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Tidal Effect at Small-Scale Sound Propagation Experiment
小規模な音波伝搬実験における潮汐の影響

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1. Introduction

The global environment has been changing dramatically like global warming issue. The Ocean has a high proportion of the earth. The global fluctuation may appear as the change of parameter in the ocean. Experiments in the ocean enable us to monitor the ocean situation. But, many people and devices are required for the experiment. Such as a large ship, crew, batteries, mooring devices are examples of these.

While, our experimental site locates on a coastal area, Hashirimizu port. This place is suitable for a small scale experiment. It is easy to set up devices because there are piers in the three sides of the port. Electricity is also available in this place. We don't need to worry about batteries. The west side is open for Tokyo Bay, the effect of tide is the same in the ocean. The big difference from tank experiment is weather conditions. In the past study, sound propagation experiment is conducted here. The results revealed the difference of received waves by transmitted frequencies [1] and relationship between travel time and water temperature [2-3]. In this study, we discuss the change of travel time by tidal effect.

2. Sound Propagation Experiment

Figure 1 shows the map of experimental site, Hashirimizu port. The average depth of this port is about 4 m. A and B means the location of transducers. In the middle of A and B on star mark, Acoustic Doppler Current Profiler (ADCP) was installed on the bottom. The height of transducers was about 1 m from bottom, the sensor height of ADCP was about 0.8 m. The distance between A and B is 120 m. The experimental period is from Aug. to Dec. 2009. The 7th M-sequence signal was transmitted and received every five minutes. Transmitted carrier frequency is 5 kHz. Four cycles of carrier waves are included per 1 digit. The travel time was obtained by the demodulation of received waves.

3. Experimental result

The data from 31th Oct. to 5th Nov. 2009 was used for this analysis. The sound propagation data from B to A is used this time. After the demodulation, four peaks appeared. That is the result of transmiting the signal M-sequence of four cycles. The 2nd peak is selected to estimate travel time. The travel time is the time subtracted one cycle from 2nd peak time. **Figure 2** shows the comparison between travel time and tide [4]. The travel time and tide are plotted by solid and dotted line respectively. In the result, we affirmed that travel time had two time frames; around 75.8 and 76.5 ms. The other fact was that travel time was dependent on the height of tide. If the tide was higher, the depth of water would be deeper. Therefore, the change of water depth effects on travel time.

After 11/3, the travel time increased about 0.2 ms. During the observation period, ADCP had been measuring the water temperature. Comparing the water temperature with travel time, the reason of 0.2 ms difference was concluded with the effect of changing water temperature. It also means the reason of two time frames isn't the effect of changing water temperature.

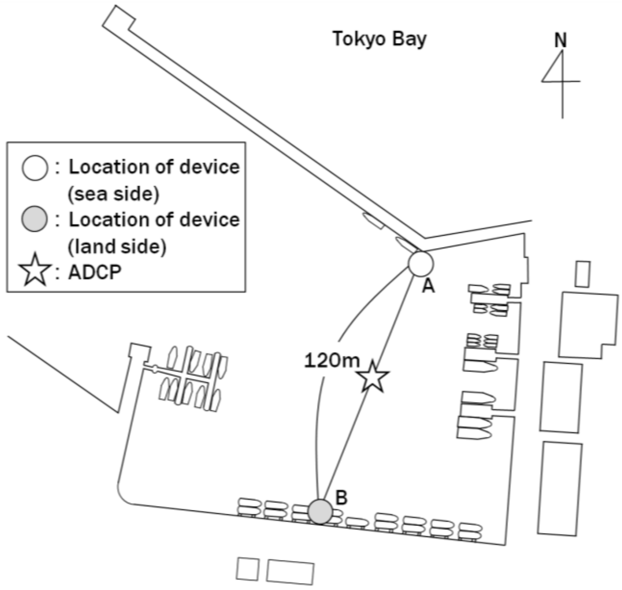

Fig. 1 Map of experimental area.

4. Discussion

Finite Difference Time Domain (FDTD) method was used for numerical analyses in order to investigate that the change of travel time effects by tide. 120 m×18 m was a calculation space. There were 0.5 m distances between transducers and piers. The height of transducers was 1 m from bottom. The range for propagation was 120 m. The direction was from B to A. Both piers was set as rigid body. When sound waves reflected on piers, the enegy of them was preserved completely. The reflection of sea surface caused phase reversal and no loss of energy. In the FDTD model, the top layer was water. In the water, sound speed was 1500 m/s, attenuation coefficient was 0 dB/λ, density was 1000 kg/m^3. Sedimentary layer was set under the water. The thickness could be changed arbitrarily. If water layer were 5 m, the thickness would be 13 m. The parameter for sedimentary layer was adopted actual data, density; 1680 kg/m^3 and porosity; 54.8 % by earlier study [5)]. Using this data, sound speed; 1618 m/s and attenuation coefficient; 0.97 dB/λ were estimated [6).] The bottom layer was absorption layer. The thickness was about 0.8 m. Space split; Δx was 1.5 m, time step; Δt was 1 μs. The wave signal of 7th M-sequence with 4 waves were the same as the experiment. But there is no noise in simulation, signal transmitted only 1 time. The height of tide was changed to 1.0, 1.5, 2.0, and 2.5 m for finding out the change of travel time by tide.

