3Pa6-2

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 399-400
13-15 November, 2012

A study of reciprocal sound propagation and water flow at Hashirimizu port
走水港における双方向音波伝搬と流れの検討

Hanako Ogasawara‡, Kazuyoshi Mori, and Toshiaki Nakamura (Dept. of Earth & Ocean Sci., National Defense Academy)
小笠原英子‡，森和義，中村敏明（防衛大学校地球海洋学科）

1. Introduction

Since 2005, we have achived reciprocal sound propagation experiment at very shallow water, Hashirimizu port in Yokosuka[1-3]. As it locates at the enterence of the Tokyo bay, it is possilbe to measure how sounds are vaies according to the natural environmental changes such as temperature, tidal current and wind forces. Acoustic methods have been used in many ways such as signal communication, environmental monitoring tools, and detection system because of its advantage that it is less attenuation than optics or radiowave. We had analyzed reciprocal sound data which was traveling more than 100 km retrieved in the equatorial central Pacific Ocean while a whole year in 2000[4-6]. However, it is still uncirten at the shallow area because of many reflections from sea sureface and seabed make received signals complicated at the shallow area. The hashirimizu port has small connection with the Toky bay and is surrounded by bank. It is a suitable place to monitor the behaviors of sound propagation.

2. Experiment

A pair of sound propagation system was placed on either bank of Hashirimizu port with the distance about 110m at the 0.9 m hight from the seabed. The arreangement of the propagation sistem is shown in Fig. 1. The depth of the port is about 5 m in average. There are not so much bamp and the bottom is mainly covered with silty mud.

The experimental system is very simple. M-sequence signal is sent from one side of the bank and received at the opposite side. The signal is modulated by M-sequence with the carrier frequency of 12.5 kHz and repeated 4 sets of the modulated signal at one time. The length of the signal is 20.35 ms. Both of the system are synchronized with global positioning system (GPS) clock generates 1 pulse per second signal with accuracy of ± 200 ns. As the distance between the systems are too short, it is impossible to propagate reciprocally at the same time. Therefore, signal is sent opposite side after 30 s from the previous propagation and considered as a set of a reciprocal between the reciprocal propagation but we believe sound propagation. Specifically, there is 30 s delay it is enough short to change ocean environment dynamically.

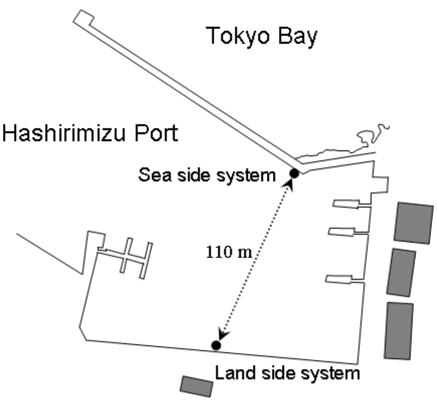

Fig. 1 Arrangements of the experimental equipments.

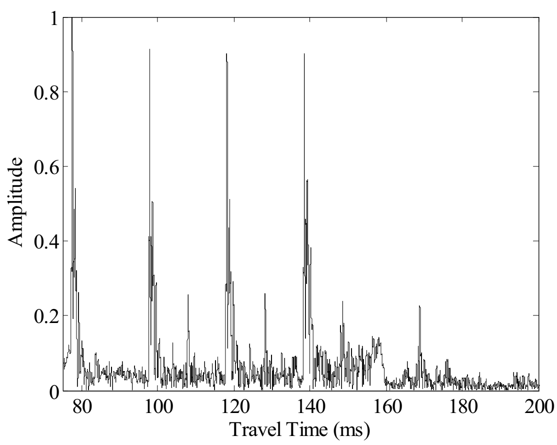

Fig. 2 Sample received signal.

3. Data Analysis

The received signals were demodulated and calculated the amplitude component from the correlated result. Figure 2 shows the sample of the received signal. As the M-sequence signal repeated 4 times, there are 4 large peaks. There are another set of 4 peaks around 120 ms although their amplitude were smaller than the first ones. Thinking propagation way in geometrically, it is considered appropriate that these small peaks reflected the bank at the east side of

---

ogasawar@nda.ac.jp

the port and propagated to the receiver side with reflected once as shown in Fig. 3.

