2P6-5

Performance Evaluation of the Rake Receiver in the Underwater Acoustic Communication System

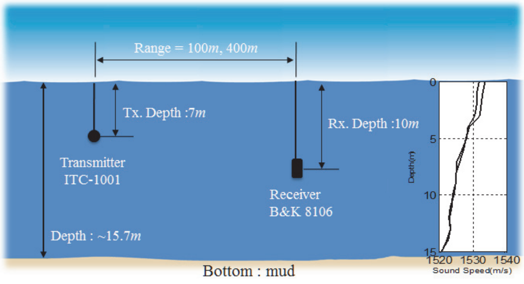
Kyu-Chil Park†, JiHyun Park, and Eun Young Lee
(Pukyong Nat'l Univ., KOREA)

1. Introduction

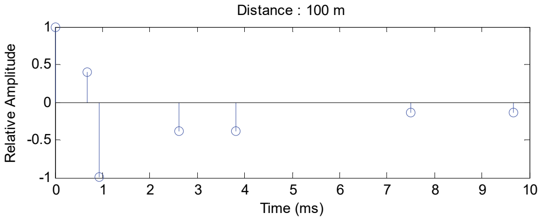
It is known to represent a multipath fading channel in the underwater acoustic communication system in the shallow water.1-2) This causes the amplitude variation, the phase change, and the intersymbol interference (ISI)3-4) in a transmitted signal so the performance of the underwater acoustic communication system degrades. To compensate for these channel distortions, 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 rake receiver on the QPSK modulation and demodulation system in the shallow water condition.

2. Experimental Conditions

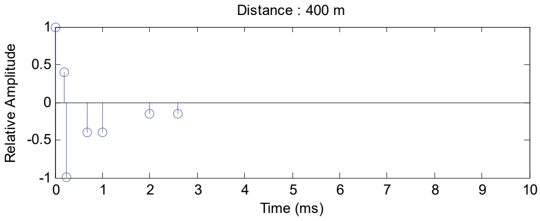
Figure 1 shows (a) the configuration of a sea experiment, (b) impulse response at 100 m and m (c) impulse response at 400 m in a very shallow multipath channel located in Geoje Island, Korea. The depths of the receiver and the transmitter are set to be 7 and 10 m, respectively. We assumed that the channel response had only 7 delayed impulse signals for the shallow sea, namely, direct, bottom reflected, surface reflected, bottom-surface reflected, surface–bottom reflected signals and so on. The carrier and sampling frequencies are respectively chosen as 8 kHz and 64 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. The specific experimental parameters are given in **Table I**.



(a)



(b)



(c)

Fig. 1 Experimental configuration, (a) block diagram, (b) impulse response at 100 m and (c) impulse response at 400 m for the shallow water simulation.

Table I. Simulation and experimental parameters

Mod/Demod. System	QPSK
Carrier frequency (kHz)	8 kHz
Sampling frequency (kHz)	64 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 140 Hz and 510 Hz at 100 m and 400 m in shallow water, respectively. It means that except 400 sps / 100 m is 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-

---

kcpark@pknu.ac.kr

selective fading channels, then an equalizer is required for the channel compensation. **Figure 2** shows the constellations with carrier frequency 8 kHz in shallow water - 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.

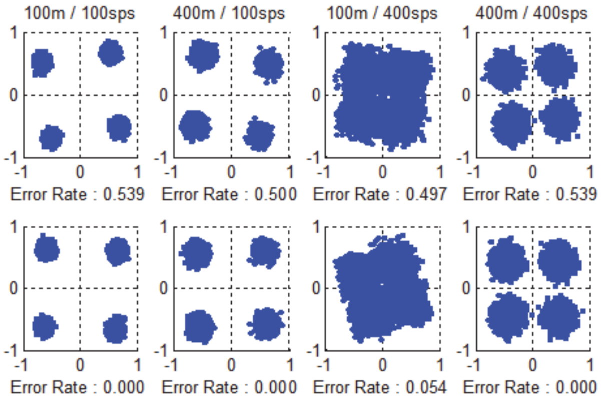


Fig. 2 Results of phase compensation in the shallow water.

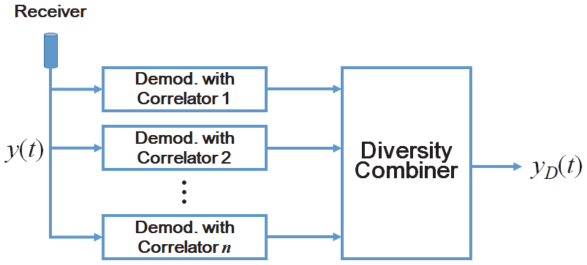


Fig. 3 A block diagram of a rake receiver with multi paths.

The rake receiver is mainly used for the CDMA method, and it is possible to obtain a better signal by bundling the multi-path signals with time difference arriving at different paths[6]. Since these reflected signals are recognized as independent signals spread by different codes, if all of them are combined, good signal quality with less fluctuation of received power is obtained shown as **Fig. 3**. So it can be applied for the underwater acoustic communication system in the shallow water even though it has not any spread spectrum signals.

Figure 4 shows the results using a rake receiver by 2 demodulators with the correlator 1 and 2 for the direct and bottom reflected signal. The main difference against to **Fig. 2** is that result of 100 m / 400 sps is improved 87% from **Fig. 2**. It means the combined signal shows more good signal quality than direct only modulator. As same reason, **Fig. 5** shows the results using a rake receiver by 3 demodulators with the correlator 1, 2 and 3 for the direct, bottom reflected and surface reflected signal. The result of 100 m / 400 sps is also improved 96% from **Fig. 2**. 71% from **Fig. 3**.

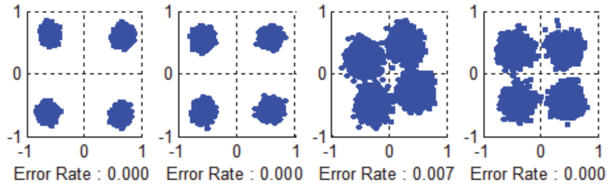


Fig. 4 Results of phase compensation in the shallow water.

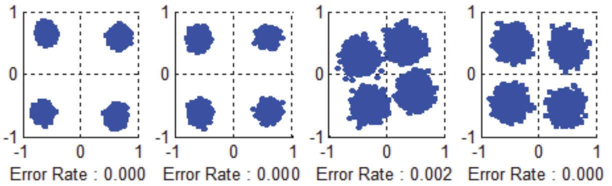


Fig. 5 Results of phase compensation in the shallow water.

4. Conclusions and further study

We introduced the approach with the rake receiver to improve the performance on the underwater acoustic communication system. The error rate was significantly decreased to put the demodulators with correlators, even though it was belonged to the 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 system in the shallow water.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2017R1D1A3B03036098).

References

1. W. B. Yang and T. C. Yang, Proc. IEEE Oceans 2006 (2006) 1.
2. T. C. Yang, J. Acoust. Soc. Am. **131** (2012) 129.
3. J. Park, J. R. Yoon, and J. Park, Jpn. J. Appl. Phys. **48** (2009) 07GL03.
4. J. Kim, K. Park, J. Park, and J. R. Yoon, Jpn. J. Appl. Phys. **50** (2011) 07HG05.
5. F. B. Jenson and W. A. Kuperman, *Computational Ocean Acoustics* (AIP Press, New York, 1994).
6. Rake receiver, http://www.ktword.co.kr/abbr_ view.php?m_temp1=2586.