Specification of sound scattering in target ranging used ICA (Independent Component Analysis)

ICA(独立成分分析)を用いた目標漂定における音波散乱の特定

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1. Introduction

In active target ranging, the radiated sound wave is produced the reflection from not only the target but also the sea bottom, the sea surface, etc.. In shallow water, the reverberation is appeared strongly. As a result, the signal of target is hid by the reverberation in the monostatic target ranging. But the reverberation is reduced by using the receiver arranged forward, and target signal can be obtained. Time reversal (TR) processing is the one method. On the other hand, Tsurugaya et al. are examined the application of ICA (Independent Component Analysis) for target ranging[1]. ICA is used to the picture processing. The separated signal obtained by ICA has information on a variety of sound propagation routes. And, the selecting the separated signal becomes important in the target ranging by the ICA processing. Then, the selecting of the separated signal and the converging of TR sound field is examined.

The rica (reconstruction independent component analysis) function of MATLAB is used for ICA processing. And, the calculation for sound propagation is used FOR3D[2].

2. Signal separation by ICA

2.1 Result of ICA processing

The environment and the parameters used for the examination are as follows. Bottom depth is 100m, and the receiving point is 10km from sound source. Three adjacent receivers (1m interval) are set. Sound velocity in water is 1500m/s. Target in the range of 5km from sound source is the thickness of 1.5m, the length of 10m, and sound velocity 1600m/s. Frequency of the used sound wave is 1kHz, and burst signal of 5 cycles. Sound source depth (SD) is 50m. Received signal is independent, so the separated signal is obtained by ICA processing. The received signal of adjacent receiver are showed in Fig. 1. The receiver depth is 1m, 2m, and 3m. Because three receiving depths are adjacent, the shape of received signal are resembled. However, the pulse has extended to repeat a multiple reflection with the sea surface and the bottom. This received signal is processed by ICA. The separated signal after ICA processing is shown in Fig. 2. Each separated signal is corresponded to each received signal. The shape of this separated signal received with the depth interval of 1m is very different. It is confirmed to be able to apply ICA processing to three received signals.

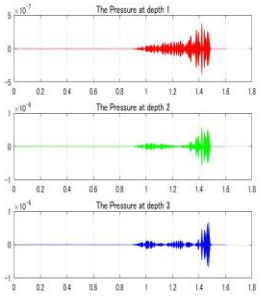

Fig. 1 Received signal at depth of 1m, 2m and 3m

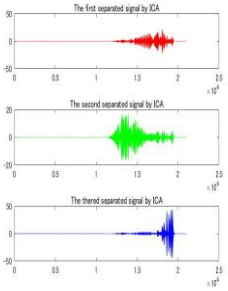

Fig. 2 Separated signal after ICA processing

2.2 Confirmation of separated signal

The obtained separated signal by ICA processing is examined by using Time Reversal (TR) processing. Each separated signal is processed by TR processing. The TR sound field is shown in Fig. 3. This figure is corresponded to the separated signals shown in Fig.2 The first separated signal is converged at sound source position. The second separated signal is converged at range 6km and depth 60m. The third separated signal is 6km and

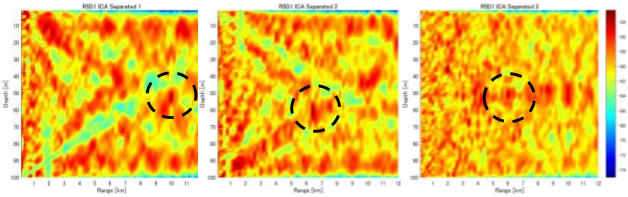

Fig. 3 Distribution after TR processing
left; first separated signal
middle; second separated signal
right; third separated signal
○is denoted the point of convergence

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50m. Target position is 5km, and depth is 10m. However, converging to the target is not obtained on this condition.

3. Relation between receiving depth and the convergence

To obtain the scattering information from the target, three sound sources (10m in depth, 50m, and 90m) are used. The receiver is three. Target is set up the depth of 40m, the width of 10m, and the length of 100m. Distance from sound source is 4km. The sound speed of the target is 3000m/s. And, the frequency is 600Hz, and 5cycle burst signal.

