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Experiment of time-reversal communication at the range of 300 km

位相共役通信の 300km での実験結果

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1. Introduction

In Japan Agency for Marine-Earth Science and Technology (JAMSTEC), our research group is assigned to the researches on underwater acoustic technologies.

We have studied the application of time-reversal to the communication with a long cruising autonomous underwater vehicle (AUV) in the deep ocean and have proposed the method of combining time reversal with adaptive equalization [1-3] to realize communication with a moving vehicle [4,5] or communication under current flow [10].

In the previous experiments, communications at the ranges from 10 to 100 km were demonstrated with synthetic time-reversal array [6-9]. In this experiment, passive time-reversal communication was achieved with a real receiver array to the range of 300 km first as the experiment intended for communication.

2. Experiment scheme

In our first experiment [6,7], bi-directional active and passive time reversal communications were executed with one pair source-receiver systems while changing the depth of the TRA side system using underwater winch. It was confirmed that the same convergency can be obtained in fact with both active and passive time reversal. In the subsequent experiments at the range from 20 to 100 km [8,9], only passive time-reversal communication were carried out with a synthetic receiver array.

The experiment described in this paper was executed at the range of 300 km in the 4000-m-deep and flat bathymetry area as shown in **Fig. 1**. In this experiment, a real receivers array was used, which was composed of 20 receiver systems. This 20-channels receiver array was moored at the point indicated as “Rx” in Fig. 1 (a). The intervals between the receivers were 6.0 m approximately. The array depth was 1,300 m approximately as shown in Fig. 1 (c), illustrated with the sound velocity profile around the mooring point. The source system, whose center frequency and bandwidth was 500 ± 50 Hz, was suspended from the research vessel to the depth of 1,000 m approximately as shown in Fig. 1 (b), illustrated with the source velocity profile. During measurements, the ship position was kept as constant as possible, around the point indicated as “Tx” in Fig. 1 (a). As shown in these figures, the source and receivers are placed around the axis of SOFAR channel.

In this experiment, only passive time-reversal communication was performed. The results can be interpreted as the performance prediction of active time reversal as well as passive time reversal itself.

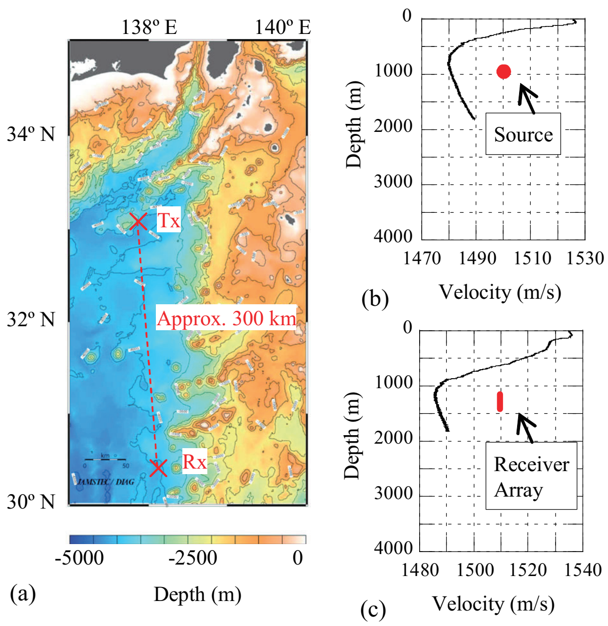

Fig. 1 (a) The experiment site. The sound velocity profile around (b) the source point and (c) the receiver array point.

In this experiment, four kinds of probe signals are used: chirp pulses with duration 5.0 and 10.0 s, 8th and 9th M-sequence signals. In the cases of chirp pulses, the sweep bandwidth is 475 to

525 Hz. The M-sequences for probe signals are generated through 4th root-raised cosine filter, while data signals are generated through root-raised cosine filter. The received signals of the probe M-sequence singals are correlated with the original M-sequence before passive time-reversal process. By the cross-correlation as passive time reversal, data signals just like generated through raised cosine filter can be obtained while multipath signals are eliminated by time-reversal focusing.

