shallow sea, namely, direct, bottom reflected, surface reflected, bottom-surface reflected, and surface–bottom reflected signals. We also set 2 delayed impluse signlas for the deep sea with direct and surface reflected. The carrier and sampling frequencies are respectively chosen as 16 kHz and 128 kHz. The transmission rates are set to be 100 and 400 sps. The transmitted image is the standard Lenna image consisting of 9,800 bits of data.



(a)

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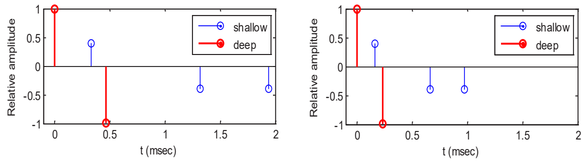
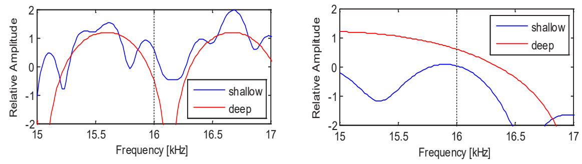


(b)



(c)

Fig. 1 Experimental configuration, (a) block diagram, (b) impulse response at 100 m and 400 m, (c) their frequency responses for the shallow water simulation. Red lines show the impulse responses for the deep water.

The specific experimental parameters are given in **Table I**.

Table I. Simulation and experimental parameters

Mod/Demod. System	QPSK
Carrier frequency (kHz)	16 kHz
Sampling frequency (kHz)	128 kHz
Symbol rates (sps)	100, 400
Data Transmission Type	Packet
Tx and Rx range (m)	100, 400
Tx and Rx depth (m)	7, 10
Depth (m)	~15.7
Bottom property	Mud
Data (bits)	Image 9,800 bits

3. Numerical simulations and their results

The channel's coherence bandwidth was calculated all simulation situation from Ref. 5. They were calculated about 200 Hz and 760 Hz at 100 m and 400 m in shallow water, respectively. They were also calculated about 432 Hz and 1.7 kHz at 100 m and 400 m in deep water. It means that 100 sps and 380 sps only are belonged to non-frequency-selective fading channels due to the scheme of the experimental environment in shallow water, then only the phase compensation is required. On the other hand, the others belong to frequency-selective fading channels, then an equalizer is required for the channel compensation. **Figure 2** show the constellations with carrier frequency 16 kHz in deep sea - top: before compensation, bottom: after compensation. Comparing the each result, the error rates were decreased to all 0. It means that the phase compensation technique is useful in the non-frequency-selective fading channels.

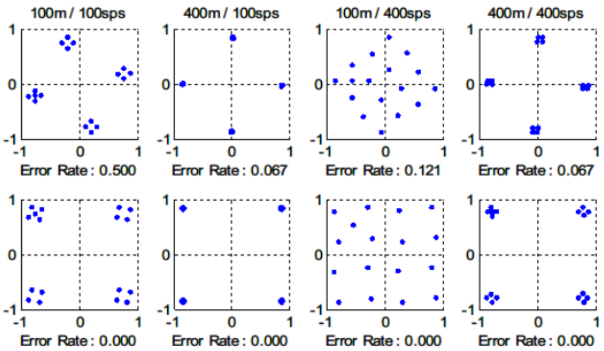


Fig. 2 Results of phase compensation in the deep water.

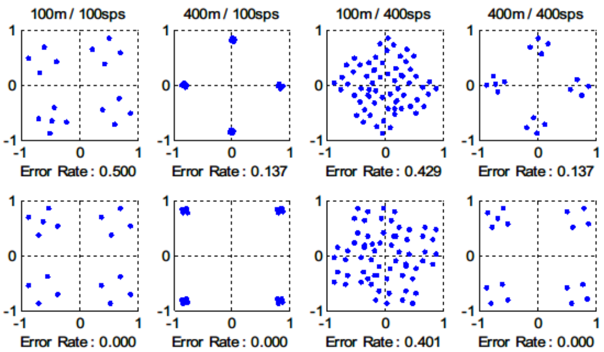


Fig. 3 Results of phase compensation in the shallow water.

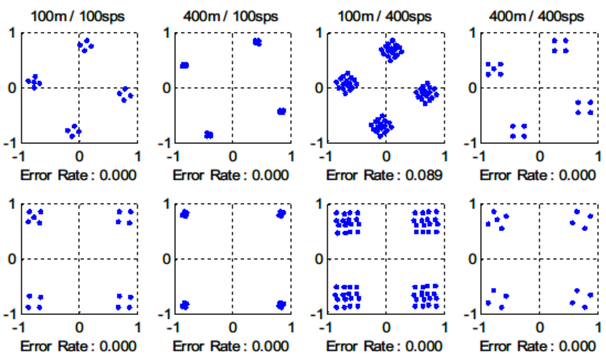


Fig. 4 Results of phase compensation in the shallow water with carrier frequency change to 15.8 kHz.

At range 100 m in **Fig. 1** (c), there are several fading in frequency spectrum like as 15.8 kHz and 16.2 kHz around original carrier frequency 16 kHz. Even though 16 kHz was not being in fading, the error rate after phase compensation on 400 sps was 0.401 as shown in **Fig. 3**. We could find the result owing to the frequency-selective fading channel. We tried to change the carrier frequency with little variation like as 15.8 kHz and 16.2 kHz in consideration of the Doppler Effect. As mentioned before, these frequencies had a fading in spectrum. **Figure 4** shows the results with carrier frequency 15.8 kHz. All the result after phase compensation at range 100 m, the constellations are more concentrated in each spots than Fig. 3's ones. There is no error in 400 sps, even though there is located in the center of fading. The other error rate in carrier frequency 16.2 kHz was 0.188 which had improved about 53% than one of the original 16 kHz. The average powers of each carrier frequency span with 250 Hz were 67.01, 61.45, and 60.69 at 16.2 kHz, 16 kHz, and 15.8 kHz, respectively. In the shape of the spectrum, only 16 kHz had convex from the carrier frequency. From two aspects, the error rate would be decrease with high power in bandwidth. And the convex of the center frequency seemed to have little effect.

4. Conclusions and further study

We introduced the approach for carrier frequency variations to improve the performance on the underwater acoustic communication channel. The error rate was significantly decreased to put carrier frequency at the fading, even though it was on frequency-selective channel. This result could be used for the input signal of the acoustic equalizer that could be getting more improvement on underwater communication channel in the shallow water.

References

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