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Spatial performance analysis of passive time reversal communications in time-varying channel during SAVEX15

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1. Introduction

Underwater acoustic communication channel is characterized by a severely limited channel compared to the radio wave communication channel. The available bandwidth is limited by frequency-dependent ambient noise and absorption loss in seawater. The time-varying multipath propagation due to the interaction with the ocean boundaries of the sound with relatively slow speed compared to that of radio wave causes an Inter-Symbol Interference(ISI). In addition, the relative movement between source and receiver and sea-surface movement produce significant Doppler shift and spreading. These effects give rise to a distortion of the communication signal. To compensate for this distortion, a number of signal processing approaches have been suggested .1)

The passive time-reversal(TR) approach involves the back propagation from receiver array to source under the assumption of stationary environment, and the resulting signal is temporally and spatially focused on the source location. The temporal focusing mitigates the ISI and the spatial focusing improves a signal-to-noise ratio(SNR).2) However, the TR performance deteriorates in case of rapidly time-varying channels. This paper presents the results of passive TR performance analysis as a function of receiver depth in time-varying channel.

2. Experiment

The Shallow-water Acoustic Variability Experiment(SAVEX15) was conducted in the northern East China Sea(ECS), approximately 100 km off the southwest of Jeju Island, Korea, during 14-28 May, 2015. Acoustic communication data were transmitted and received by an 8-element vertical Source/Receive Array(SRA) consisting of transducers with 7.5-m element separation(with a top transducer at 20 m in depth) and 16-element Vertical Line Array(VLA) consisting of hydrophones with 3.75-m element separation(with top hydrophone at 23.5 m in depth). The communication signal was transmitted at a transducer located at 27.5 m in depth and received by VLAs deployed approximately 2.3 km away from the SRA.

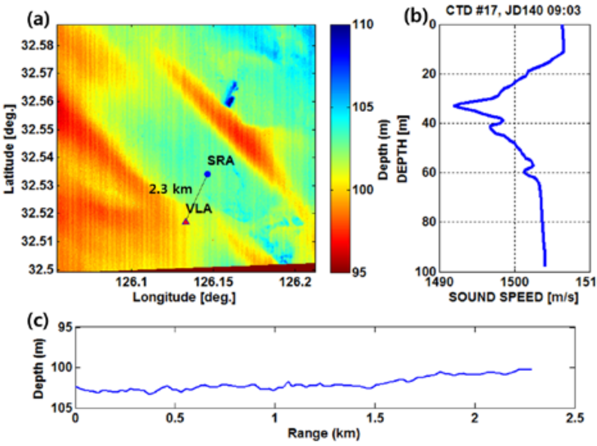

Fig. 1. (a) Bathymetry of the experimental site and the SRA and VLA positions, (b) sound speed profile, (c) water-depth profile between SRA and VLA.

Communication sequence consisted of a 20 ms long, 13-17 kHz LFM pulse as a probe signal, after 0.48 s, followed by BPSK sequence lasting 3.5 s, with a carrier frequency of 15 kHz and a symbol rate of 1000 symbols per second. Sound speed profiles were measured by frequent CTD(Conductivity Temperature Depth) casts and the bathymetry of the site was measured by a multi beam echo sounder(**Fig. 1**).

3. Results and discussion

The RMS delay spread and RMS doppler spread were estimated to investigate the characteristics of communication channel of the site.

Fig. 2 shows an example of the channel intensity impulse response estimated by matched filtering of LFM pulse. Because the strong sound channel axis existed at ~ 40 m in depth, as seen in Fig. 1(b), the channel intensity decreased with depth for the depth below the sound channel axis. On the other hand, the delay spread increased with depth.

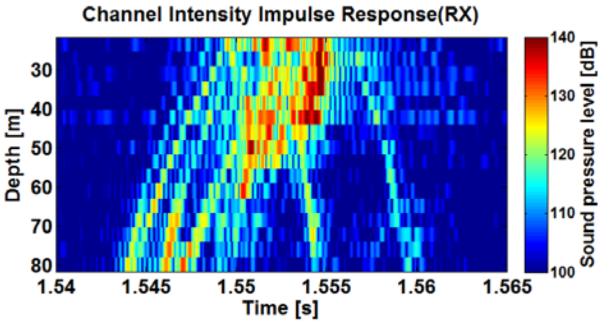

Fig. 2. Channel intensity impulse response

Fig. 3 shows communication performances and channel parameters for each element as a function of receiver depth in time-varying channel. Phase tracking was carried out using a DFPLL(Decision-feedback Phase-locked loop), and DFE(Decision-feedback equalizer) was applied to eliminate the ISI remaining after TR.

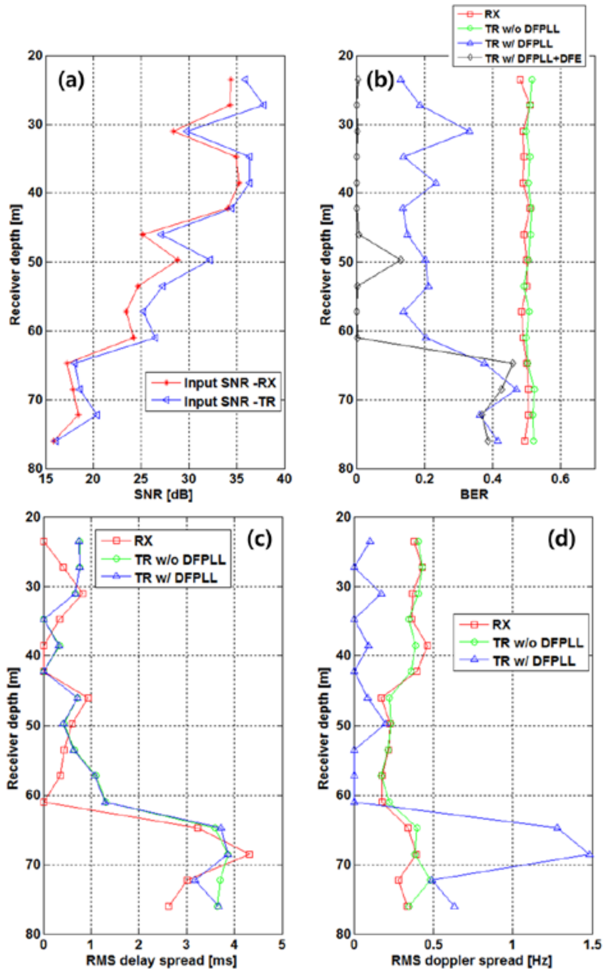

Fig. 3. Communication performances and channel parameters for each element. (a) Input SNR (b) Bit error ratio(BER), (c) RMS delay spread and (d) RMS doppler spread

As a result, both of the input SNRs for the received signal(RX) and the resulting signal after TR decreased with depth. The RMS delay spreads and Doppler spreads for the signals after TR were not reduced compared to those for the RXs because of the side-lobe effects by single element processing. In addition, the communication performance after TR did not improve because the Doppler effect was not compensated. The results after TR, DFPLL and DFE show the best performance compared to other cases for the receiver depths between 23.5 and 61 m. However, the performances for the depth below 61 m did not improve owing to low input SNR, and high RMS delay spread.

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