3P6-3

Adaptive Bidirectional Equalization with Burst Error Detection for Long-Range Underwater Acoustic Communication

Hyeonsu Kim[1†], Sunhyo Kim[1], Jee Woong Choi[1*], and Ho Seuk Bae[2] ([1]Dept. of Marine Science and Convergence Eng., Hanyang Univ.; [2]The 6th R&D Institute, Agency for Defense Development)

1. Introduction

Underwater acoustic communication systems generally require an equalization system to compensate for the effects of the channel since underwater acoustic communication channels suffer from inter-symbol interference (ISI) caused by multipath propagation of acoustic waves [1]. One of the representative equalization systems, the time reversal (TR) technique, has been studied as a technique for obtaining high reliability in an underwater communication system [2]. In addition, the equalizer added after the TR processing provides reliable communication performance by eliminating the residual ISI. The decision feedback equalizer (DFE) is one of the equalizers that can be effectively used in combination with the TR technique and is generally known to have superior performance over decision direct equalizer (DDE) [3]. However, the DFE has the disadvantage that the performance is drastically degraded when error propagation occurs. Bidirectional equalization has been proposed to overcome such drawbacks [4]. The bidirectional equalization technique can obtain the diversity and reduce the error rate by combining the soft output performing the forward equalization and the soft output performing the backward equalization on the communication frame. However, even if the bidirectional equalization technique is applied, the DFE greatly increases the error rate due to error propagation when a burst error occurs.

In this paper, we propose a bidirectional communication method that adaptively adapt the equalizer to overcome drawback of DFE. The proposed method can prevent the increase of the error rate due to error propagation by converting the DFE to the DDE when the burst error occurs. In the case of a long-range underwater communication, since the intensity of the acoustic signal is very weak, a burst error tends to occur. Thus, the proposed scheme is applied long-range communication signal containing factors of a burst error. The results show that the proposed scheme effectively improve error performance compared with conventional bidirectional communication system.

2. Proposed Scheme

Figure 1 shows the structure of a receiver that performs bidirectional equalization. To produce a soft output, the received communication signal is combined with TR and equalized in forward direction. And another soft output is produced in backward direction. The two soft outputs are combined to obtain the final soft output, which is used to determine the final symbol. Figure 2 shows the structure of the communication frame used in the bidirectional equalization. In order to perform TR processing, the channel should be initially estimated using a known sequence. Therefore, the training signal is located at both ends of the frame and data payload is centered.

The proposed method controls only the operation type of the equalizer included in the receiver. The equalizer basically operates in a decision feedback type. If a burst error occurs, the equalizer operates in a decision direct type for preventing error propagation. The decision direct method is relatively simple to control because only the feed forward filter of the DFE needs to be used.

3. Long-Range Communication Experiment

A long-range underwater acoustic communication experiment was conducted in October 1999. Figure 3 shows the experiment site.

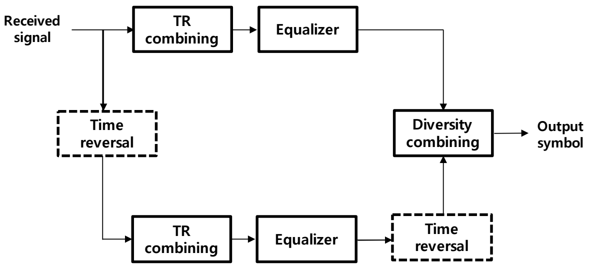

Fig. 1 Receiver structure for bidirectional communication.

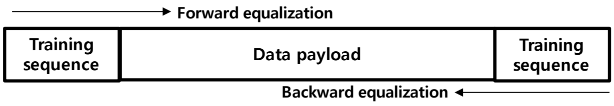

Fig. 2 Frame structure for bidirectional communication.

E-mail: hskim00@hanyang.ac.kr;
Correspondence to J.W.Choi : choijw@hanyang.ac.kr

A transmitter was installed on the shallow-water shelf near Vladivostok harbor and receiver composed of ten hydrophones spaced 10 meters was deployed near Ulleung island. Horizontal distance between the transmitter and receiver was about 560 kilometers. Average depths of transmitter and receiver are 23 and 355 meters, respectively. Communications signals were 511-digit m sequence with a center frequency of 366 Hz and a bandwidth of 45.75 Hz, and the modulation type was binary phase shift keying. Initial and last 96 symbols were used as training sequence for synchronization and channel estimation, and the remaining 319 symbols were used as information sequence. Thus, effective data rate is 28.6 bit per second.

