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Environmental Effects on the Channel Estimate Based Equalizer Performance in Underwater Acoustic Communication

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1. Introduction

In shallow water, a transmitted signal is severely influenced by sea surface and bottom boundaries. Very large reflection signals from baundaries cause inter symbol interference (ISI) effect. Under this kind acoustic channel, the channel estimate based on equalizer in adopted to compensate the reflected signals. In this study, four different least mean square (LMS) algorithm based adaptive equalizers – FFE (Feed Forward Equalizer), DDE (Decision Directed Equalizer), DFE (Decision Feedback Equalizer), and combined FFE and DFE - are applied for Binary Frequency Shift Key (BFSK) transmission system to cancel out ISI effect due to the reflected signals from baundaries.

2. Experimental Results and Analysis

Figure 1 shows a schematic layout of the experimental geometry at the bay of the Gwangan beach located in east side of Busan city, Korea. The range between the transmitter (ITC 1001) and receiver (B&K 8106) is set to be 50 or 200 m and the depth of receiver is set to be 20 m at each range and transmitter depth is set to be 7 m.

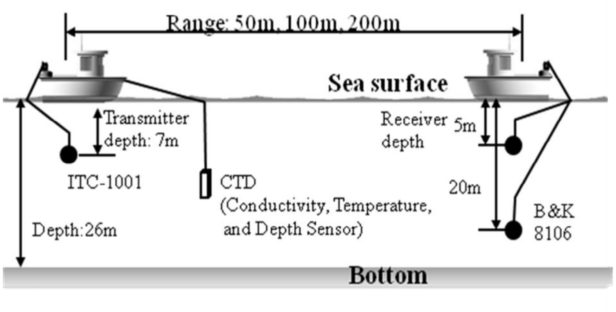
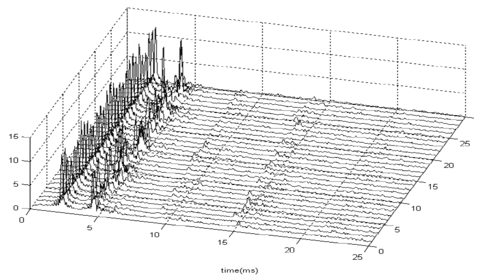


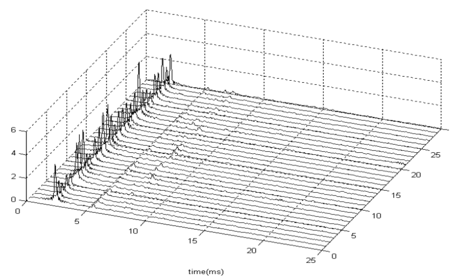
Fig. 1 Experimental configuration.

Before transmitting BFSK image signal, 4 ms linear frequency modulated (LFM) signal is transmitted during 30 s with 1s interval to measure the channel impulse response as shown **Fig. 2**.

As shown in **Fig. 2**, at short range of 50 m, the time diffrence between direct signal and 1st refection signal is within 3 msec. As the chip time(1 symbol's length) is 5 msec in our system, so direct signal and 1st reflection signal are demodulated and decided into the same decision operation.

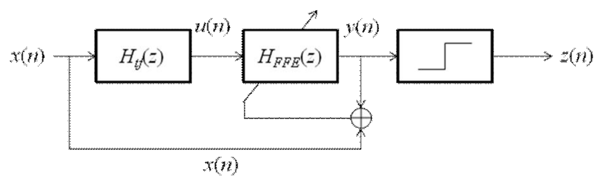


(a) Range : 50m

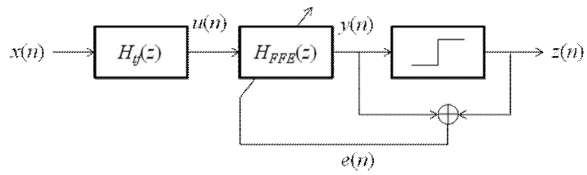


(b) Range : 200m

Fig. 2 Band limited impulse response for two different ranges.



(a) FFE



(b) DDE

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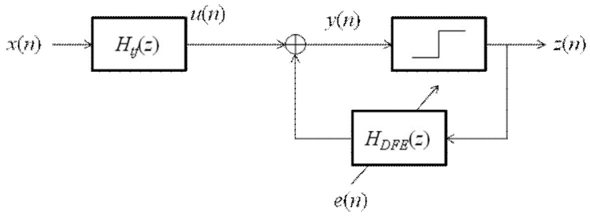
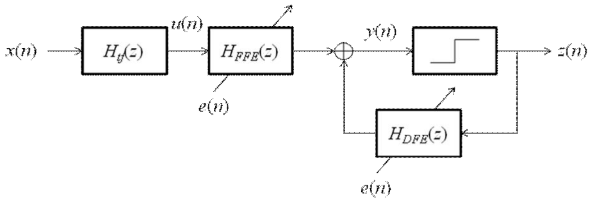


(c) DFE



(d) combined FFE and DFE

Fig. 3 Four different adaptive equalizers.

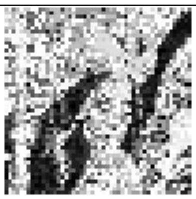
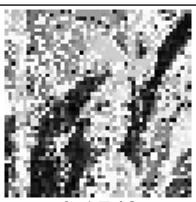
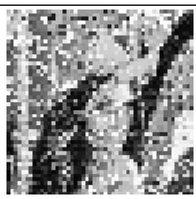
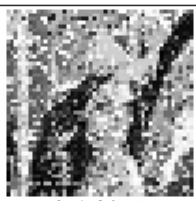
Range Eq.	50 m BER	200 m BER
No Eq.	 0.22395	 0.0409
FFE	 0.1742	 0.0294
DDE	 0.2163	 0.0317
DFE	 0.16595	 0.0379
FFE+DFE	 0.16455	 0.0312

Fig. 4 Comparison with equalization results.

The transmitted image is the standard Lenna image. It consists of 50x50 pixels and 8 bits per pixel, which therefore amounts to 20,000 bits of data. The sampling frequncy, mark frequency and space frequency are respectively chosen as 100 kHz, 20 kHz and 22 kHz. The transmission rate is set to be 200 bps. One symbol's length is chosen as 5 msec (500 points on the samping frequency).

Figure 3 shows the block diagrams of four equalizer. Here, $x(n)$, $u(n)$, $y(n)$, and $z(n)$ are respectively input signal, channel output, equalizer output, and decision output. Except FFE, the input signal $x(n)$ never used at equalzer. It means FFE needs training sequence at additional conditions.

In **Fig. 4**, at 50 m range, the image qualities and BER are generally worser than 200 m range's them owing to ISI effect. FFE shows good performance at both ranges because of training sequence and it will be also shown good performance if the communication environments are not changed. The combined FFE and DFE also show good performance at both ranges in spite of unknown input signal at the equalizer. If the communication channel is changed by some reason, the equalizers except FFE can adapt to the channel variation because of decision operation between $y(n)$ and $z(n)$.

3. Conclusions

In this study, the performance of four different channel estimate based equalizes are analyzed using a real experimental data. The FFE and the FFE+DFE show better performance than the other two equalizers. The performance dependency on the channel impulse response will be presented in the future.

Acknowledgment

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