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Sound Propagation Analysis Including Wall Reflected Waves at Hashirimizu Port
走水港内における壁面反射を含む音波伝搬解析

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1. Introduction

The occurrence of global warming and abnormal weather has become a worldwide problem recently. The area of the sea accounts for about 70% of the earth. The global fluctuation may appear as the change of parameters in the ocean. Ocean acoustic tomography is a technique for measuring water temperature and current [1)], the result has been applied to noise, fluctuation and internal wave [2,3)]. The parameter in the ocean can be measured within the reach of sound waves, ocean acoustic tomography covers the wide range of a few hundred kilometers. However, as ocean acoustic tomography is a very large-scale experiment, many people and equipments are required for the experiment. Meanwhile, it is relatively easy for us to conduct a tank experiment because special equipment and a heavy task aren't need. Therefore, a tank experiment was done for reproducing the environment in the ocean or the establishment of a theory. However, natural phenomena like weather don't effect on a tank experiment.

Our experimental site locates on the coast, Hashirimizu port in Yokosuka. The environment of Hashirimizu port is similar to a tank experiment. We can set up devices easily so that the water depth is very shallow and three sides of quay walls surround this port. The electric power supply is also available. There is no need to prepare batteries to deliver the electric power into the underwater devices by electric cables. When comparing the experiment in Hashirimizu port with a tank experiment, the difference is to reflect natural phenomena. Besides the weather effect, the impact of tide is the same in the ocean. In the past study of Hashirimizu port, the experiment of the sound propagation and measuring the water temperature were conducted here. The results revealed the difference of received waves by transmitted frequencies[4)] and the relationship between the travel time and water temperature [5,6)].

In this paper we will analyze reflected wave from the bank of the port. As there is only a pair of transducers, but it is able to monitor wide area compare to the traditional method.

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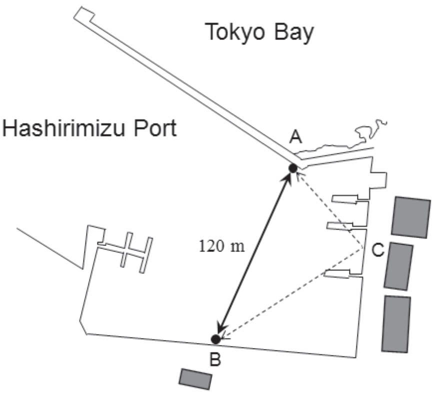

Fig. 1 Map of the experimental area.

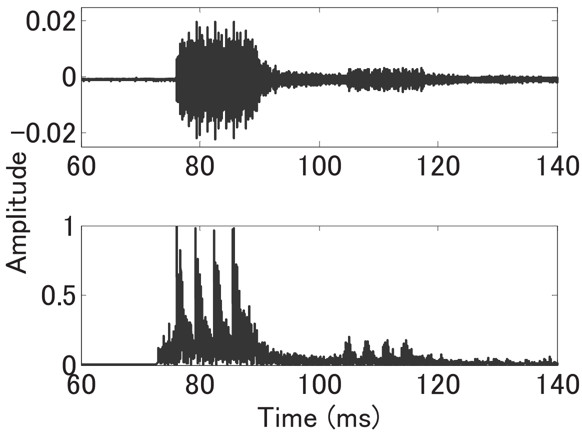

Fig. 2 Received signal (upper) at 10:05, 2011/06/02 and its correlated result (lower).

2. Experiment

Figure 1 shows the experimental place, Hashirimizu port. The transceivers were located near the bank side explained as black dot in Fig. 1. The distance between the transceivers is only about 120 m and the depth around the area is about 5 m. The 7th order M-sequenced signal with 80 kHz career frequency was transmitted reciprocally. Four cycle of the M-sequenced signal was sent at one time. As the travel distance is very short and the very shallow area, the received sound include not only the direct signal but also many reflected signals from bottom, surface and banks around the port. As it should send the same time from both system to get the reciprocal sound propagation data, it is impossible to switch the sending and receiving within a second. Therefore, the systems change their task, sending and receiving, 30 s after the first sound propagation event. As there is 30 s time delays in the reciprocal sound propagation data, we will ignore the delay in signal analysis.

3. Direct and Reflected signals

A sample of received signal is shown in the upper part of **Fig. 2**. The large amplitude block around 75 to 90 ms is the received M-sequenced signal part. After the demodulation, we can confirm four large peaks from the amplitude component as shown in the lower part of Fig. 2. But after the four big peaks in the figure, there are another set of peaks although they are smaller than the first ones. As the depth at this area is very shallow, surface and bottom reflected waves arrived almost the same time of the direct wave. It is reasonable to think that these small peaks are the waves reflected the bank which locates East side and parallel to the direct path as figured with a thin line in Fig. 1. The first bigger peak is around 76 ms and the first smaller peak is around 105 ms. As the direct distance between the transceivers is 120 m, the smaller peaks traveled 166 m. This is almost the same distance of the path which reflected once at the east side bank.