3.1 Three adjacent receiving depths

Three receiving depths with 1m interval are considered, and the result of TR processing is shown in Fig. 4. In this figure, the receiving depth of the left one is 3m, 4m and 5m, the middle one is 4m, 5m and 6m, and the right one is 5m, 6m and 7m. In the left figure, it is converged at 40m in depth, and 6km in range. This converging is target. Converging in the middle figure is 50m in depth, and range 5km. In the right figure, for converging point, both depth and range are different from the target position.

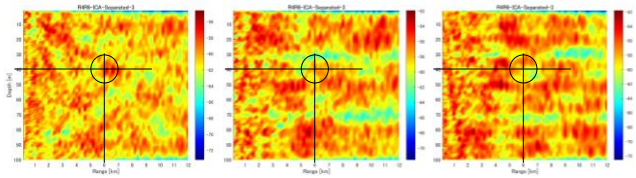

Fig. 4 TR sound field of three adjacent receivers
left; receiving depth, 3m, 4m, 5m
middle; 4m, 5m, 6m
right; 5m, 6m, 7m

3.2 Three selected receiving depths

The receiving depth is selected to clarify the scattering information from target. The subtracted sound field (SSF) by CW is used for a selection. SSF is a subtraction of sound field without target from sound field with target.

3.2.1 Selected depth, 50m, 51m and 52m

TR sound field of the receiving depth 50m, 51m, and 52m is shown in Fig. 5. Three receiving depths are all 0 in SSF. TR sound field is converged on sound source depth. In the depth where SSF is 0, the separated signal is hold a sound source information.

3.2.2 Selected depth; 80m, 85m and 90m

The selection of receiving depth from SSF is considered as follows. The contribution of SD90m is small in SSF. SSF is plus in SD10m, and is minus in SD50m. Converging on the target position is appeared clearly. However, other converging is occurred, too.

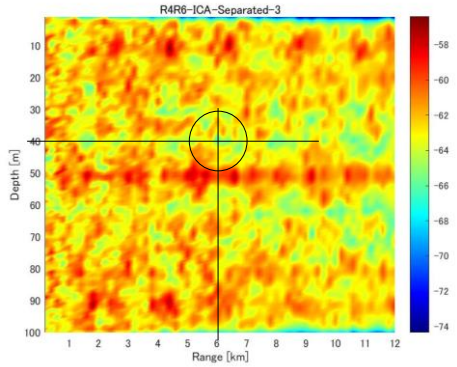

Fig. 5 TR sound field for all 0 in SSF receiving depth; 50m, 51m and 52

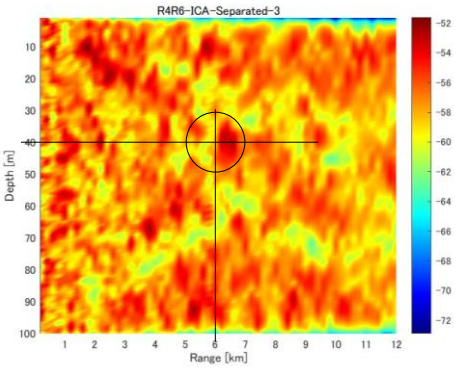

Fig. 6 TR sound field for selected receiving depth 80m, 85m and 90m

4. Summary

The separated signal was obtained by ICA processing to the received signal. Then, TR sound field was obtained from the separated signal by TR processing. And, the converging to the target was examined. The separated signal has about three informations. It is the sound source information, the reflection information on the route, and the target information. Therefore, it is not converged to the target position by all receiving depth. So, the receiving depth is selected by using SSF. And, the separated signal having the target information is selected, and converging at the target position was obtained. However, the selection of the receiving depth is required further examination.

References

1. Y. Tsurugaya, T. Kikuchi, and K. Mizutani, Proc. Marine Acoust Soc. Jpn (2021) 61. (in Japanese)
2. D. Lee *et al.*, "*Numerical Ocean Acoustic Propagation in Three Dimension*", World Scientific, (1995)