Figure 4 shows parts of channel responses estimated from signal received on Oct. 21. Least squares method was applied as an estimation method. Delay spread spanned to about 300 milliseconds and 14 in symbol interval. In empirical sense, tap size of feedforward and feedback in equalizer were set to 10 and 5, respectively.

Table 1 shows the results of the bit error rate produced by the methods applied in the receiver. In case of the conventional unidirectional equalization method, the bit error rate of 0.0064 for the decision direct method and 0.0068 for the decision feedback method are obtained. In the case of the bidirectional equalization method, the bit error rate is reduced to 0.0039 in the direct decision method. However, the bit error rate increased to 0.0120 when the decision feedback method was used. This result indicates that the error performance may not be improved even when the bi-directional equalization is applied. Lastly, the proposed method showed a bit error rate of 0.0027, which is the best performance compared to other techniques.

4. Conclusion

In this paper, we proposed the method to improve the error performance of bidirectional communication scheme by applying adaptively equalization. The proposed method selectively applies the decision direct method to avoid error propagation in DFE. The results showed that the proposed method improves the error performance compared to the conventional bidirectional communication method.

Acknowledgment

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References

1. M. chitre, J. Catipovic and M. Stojanovic:: Marine Tech. Soc. J. **42** (2008) 103.
2. T. Shimura, H. Ochi, Y. Watanabe and T. Hattori: Jpn. J. Appl. Phys. **49** (2010) 07HG11.
3. J. G. Proakis: *Digital communications, fifth edition* (Mc Graw Hall, 2008) p. 661.
4. S. Shirakawa, J. Esaki and I. Tomonaga: Jpn. J. Appl. Phys. **46** (2006) 1358.

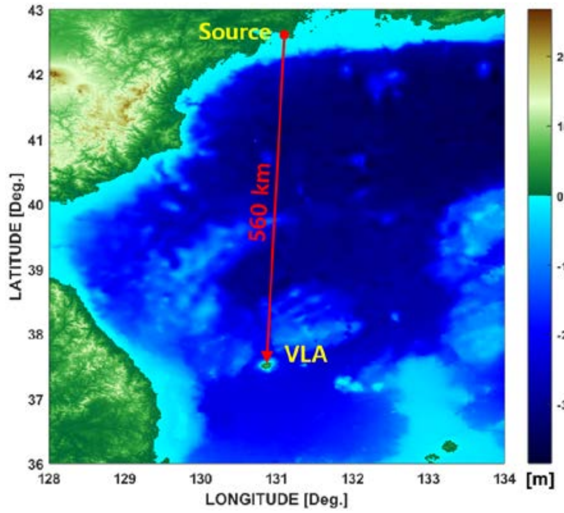

Fig. 3 Experiment site

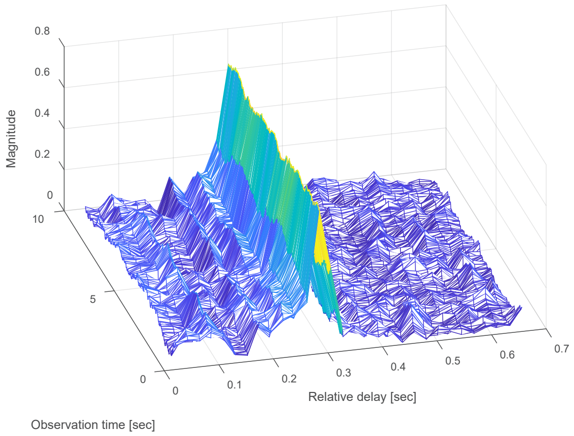

Fig. 4 Estimated channel responses

Scheme	Equalization type	Bit error rate
Conventional TR and EQ	Decision direct	0.0064
	Decision feedback	0.0068
Bidirectional TR and EQ	Decision direct	0.0039
	Decision feedback	0.0120
Proposed scheme	Adaptive	0.0027

Table 1 Bit error rate produced by each scheme.