# 3P-65

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# Effect of Water Current at Small Scale Reciprocal Sound Propagation Experiment
# 小規模な双方向伝搬実験における流れの影響

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## 1. Introduction

Japan is the island which is surrounded by the sea. In other words, Japan is surrounded by the coast. Three factors have effect on the coast area. The first is an effect from the land. It includes the water pollution of river. The second are effects from the sea. The tide and ocean current correspond to them. Last are the effects from the both (land and sea) or not distinguished. The climate and weather are the examples of them. The coast area is related to many environmental factors. Monitoring the condition of coastal areas, we can understand not only changes concerning the sea, but land or other part.[1] The reciprocal sound propagation experiment was conducted on a small scale to monitor the environment of costal area. We measured travel time between two devices, adopting the low frequency sound which has a less possibility of attenuation. Our purpose of this experiment is to calculate the current at port and study the correlation of the current with ocean phenomena.[2]

## 2. Outline of Experiment

Experimental site is located in Hashirimizu port, Yokosuka-city. **Figure 1** shows the map of this port and location of each experimental device. The length of the port is about 100 m, the width is about 150 m and the maximum depth of water is about 5 m. In daytime, oared boat and vessel come and go around the port. The port forms like an inlet, but it borders on the Tokyo bay. Therefore Ocean situations like tide and current concerns this port. The experimental period is from Aug. 2009 to Dec. 2009. Experimental device for sound transmission was set up on two sides of seabed; seaside: A and landside: B. The 7th order M-sequence signal was transmitted and received every five minutes. Transmitted carrier frequency is 5 kHz. 114 m is the distance between devices. At the same period, Acoustic Doppler Current Profiler (ADCP) was installed on the seabed at the center of two devices. ADCP measured the current of this port. Three waves are included per 1 digit. Sampling frequency is 500 kHz. The period of data is 1400 ms.

## 3. Travel Time and Current Estimation

Data series for 6 days from 31th Oct. 2009 to 5th Nov. 2009 was used for analysis. Signal waves

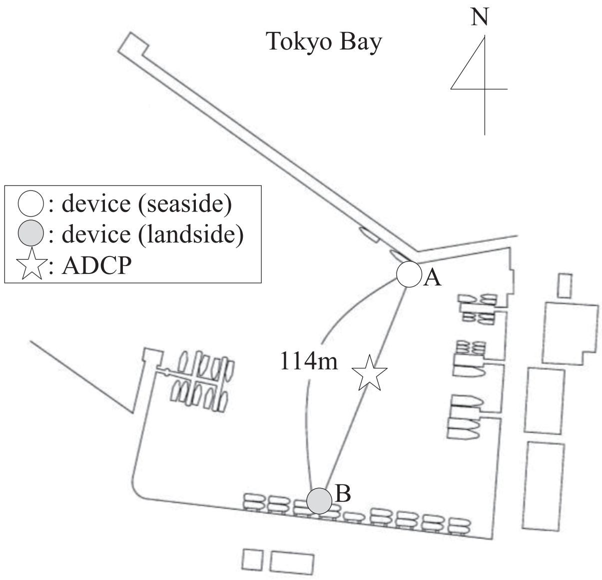


Fig. 1 Map of experimental area

were devided to the real part and imaginary part of a complex number in the calculation. Both parts of number were correlated with M-sequence signal. Amplitude component was computed by this process. After this calculation, 4 peaks appeared. That is the result of transmiting the signal 4 times. The 1st peak have the frontside effect as well as 4th peak have rearside. So we selected 2nd peak to estimate travel time. The 2nd peak was made use of estimating both travel times. $t_A$ is travel time from B to A. The opposite is $t_B$.

On the assumption that the direction from A to B is negative, current $u$ flow along this direction. The distance between 2 devices is $L$. Sound speed in the ocean c can be represented as

$$c = c_0 + \delta c , \tag{1}$$

where $c_0$ and $\delta c$ are standard sound speed and fluctuation component of the sound speed, respectively. Travel time $t_A$ and $t_B$ is written as [3]

$$t_A = \frac{L}{c-u}, \tag{2}$$

$$t_B = \frac{L}{c+u} . \tag{3}$$

$u$ is found by the transformation of equation; the difference between $t_A$ and $t_B$,

$$u = \frac{c_0{}^2}{2L}(t_A - t_B) . \tag{4}$$

ADCP measured northward and eastward current. The line between devices is out of 20° from northward. Therefore ADCP data was adjusted to the direction of *u*. Current can be found to substitude these values for the current formula.

