2P6-4

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 263-264
13-15 November, 2012

Multipath Effects on Coherent Underwater Acoustic Communication in Shallow water

Su-Uk Son[1†], Jee Woong Choi[1], and Hyensu Kim[2] ([1]Dept. of Marine Sciences and Convergence Technology, Hanyang Univ.; [2]Dept. of Electronic Engineering, Inha Univ.)

1. Introduction

Sound propagation in shallow water is greatly influenced by acoustic interactions with both sea surface and bottom interfaces, which produce the significant delay spread of transmitting communication signal. The mutlpath effects in shallow water cause severe inter-symbol interference (ISI), which makes an underwater acoustic communication difficult [2]-[4]. In this paper, the measurements of channel impulse responses in shallow water as functions of source-receiver range and receiver depth are presented and discussed in view of the performance of underwater acoustic communication.

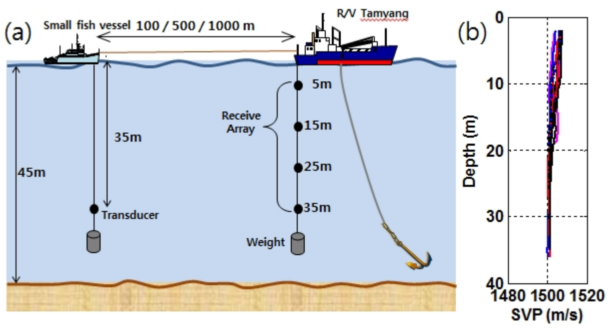

Fig. 1 (a) Experimental layout for underwater acoustic communication measurements. (b) Set of sound speed profiles measured by CTD casts.

2. Field Measurements

The underwater acoustic communication experiment was performed in the south coast of Korea in nominal water depth of 45 m in May 2012. The 4-element vertical receiving array with a hydrophone spacing of 10 m and the top element at depth 5 m was deployed from the stern of the R/V Tamyang. The transducer (Neptune model D-17) was deployed at a depth of 35 m from the side of a small fish vessel. Communication sequences were transmitted at ranges of 100, 500, and 1000 m.

Linear frequency modulated (LFM) probe signals with a frequency range between 13 and 17 kHz and binary phase shift keying (BPSK) sequences with bandwidths of 1, 2, and 4 kHz were transmitted at a center frequency of 15 kHz. **Fig. 2** shows a functional block diagram of the BPSK communication system with MMSE(minimum mean-squared error) channel estimator and linear equalizer [1].

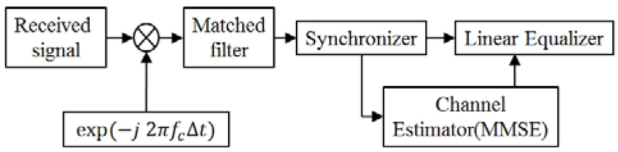

Fig. 2 Functional block diagram of receiver.

3. Results

Channel impulse response (CIR) has been measured by matched filtering with the LFM probe signals. **Fig. 3(a)** shows the arrival structures for receiver depths of 5 and 35 m, at source-receiver range of 100 m. Note that arrival time was aligned based on the direct path. It is of interest to view the overall contribution of different multipath to CIR to estimate the energy distribution of arrival paths related to communication performance. **Fig. 3(b)** shows the cumulative, time-integrated intensity channel impulse response function normalized by total energy, E(t) which was obtained by Eq. (1) in Ref. [2]. Two dominant paths are the direct path and sea-surface bounce path, accounting for more than 80 % of total energy. Here, we define the effective multi-path delay spread, $\Delta\tau$, as a time period between the arrival time of direct path and that corresponding to 90 % of total energy. For the

----
Correspondence to J. W. Choi :choijw@hanyang.ac.kr

receiver depths of 5 and 35 m, Δτ values were estimated to be approximately 12 and 16 ms, respectively. The length of multipath arrival time is strongly related to the number of tap in equalizer.

