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Underwater Communication using Acoustic Particle Velocities

Sunhyo Kim[1†] and Jee Woong Choi[1]
([1]Dep. of Marine Science and Convergence Engineering, Hanyang Univ.)

1. Introduction

Acoustic multi-paths generated in shallow water waveguide produce a significant delay spreading of transmitted signal, which is referred to as ISI (Inter Symbol Interference). Because the ISI results in distortion of communication signals, many studies have used several equalizer techniques to reduce the effect of ISI [1]. Nevertheless, it remains difficulty to estimate communication performance in spatial and temporal variations of communication channel in shallow water. Generally, underwater communication systems have used a receiver array, which measures an acoustic pressure. However, the array length and the receiver number should be increased to improve the communication performance, which results in the degradation of space efficiency. Therefore, in this paper, vector sensor technique is applied to overcome receiver array. And the experimental data is used to demonstrate the usefulness of particle velocities for acoustic communication.

2. Acoustic particle velocity algorithm

The vector sensor can measure scalar pressure as well as the horizontal and vertical particle velocities at a single point in two-dimensional space. It is similar to a single-input multiple-output system, a so-called SIMO. If two pressure hydrophones are assumed to be placed close together, the pressure gradient $v(\tau)$ is approximated by a Finite Difference Approximation(FDA) [2], which is

$$v(\tau) = -\frac{1}{\rho}\int_{0}^{\tau}\frac{P_2(\tau) - P_1(\tau)}{d}d\tau\,,$$

where P_1 and P_2 are the signals received by two hydrophones, d is the hydrophone separation distance, and τ is time variable.

3. Field Measurements

Experiments for underwater acoustic communication were conducted in shallow water environments; (southern coast of Korea in November 2015, water depth of 60 m). An omnidirectional transducer was used as a source, which was deployed at depths of 30 m. Communication signals were received by two channel receiving array, which very closely located (2.5 cm) in an acoustic field (**Fig 1**).

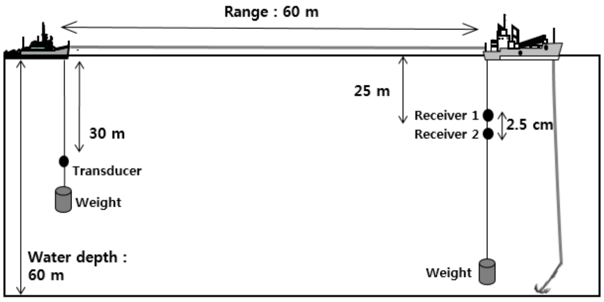

Fig. 1. Experimental layouts of underwater acoustic communication measurements for southern coast of Korea.

Sound speed profiles were measured by CTD (Conductivity-Temperature-Depth) casts during the experiment periods. The sediment components were analyzed from grab samples. The mean grain sizes of southern coast of Korea were 8.8 ∅, which is referred to as soft bottom.

Communication signal configuration consisted of 9–13 kHz LFM probe signal, followed by a pause lasting 0.5 s, and followed by BPSK signals with a center frequency of 11 kHz and a symbol rate of 1000 symbols per second. The communication experiments were performed at source-receiver ranges of 60 m.

4. Results

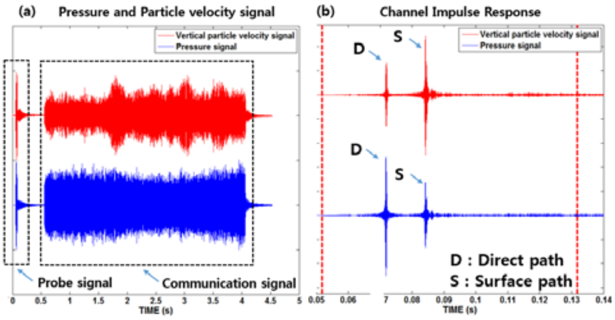

Fig. 2. (a) Pressure and vertical particle velocity signal, (b) Channel Impulse Response at source-receiver range of 60 m. D and S indicate direct, surface path.

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

Fig. 2 (a) and (b) show the received pressure and vertical particle velocity signals, and their channel impulse responses(CIR). The CIRs were estimated by matched-filtering with the LFM probe signals. The experimental site is characterized by a channel having two dominant paths(direct and surface path).