## 4. Discussion

**Figure 2** shows the arrival time and correlation value during analysis period. The white line and background discribe the travel time and correlation value during analysis period. Most of the data have 2 dark areas; nearby 152.0 and 152.9 ms. **Figure 3** shows 2 samples of correlation between received signal and M-sequence signal. Both figures have 2 large spikes. In the left figure, the left spike is a peak. On the contrary, the right spike is a peak in the right figure. This is the same that 2 patterns of arrival time appeared in Fig. 2. **Figure 4** shows the travel time and the tide during analysis period. The amplitude of tide was getting higher in the analysis period. The average of tide is 166 cm in this period. We found that the travel time is short when the tide is high, jumping up or down when the tide is a certain height and syncronized when the tide is low. But the reason haven't been discovered. This is our future problem. **Figure 5** shows the current measured by ADCP. This data is corrected to the the direction of *u.* The mean value of this data is -0.27 [cm/s]. The minus means southward of the current. Now, we are trying to calculate the current by using sound propagation. After the calculation, we have a plan to compare the current by ADCP with by sound transmission.

## 5. Conclusion

Reciprocal sound propagation experiment for shallow water conducted from Aug. 2009 to Dec. 2009. There are 2 patterns of travel time (nearby 152.0 and 152.9 ms). While, almost data have 2 big spikes, either is a peak. The travel time is short when the tide is hight, jumping up or down when the tide is a certain height and syncronized when the tide is low. We will investigate the reason and calculate the current by sound transmission.

**Acknowledgment**

I would like to express my sincere feeling of gratitude to the crew in Hashirimizu port.

**References**

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2. H.Ogasawara, K.Mori, and T. Nakamura: Jpn. J. Appl. Phys. **49** (2010) 07HG15

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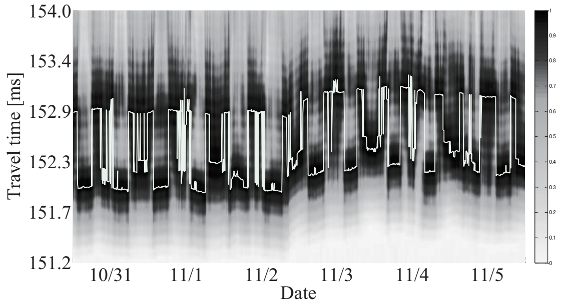


Fig. 2 Travel time during analysis period; white line and correlation value during analysis period; background.

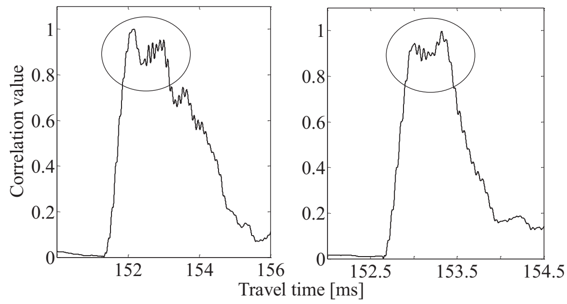


Fig. 3 2 samples of correlation received signal with M-sequence signal. Left side is a peak.; left figure, rightside is a peak; right figure.

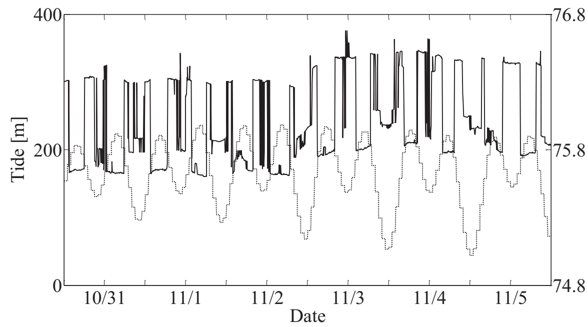


Fig. 4 The comparison between the travel time and tide. Solid line and dotted line represent the travel time and tide.

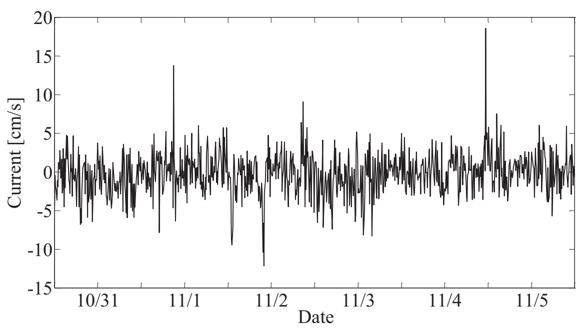


Fig. 5 The current measured by ADCP. This data was corrected to the direction of u.