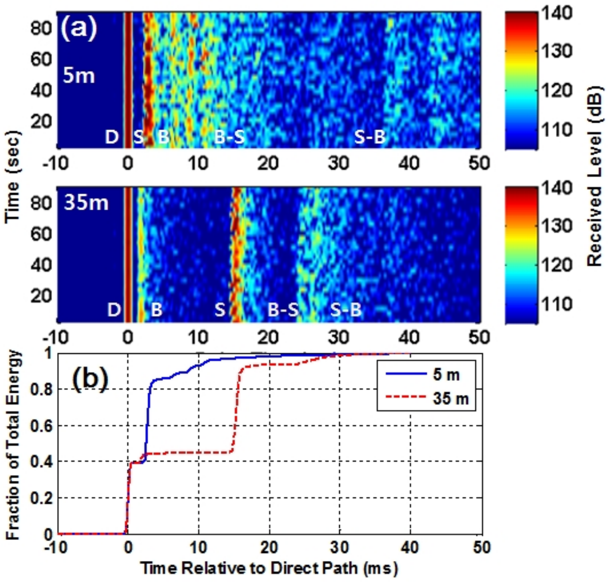

Fig. 3 (a) CIR estimated by matched-filtering with the LFM probe signals at source-receiver range of 100 m and at receiver depths of 5 (upper) and 35 m (lower). (b) Cumulative time-integrated intensity channel impulse response function normalized by total energy based on (a).

Fig. 4 shows the E(t) for the receiver depth of 35 m and for source-receiver ranges of 100 m, 500 m, and 1 km. For the case of the range of 100 m, only 45 % of energy arrives within 2 ms, corresponding to the tap number of 2. In this case, the bit per error (BER) and the mean square error (MSE) were 0.16 and -2.2 dB, respectively. However, when the tap number of 16 was used which is corresponding to the effective multi-path delay spread, the BER performance was improved to 0.04 and MSE decreased to -4.6 dB (**Table 1**).

For the cases of ranges longer than 500 m, more than 85 % of total energy arrive within 2 ms and Δτ values are less than 10 ms. When the tap numbers increased from 2 to 10, the MSE values decreased more than 2 dB. However, for the tap numbers higher than 10, the MSE did not change significantly.

Lastly, the CIRs measured as functions of source-receiver range and receiver depth will be discussed in detail in view of the performance of underwater acoustic communications.

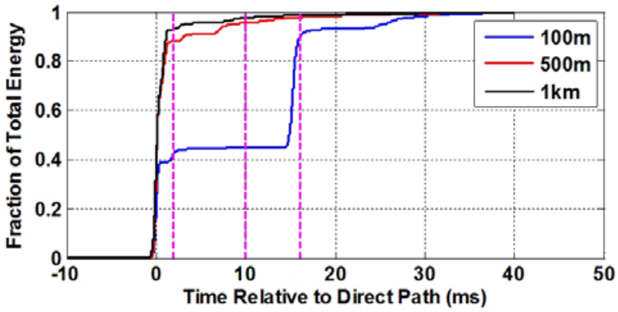

Fig. 4 Cumulative time-integrated intensity channel impulse response function normalized by total energy, based on the CIRs measured for source-receiver ranges of 100, 500, and 1000 m at depth of 35m.

Table 1. BER and MSE performance as a function of number of taps at each source-receiver range

Range(m)	**Number of taps (symbol)**		
	2	**10**	**16**
	BER / MSE(dB)		
100	0.16 / -2.2	0.09 / -3.4	0.04 / -4.6
500	0.19 / -1.5	0.05 / -4.2	0.05 / -4.3
1000	0.13 / -3.1	0.03 / -5.2	0.03 / -5.6

Acknowledgment

This work was supported by Agency for Defense Development, Korea (UD100002KD).

References

1. J. G. Proakis: *Digital Communications*, 3rd ed. (McGraw-Hill, New York, 1995) p. 640.
2. P. H. Dahl and J. W. Choi: U.S. Navy J. of Underwater Acoustics **56** (2006) 141.
3. D. Rouseff, M. Badiey and A. Song: J. Acoust. Soc. Am. **126** (2009) 2359.
4. G. F. Edelmann, T. Akal, W. S. Hodgkiss, S. Kim, W. A. Kuperman and H. C. Song: IEEE J. Oceanic Eng. **27** (2007) 602.