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Sound Refocusing Simulation using Time Reversal Mirror in a Shallow Water Environment

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1. Introduction

TRM(Time Reversal Mirror) principles are described in review papers of M. Fink, the inventor of TRM, and his associates [1]. In Recent Choi carried out the study of the waveform and spatial focusing experiment [2].

In this paper it is considered the approach to predict TRM parameters based on the calculations of impulse response from underwater acoustic ray model in shallow water. The collection of impulse responses allows calculation of spatial structure of the TRM for variety of parameters. For simulation of acoustic source localization using time reversal mirror in the shallow water, we have to know the impulse response of the environment. Throughout this process we can reproduce an original signal at focal point. To apply this TRM simulation to shallow water environment, after extracting the impulse response about simple condition as shallow water, we analyze the acoustic focusing by TRM inversion.

2. Results of Simulation

It is used the Bellhop acoustic ray model For simulation in shallow water condition for acoustic wave. It is extracted the impulse response from the acoustic propagation model. The source frequency is 200 Hz of Gaussian Envelop. Using the impulse response signals and time reversed signal from the Model, it can be got the TRM refocusing at source target position.

Figure 1 shows the source target signal (e), impulse response function (h) and received signal (s) estimated by acoustic model in shallow water condition. From the convolution of the impulse response and time reversed signal, we can get the focusing signal as shown in Fig.2.

Figure 3 shows the sound ray using the sound propagation model in the case of one hydrophone as a source at depth of 50 m.

For TRM simulation, 9-elements hydrophone array are used as a re-emitted source at 0 m range. When the time reversed signal be re-emitted at hydrophone array position, we can simulate the spatial focusing effects at the position of source as shown in Figs 4,5 in the case of T1 profile of temperature. In here the source localization is not perfect because of TRM using single hydrophone. But in the case of hydrophone array (9-elements) as shown in Fig. 6, we can see very good result than single case.

For the case of T2 profile of temperature, the same simulation of T1 case is carried out as shown in Figs 7, 8 and 9.

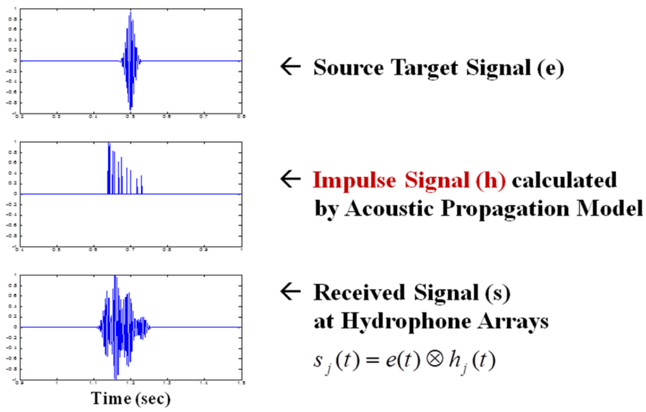

Fig.1. Source target signal (e), impulse response function (h) and received signal (s) estimated by acoustic model.

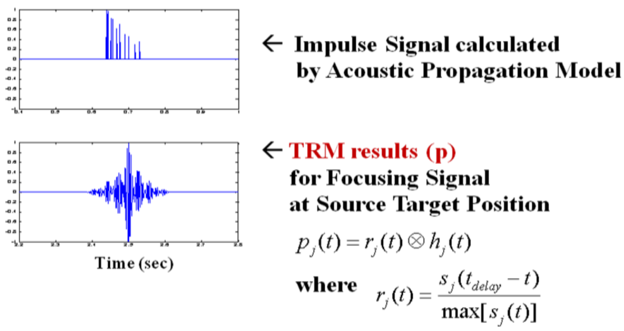

Fig. 2. Focusing signal by TRM simulation.

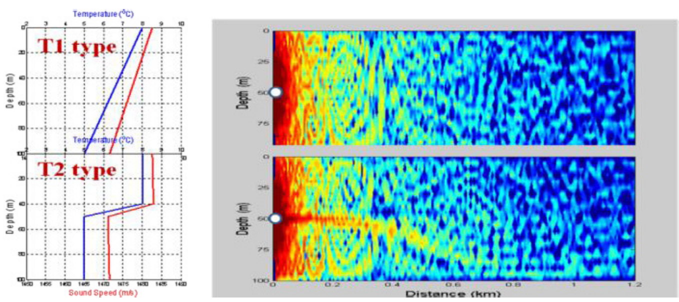

Fig. 3. Sound ray using the sound propagation model in the case of one hydrophone as a source at depth of 50 m.

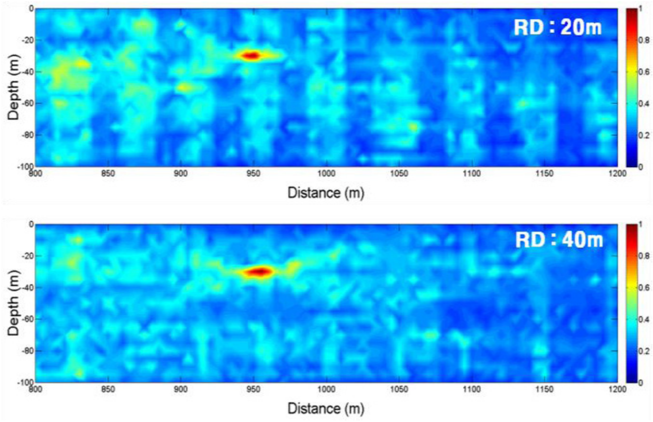

Fig. 4. Source localization results by TRM simulation about T1 type at source target depth 30 m, 950 m range (receiver Depth 20 m and 40 m each case).