Figure 3 shows the wave shape after correlation by FDTD method. Gray broken lines are drawn in the same time of column figures. The peak time is almost the same in column figures. When tide is 1.0 and 2.5 m, travel time is shorter and tide is 1.5 and 2.0 m, longer. Travel times are longer than experimental results. This means the in-situ progagation range is less than 120m or in-situ sound speed is faster than 1500 m/s. The difference of two time frames is about 0.7 ms in FDTD simulation, it is the same scale as experimental result in Fig. 1. Therefore, we confirmed that the result of experiment is corresponded to that of simulation.

5. Conclusion

Small-scale sound propagation experiment was conducted from Aug. to Dec. 2009. The sinusoidal wave of 5 kHz with 7th M-sequence modulation was transmitted. After 120 m propagation, the received wave was demodulated, correlation peak was used for calculating a travel time. In the result, we found that the travel time gathered on two time frames. For making sure of the reason, travel time and tide were compared. Consequently, the travel time changed to the tidal change. Then, FDTD method was used for confirming experimental phenomenon. The height of tide was changed in FDTD simulation. The travel time was calculated by the same way of experiment. Finally, we confirmed that the travel time had two time frames in FDTD simulation. In the near future, we will study the reason of the phenomenon that travel time has two time frames by tide.

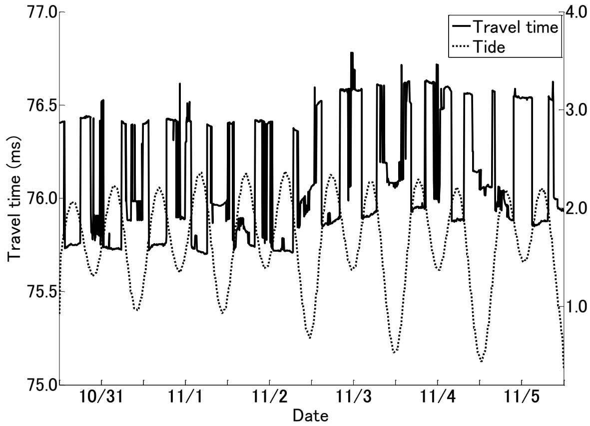

Fig. 2 The comparison between the travel time and tide. Solid line and dotted line represent the travel time and tide.

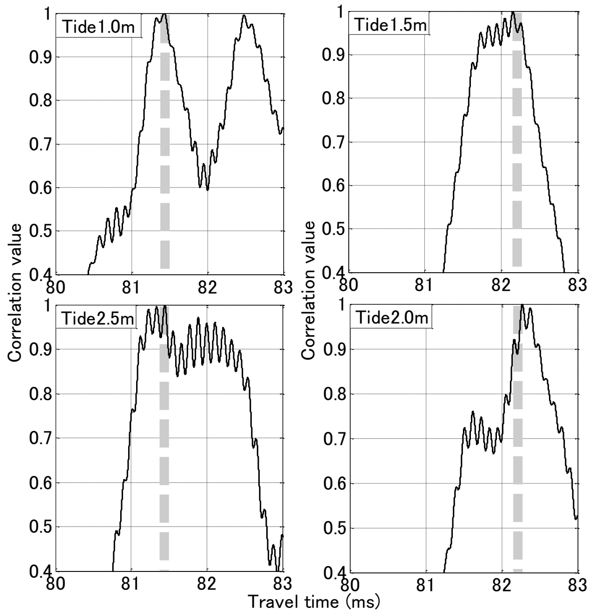

Fig. 3 The wave shape of correlation calculated by FDTD method. Gray broken lines are drawn in the same time zone of column figures.

Acknowledgment

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References

1. H. Ogasawara, K. Mori, T. Nakamura: Proc. of 10th ECUA (2010) 251
2. H. Ogasawara, K. Mori, T. Nakamura: Proc. of 10th WESPAC (2009) 298
3. H.Ogasawara, K.Mori, and T. Nakamura: Jpn. J. Appl. Phys. **49** (2010) 07HG15
4. S. Kamimura, S. Sato, Y. Yamada, H. Ogasawara, K. Mori, T. Nakamura: Proc. of 31th USE (2010) 585
5. H. Ogasawara, K. Mori, T. Nakamura: 2010 Proc. of Marine Acoust. Soc. Japan (2010) 27 [in Japanese]
6. C. S. Clay and H Medwin, *Acoustical oceanography: principles and applications*, (John Wiley and Sons, New York, 1977), Chap. 8.2, p. 258.