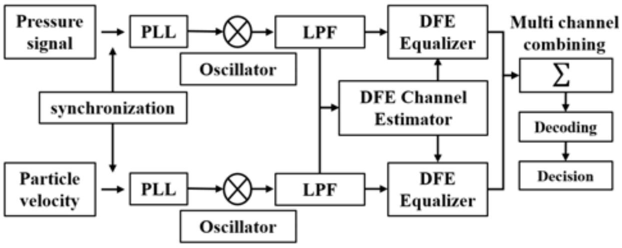

Fig. 3. SIMO Communication processing block diagram

Fig. 3 shows a SIMO system signal processing block diagram. The received pressure and vertical particle velocity are passed through PLL(Phase Locked Loop), DFE(Decision feedback equalizer) and MC(Multi-channel Combining) to predict the communication performance [3].

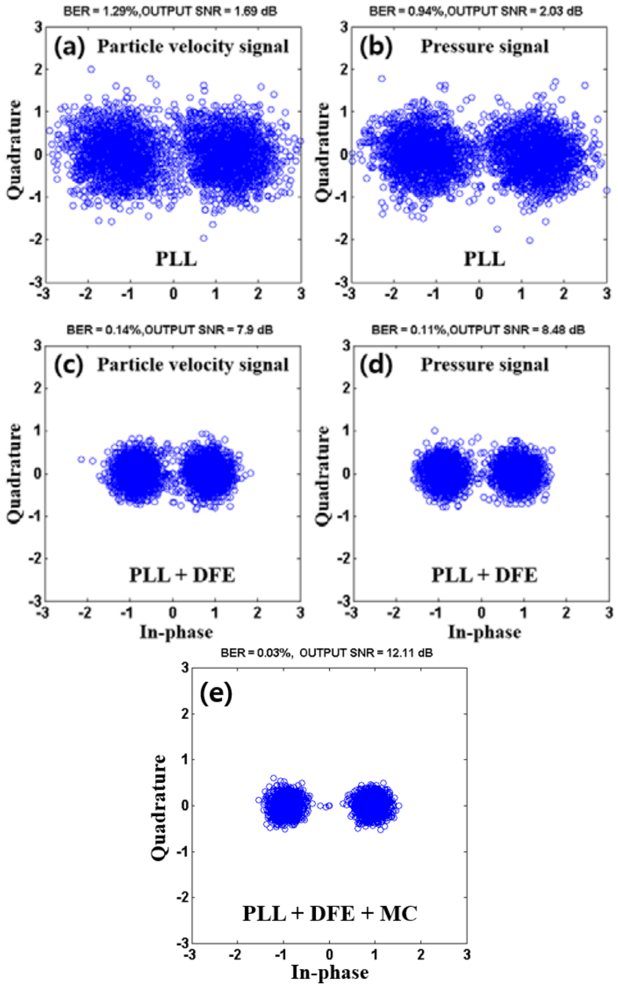

Fig. 4. Communication performances in term of BER and output SNR. (a) and (b) show communication performance After PLL using particle velocity signal(BER : 1.29 %, output SNR : 1.69 dB) and pressure signal (BER : 0.94 %, output SNR : 2.03 dB), (c) and (b) show communication performance After PLL + DFE using particle velocity signal(BER : 0.14 %, output SNR : 7.9 dB) and pressure signal (BER : 0.11 %, output SNR : 8.48 dB), (d) shows communication performance After PLL + DFE + MC (BER : 0.03 %, output SNR : 12.11 dB).

Fig. 4 shows the demodulation results of PLL, PLL + DFE and PLL + DFE + MC for particle velocity and pressure signal. The communication performances obtained using the PLL + DFE + MC method are better than the results obtained without MC method. In conclusion, the results imply that communication performance using particle velocities can be used to reduce the receiver size significantly for the compact underwater platforms.

Acknowledgment

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References

1. J. G. Proakis: *Digital Communications*, 3rd ed. (McGraw-Hill, New York, 1995) p. 640.
2. M. J. Crocker and F. Jacosen: *Handbook of ACOUSTICS*, (John Wiley & Sons, Inc, 1998), p. 1093.
3. A. Abdi and H. Guo: IEEE Trans. Wireless Commun. (2009) pp. 3326-3329.