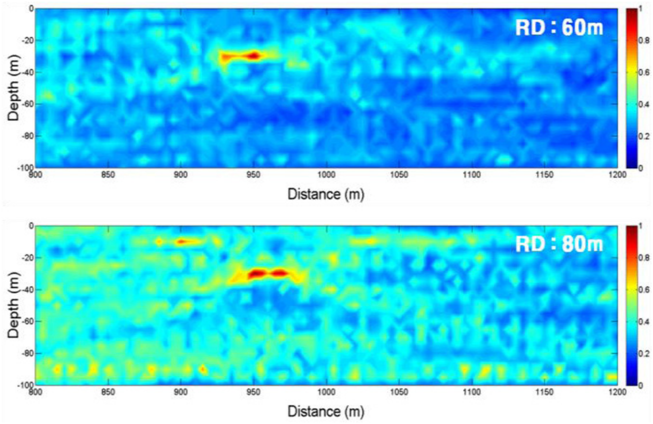

Fig. 5. Source localization results by TRM simulation about T1 type at source target depth 30 m, 950 m range (receiver Depth 60 m and 80 m each case).

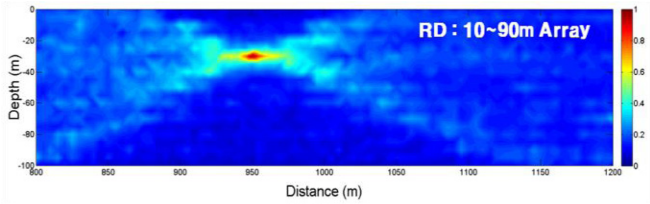

Fig. 6. Source localization results by TRM simulation about T1 type at source target depth 30 m, 950 m range (receiver array case : 9-elements).

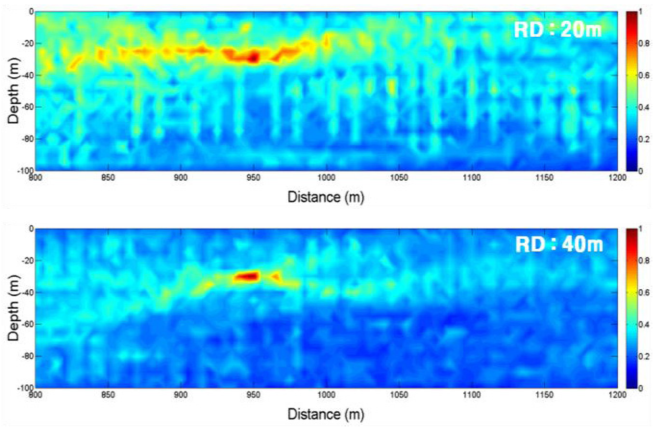

Fig. 7. Source localization results by TRM simulation about T2 type at source target depth 30 m, 950 m range (receiver Depth 20 m and 40 m each case).

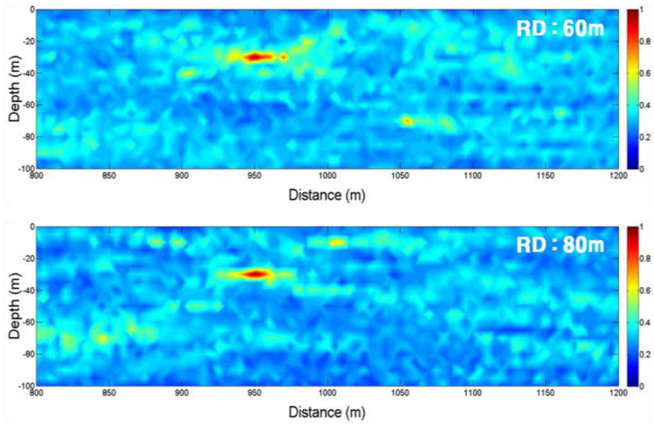

Fig. 8. Source localization results by TRM simulation about T2 type at source target depth 30 m, 950 m range (receiver Depth 60 m and 80 m each case).

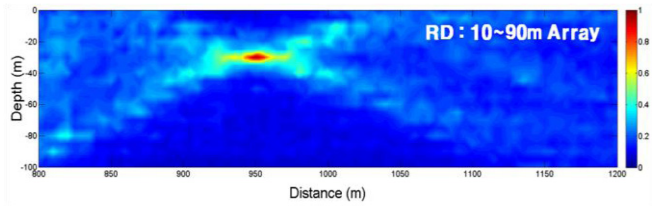

Fig. 9. Source localization results by TRM simulation about T2 type at source target depth 30 m, 950 m range (receiver array case : 9-elements).

3. Conclusion

TRM refocusing is simulated at the source target position by time reversal algorithm using the impulse response calculated by sound propagation model (Bellhop). In result, the spatial focusing and time signal patterns can be built by TRM simulation for shallow water condition.

Acknowledgment

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References

1. M. Fink, Time reversed acoustics, Scientific American, November (1999) 91-97.
2. B.K. Choi, B.C. Kim, A. Sutin, A. Sarvazyan, Ultrasonic focused waveform generation using time reversal acoustic focusing system, J. Mech. Sci. & Tech. 22 (2008), 699-707.