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Analysis of Experimental Results for Space Diversity Techniques in Underwater Acoustic Communication

Kyu-Chil PARK[1†], Hyunsoo JEONG[1], Jihyun PARK[2], and Jinnam PARK[3] ([1]Dept. of Info. and Comm. Eng., Pukyong Nat'l Univ.; [2]Inst. of Acoust. and Vib. Eng., Pukyong Nat'l Univ.; [3]Dept. of Electr. Eng., Kyungsung Univ., Korea)

1. Introduction

Underwater acoustic communication is characterized by multipath fading due to multiple reflections from the surface and the sea floor.[1-2] This causes amplitude variations, phase shifts and inter-symbol interference (ISI) in the transmitted signal, which degrades the performance of the underwater acoustic communication system.[3-4] Many technieques have been applied to compensate this problem, such as PLLs (phase locked loop) and acoustic equalizers and so on. In this study, for the communication performance improvement and to apply the space diversity technique, we experimented and evaluated its results, on the QPSK modulation and demodulation system in water tank.

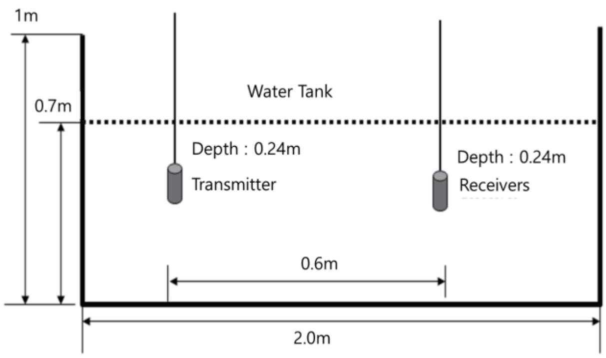
2. Experimental Conditions

Figure 1 shows (a) the experimental configuration in water tank and (b) the receiver sensors' structures. The size of the water tank is 2m, 1.5m and 1m in height, width and height respectively. The depths of the transmitter and the center of the receivers are set to be 0.24m. Five sensors are constructed in the form of crosses, horizontally and vertically. The distance from each sensor is 0.08m in width and length respectively. The carrier and sampling frequencies are respectively chosen as 16 kHz and 128 kHz. The transmission rates are set to be 100 sps. The transmitted image is the standard Lenna image consisting of 9,800 bits of data. The specific experimental parameters are given in Table I.

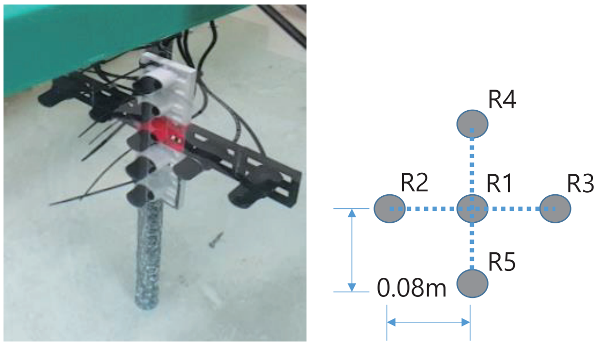
Table I. Simulation and experimental parameters

Mod/Demod. System	QPSK
Carrier frequency (kHz)	16 kHz
Sampling frequency (kHz)	128 kHz
Symbol rates (sps)	100
Data Transmission Type	Packet
Tx and Rx range (m)	0.6m
Tx and Rx depth (m)	0.24m
Depth (m)	~0.7m
Data (bits)	Image 9,800 bits

kcpark@pknu.ac.kr



(a)



(b)

Fig. 1 The experimental configuration in water tank on (a) and the receiver sensors' structures on (b).

3. Experimental results and discussion

Figure 2 shows the frame structure for packet data transmission. The transmission time of each frame is set to be 1s. The linear frequency modulation (LFM) was used for measuring the channel characteristics and symbol time alignment, and ranges from 14 kHz to 18 kHz.

Figure 3 shows an example of (a) a transmission signal, (b) a received signal at sensor R1, and (c) the cross-correlation function between the two signals. The result shows the LFM signal's length is enough to get the symbol time alignment.