3. Experiment result

Here, the experiment results are described, with demodulated symbols plotted on the constellation map. In these figures, “TR only” indicates using only time reversal, and “TR+AE” indicates the proposed method of combining time reversal and adaptive equalization. In this experiment, binary phase shift keying (BPSK) was used with the data rate of 50 and 100 bps, and 2047 symbols were transmitted. In case of the proposed method, the initial 200 symbols are used for training of the adaptive equalizer.

In **Fig. 2**, the demodulation results are shown when the probe signal is 8th M-sequence at the data rate of 50 bps. In **Fig. 3**, the demodulation results are also shown when the probe signal is 9th M-sequence at the data rate of 100 bps. In these results, the demodulated symbols are rotated in the cases of TR. This phase rotation is supposed to be due to the ship drifting, although the ship position was kept as far as possible. Such Doppler Effect is compensated well in the cases of TR+AE.

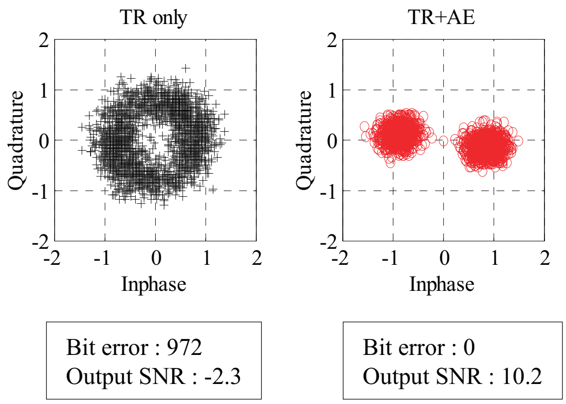

Fig. 2 Demodulation results when the probe signal is 8th M-sequence with the data rate 50 bps.

Comparing Fig. 2 and 3, the improvement with longer M-sequence probe signal is observed. If the source and receivers are stable and the environment is time-invariant, it is expected that longer M-sequence gives the better SNR after the correlation. In the meantime, when the Doppler Effect is accompanied, longer M-sequence is unfavorable. Therefore, shorter M-sequence with the data rate 100 bps brings in better results than the cases of 50 bps. Note that the effective data rate decreases as a matter when a longer probe signal is used.

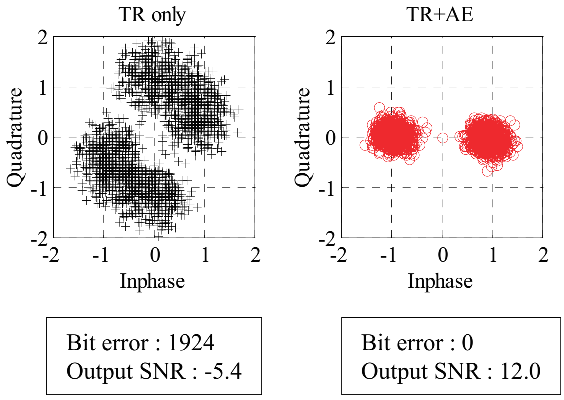

Fig. 3 Demodulation results when the probe signal is 9th M-sequence with the data rate 100 bps.

Although the results in cases of chirp pulse are not shown here, they are inferior to the results of M-sequence, because the correlation result of chirp pulse has remarkable sidelobes, which cause residual ISI after passive time-reversal.

4. Summary

Time-reversal communication at the range of 300 km was achieved first as the experiment intended for communication. It is confirmed that the proposed method has an impact to compensate Doppler Effect.

Acknowledgment

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References

1. T. Shimura: Acoust. Sci. Technol. **25** (2004) 364.
2. T. Shimura et al.: Jpn. J. Appl. Phys. **44** (2005) 4722.
3. T. Shimura et al.: Acoust. Sci. Technol. **26** (2005) 526.
4. T. Shimura et al.: Jpn. J. Appl. Phys. **45** (2006) 4847.
5. T. Shimura et al.: ECUA2006 (2006) 879.
6. T. Shimura et al.: Jpn. J. Appl. Phys. **46** (2007) 4956.
7. T. Shimura et al.: Jpn. J. Appl. Phys. **47** (2008) 4360.
8. T. Shimura et al.: Oceans/Techno Ocean 2008 (2008).
9. T. Shimura et al.: Acoustics’08 (2008) 699.
10. T. Shimura et al.: Jpn. J. Appl. Phys. **48** (2009).