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Acoustical Environment Measurement at a Very Small Port
小規模港湾における音響的な環境計測

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1. Indroduction

Water temperature changes at the coastal area has large effect from human life activities like heat waste water from plants or vessels. As fresh water from rivers and household effluent make large salinity changes compare to the open sea. Moreover, sea level changes are also large according to tidal effect. In these circumstances, it is importatnt to monitor sea enviromental changes for fish farming and protect marine resources. Acousting monitoring method is suitable for monitoring such a large area with a few sensors because it is possible to get average information along the sound propagation path. Multiple transmiter and recerivers make it possible to monitor temperature and current in the wide area with tomographic method.

We have oparated reciprocal sound propagation experiment with a distance of about 120 m in a small port, Hashirimizu port in Yokosuka city. As the maximu depth at the experimental area is about 6 m, there ara many reverberations both from sea surface and bottom. Although received signal included many reverberations, we have tried to find effect of water changes and current changes along the path by acoustic method. From some analysis of the experimental result, sea level change by tidal effect and large temperature gradient at the sea surface effected sound path between the two transeivers.

The sending signal was phase modulated M-sequence signal and it repeated four times at one shoot. To inprove S/N ratio, four times repeated signals were added with the length of a M-sequence signal and demodulated by correlation. Many peaks were detected not only with the big main peak from the demodulated signal because of reflected waves. The time series of main peak showed environmental changes along the prpagated area but it sometimes changed discontinuously. There were very small peak but relatively continuous time series changes before the main big peak. In this report, we will forcus on these small peaks before the main peak.

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.

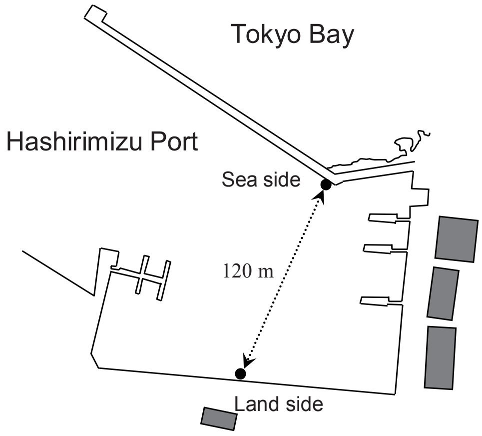

Fig. 1 Map of Hashirimizu Port.

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. Signal Processing

We can get cross-correlation value $R_{xy}(t)$ of the original signal $x(t)$ and recorded signal $y(t)$

$$R_{xy}(t) = \frac{1}{N}\sum_{i=0}^{N-1} x(i)y(i+t)$$

where, N is length of the M-sequence. After the correlation, amplitude component of the correlation value becomes very sharp pulse like a pulse compression. If the signal starts from time T_r. 4 steep peaks appear at T_r, T_r+T_m, T_r+2T_m, and T_r+3T_m where T_m is the length of the one cycle M-sequence signal. But there are some noises before T_r and after T_r+3T_m from the demodulation signals. Although the M-sequence is repetition signal, the sending

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signal breaks its repetition at the beginning and ending of the signal. Therefore some artifacts appear at the breaking point because of luck of the M-sequence signal repetition. As the true travel time T_r cannot understand from the raw received signal, let us decide tentative travel time T_r'. Then cut the signal 4 blocks as the length of the one cycle M-sequence signal, T_m from T_r'. The second and the third block are used for cross-correlation. After the demodulation by the replica M-sequence signal, pick up the middle block for the analysis of travel time. If the delay of the biggest large peak from the beginning of the block is T_d, therefore travel time Tr must be $T_r' + T_d$.

4. Discussion

A sample of the demodulated result is shown in Fig. 2. As the carrier frequency of the sending signal was 12.5 kHz and 2 waves applied to 1 digit, signal length T_m = 20.32 ms. The biggest beak appeared around 77 ms and many peaks follows after the main peaks. Ray tracing was calculated by Bellhop. The transducers were placed 1 m from the sea surface and bottom shape was from multibeam sonar result. Sound speed was uniform, 1530.5 m/s and calculated angle of the beam from the source was ±80 ° with 0.1° steps. Figure 3 shows the result of received time and its output angle. As the second and the third part of the repeated signal, it includes the late part of the first and the second repeated signal when adding the length of T_m. Figure 4 shows rearranged according to the correlated signal area. Dots around 77 ms and 0° area indicates the first big peak in Fig.2. After the main peak, many reflected waves arrived but as in this area, the second and the third signal parts were overlapped, the travel time of some dots in Fig 4 were not correct. For example, '+' around 75 ms is the fastest dot in Fig.4. As this ray started with large output angle from the source, the ray propagated with many surface and bottom reflections, this ray arrived one or two lap behind.

5. Conclusion

The reciprocal sound propagation experiment had conducted to monitor coastal area environmental changes. When we focus the time series of correlated results, small peaks detected before the main peak. These small peaks came from the multi- reflected ray with big output angle. As the signal was overlaid several times for S/N improvement, those small peaks before the main big peak were actually arrived after the main peak.

References

1. 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.

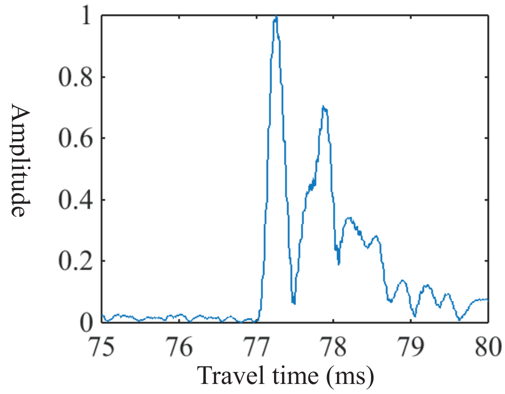

Fig. 2 Demodulated received signal.

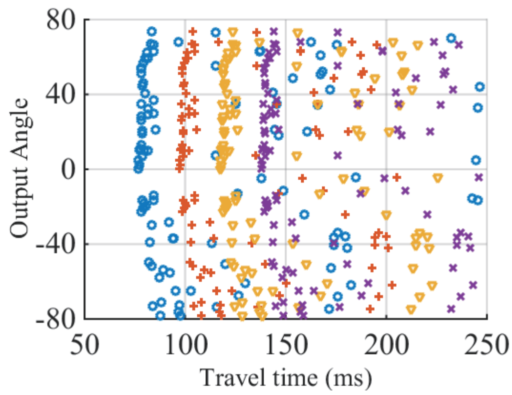

Fig. 3 Ray tracing result. Rays were plotted four times with the delay of *Tm*, same as the sending signal.

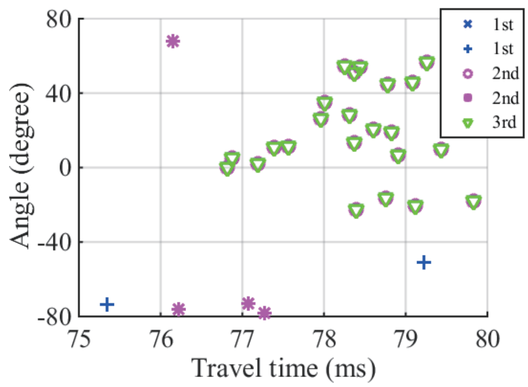

Fig. 4 Number of rays according to the travel time and its cumulative time from the first arrival peak.