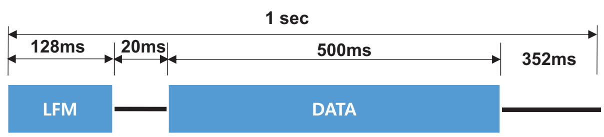
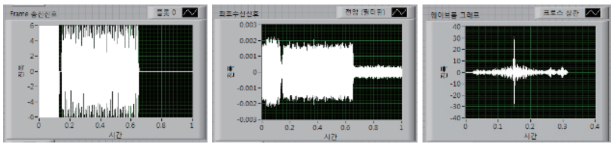


Fig. 2 Frame structure for packet data transmission.



(a) (b) (c)

Fig. 3 An example of signals at the transmitter, the receiver sensor R1, and their cross-correlation function.

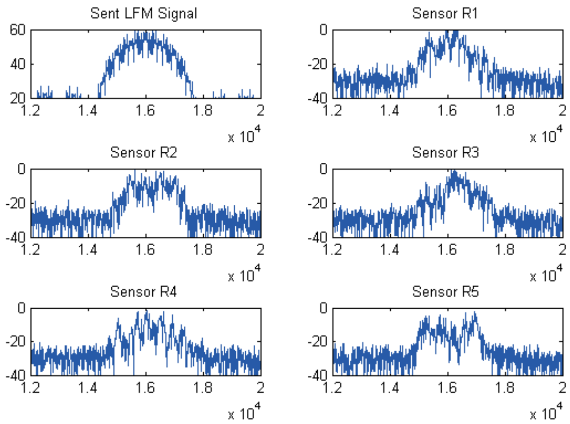


Fig. 4 Each channel's characteristics by spectrum analysis from their received LFM signals on each sensor.

Figure 4 shows each channel's characteristics by spectrum analysis from their received LFM signals. From left top to right bottom, a send signal and 5 received signal on each sensors. All channel have the spectrum distortion on the main rob due to multiple reflections. The cross-correlation function was applied to check the similarity between the received signal and the transmitted signal of each sensor. **Figure 5** shows the result both time (left) and frequency domain (right), respectively. From top to bottom, figures related with sensor R1, R2, R3, R4, and R5, respectively. In the similarity of time axis, sensor R1 (center) was the highest and sensor R2 (left) was the lowest. This may be considered to mean that the received signal on sensor R2 is somewhat spread on the time axis by multiple reflections. In the similarity of frequency axis, sensor R1 also was the highest. From both results, we can easily expect the sensor R1's communication results to be the best.

Figure 6 shows all experimental results. The order of the figures is the same as that of **Figure 4**, and the results on Sensor R1 show no error.

4. Conclusions and further study

In this study, to improve the communication performance and to apply the space diversity technique, we experimented and evaluated its results, on the QPSK modulation and demodulation system in water tank. Using the cross-correlation function between the transmitted signal and the received signal, the similarity of the signal was investigated on the time axis and the frequency axis. The communication performance of the channel with high signal similarity was the best in both areas, and it is expected to be applied to the application of spatial diversity in the future.

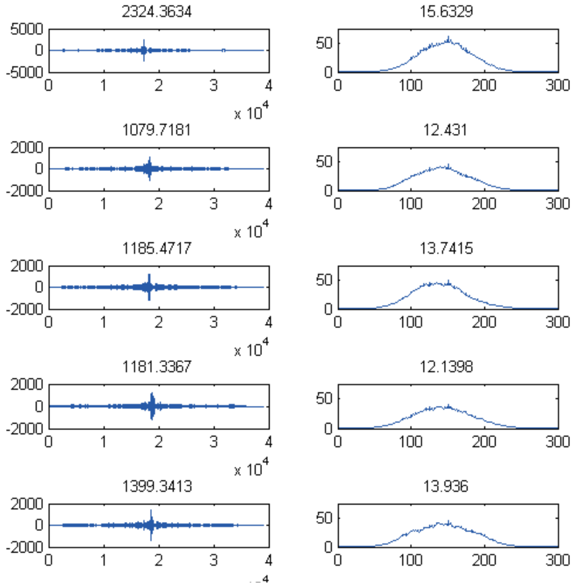


Fig. 5 Cross-correlation function between each channel and the sent LFM signal in the time and frequency domain.

Fig. 6 Lena image and transmission result to each channel

Acknowledgement

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References

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