The reciprocal travel time of direct path t_{AB} and t_{BA} provides average temperature change and flow speed along the travel path[7] as

$$u_{\mathrm{AB}} = \frac{1}{2}\frac{c_0^2}{\overline{\mathrm{AB}}}\left(t_{\mathrm{BA}} - t_{\mathrm{AB}}\right) \quad , \qquad (1)$$

$$\delta c = \frac{1}{2}\frac{c_0^2}{\overline{\mathrm{AB}}}\left(t_{\mathrm{BA}} + t_{\mathrm{AB}}\right) - c_0 \, , \qquad (2)$$

where, sound speed $c=c_0+\delta c$, and u_{AB} denotes flow speed along the path AB. Sound speed fluctuation mainly caused by temperature. On the other hand, travel time of the reflected path can be written as

$$t_{\mathrm{ACB}} = \frac{\overline{\mathrm{BC}}}{c + u_x \cos\theta - u_y \sin\theta} + \frac{\overline{\mathrm{AC}}}{c + u_x \sin\theta + u_y \cos\theta} \, , \qquad (3)$$

where, θ is the angle between AB and CB[8]. Assume that temperature and flow speed are uniform in the port and AC and BC is perpendicular, relation of three points A, B, C and flow vectors can be decomposed as shown in **Fig. 3**. Therefore, it is possible to calculate u_y from eq.(3). It is not possible to get flow component across the travel path by two transceivers. But, waves reflected from the bank provide more information. Unfortunately, there is no way to separate travel time at the reflected point, C. Thus, we have to provide some condition that the temperature change is uniform in the port. In real, temperature change is not uniform

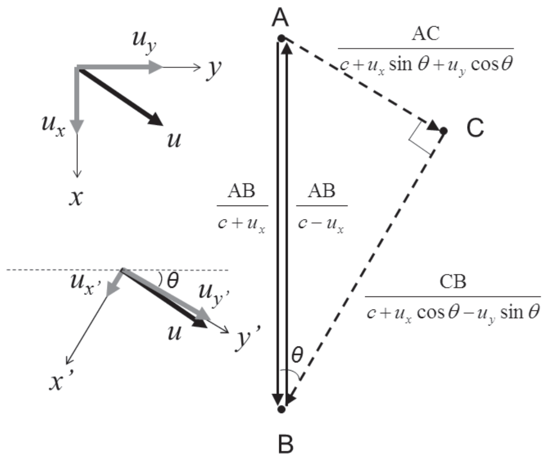

Fig. 3 Relation of two coordinate to decompose flow vector.

especially near the bank because in summer, the bank is extremely hot by sunshine. Therefore water temperature near the bank is warmer than the center area. Water flow in the port is not uniform, neither. But acoustic data is stored every 5 minutes in the experiment. Time series of the result would explain somehow ocean environmental changes.

4. Conclusion

A simple flow estimation method from a pair of reciprocal sound transmission including reflected wave at the side bank was described. Although temperature and flow speed at the measurement area had to be assumed uniform, it was possible to get not only the flow component along the direct path, but also that across the path only with a pair of transceivers. Therefore it is theoretically possible to get total flow value and its direction.

References

1. W. Munk, P. Worcester, and C. Wunsch: *Ocean Acoustic Tomography*, (Cambridge Univ. Press, New York, 1995) Chap. 1.
2. T. Nakamura, H. Fujimori, and I. Nakano: Jpn. J. Appl. Phys., **42** (2003) 3194.
3. H. Ogasawara, T. Nakamura, H. Hachiya, H. Fujimori, and K. Mizutani: Jpn. J. Appl. Phys., **45** (2006) 4842.
4. H.Ogasawara, K.Mori, and T. Nakamura: Jpn. J. Appl. Phys., **49** (2010) 07HG15.H.
5. S. Kamimura, H. Ogasawara, K. Mori and T. Nakamura: Jpn. J. Appl. Phys. **51** (2012) 07GG08.
6. H.Ogasawara, K.Mori, and T. Nakamura: IEICE-113, **317** (2013) 31.
7. Marine Acoustics Society of Japan: *Kaiyo Onkyo no Kiso to Ouyo* (Basics to advance of ocean acoustics) (Seizanshoten, Tokyo, 2004) p.220 [in Japanese].
8. K. Kudo, K. Mizutani and M. Ishii : Proc. Symp. Ultrason. Electron., **26** (2005) 233.