It is possible to explain the propagation time t_1 and t_2, which is the direct path and the reflected path from A to B reciprocally, with the current u, v and sound speed in the sea, c as following[7].

$$t_1 = \frac{r_1}{c+u},$$

$$t_2 = \frac{r_2}{c + u\cos\theta + v\sin\theta} + \frac{r_3}{c + u\cos\theta - v\sin\theta}.$$

r_n indicates the distance of each path explained in Fig. 3 and θ is an angle between r_1 and r_2. Current along the direct pass u can be estimated from the reciprocal sound propagation time of the direct arrivals as

$$u = \frac{c_0^2}{r_1} d,$$

where d is the proportional value of the difference of the reciprocal arrival time. Thus, we can obtain the current of the vertical direction to the direct pass. Figure 4 shows the estimated average flow vertical to the direct path r_1, vertical flow measured by acoustic Doppler current profiler which was located at the middle of the direct path, water temperature, and surface level from the system. The absolute value of the estimated current and ADCP current is quite different but its trend through the experimental period are similar in some parts. The estimated current has big gap in several points. These are caused by faults of peak tracking from the received signals. It is necessary to improve the peak tracking for accurate estimation.

4. Conclusion

We applied water flow estimation method using the direct path and the reflected path. The reflected path enable to estimate average flow which is vertical to the direct path. This method allows two dimensional flow estimation only from one pair of the reciprocal sound propagation system. Although the value itself in this analysis have to improve its accuracy, this has large potential for monitoring ocean environment.

Acknowledgment

We would like to thank all of the members in Hashirimizu port, National Defense Academy for helping the experiments and allow us to use the part of the place.

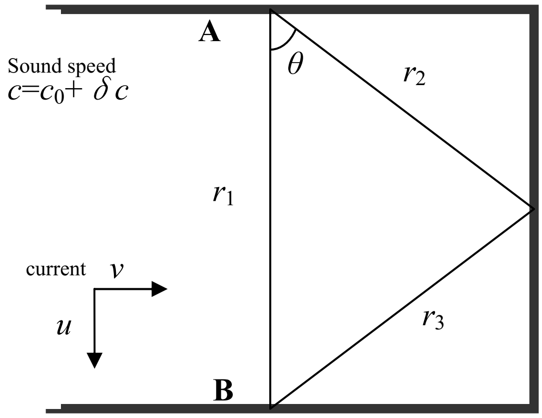

Fig.3 Propagation paths and direction of currents.

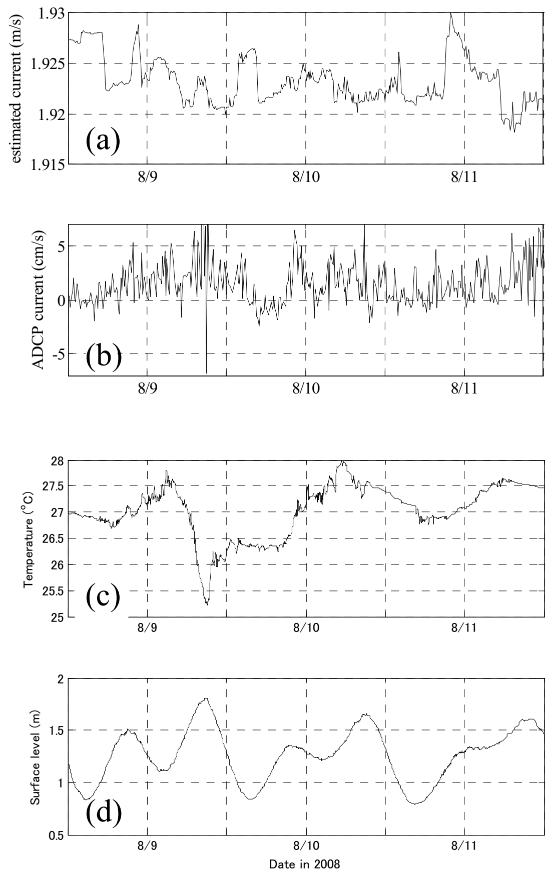

Fig. 4 (a) estimated flow by direct and reflected travel time, (b) flow speed by ADCP, (c) water temperature and (d) surface level from the propagation system.

References

1. S. Kamimura, H. Ogasawara, K. Mori and T. Nakamura: Jpn. J. Appl. Phys. **51** (2012) 07GG08.
2. H. Ogasawara, K. Mori and T. Nakamura: Jpn. J. Appl. Phys. **49** (2010) 07HG15.
3. H. Ogasawara, K. Mori and T. Nakamura: Proc. 10th ECUA (2010) 251.
4. H. Ogasawara, T. Nakamura, H. Hachiya, H. Fujimori, K. Mizutani, Jpn. J. Appl. Phys. **47** (2008) 4349.
5. H. Ogasawara, T. Nakamura, H. Fujimori, K. Mizutani, Jpn. J. Appl. Phys. **46** (2007) 4998.
6. H. Ogasawara, T. Nakamura, H. Hachiya, H. Fujimori, K. Mizutani, Jpn. J. Appl. Phys. **45** (2006) 4842.
7. K. Kudo *et al.* : Jpn. J. Appl. Phys. **42** (2003) 3189.