3Pb6-5

Relationship between target position and processing waveform related to ICA (Independent Component Analysis) processing

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1. Introduction

When using sound wave to targeting underwater objects, there are an active targeting and a passive targeting. In passive targeting, it is difficult to separate the target signal from the received signal. In the targeting, the application of ICA (Independent Component Analysis), which is used for face recognition, is being applied in order to separate scattered signal. Tsurugaya et al. are applied ICA processing to the received signal to obtain a separated signal for target ranging[1-3]. Then, in order to confirm the separation signal, Time-reversal (TR) processing is performed and an examination is made to obtain a target position from the converged state in the TR sound field. The signal separation is changed greatly with the variation of the receiving depth. Here, ICA processing is performed on the receiving signal.

Therefore, we are examined a method of performing ICA processing on each received signal for each of three sound sources and add them when obtaining TR sound field. And the calculation for sound propagation is used FOR3D[4].

2. ICA processing

The observed signal is consisted of the sum of several statically independent original signals. Therefore, ICA processing is an optimization problem that is used the observed signal x to find the separation matrix W in which each component of the separation signal y is independent of each other. The equation for this optimization problem is as follows.

$$\hat{W} = \arg\min_{w} D(y) = \arg\min_{w} D(Wx)$$

Here, $D(\cdot)$ is an evaluation function that evaluates independence. The separation matrix can be obtained by minimizing the evaluation matrix.

For ICA processing, rica (reconstruction independent component analysis) function of MATLAB is used by the gradient method.

3. ICA processing and TR sound field

In the processing, three sound source are used to obtain scattering from target (TGT). ICA processing and TR processing are performed on each receiving signal that is reached the receiver from three sound source (source depth 25,50,70 m). Next, TR processed signal is radiated from the receiving depth, and three signals are added at the same point of distance and depth to obtain TR sound field. Sound source is a burst signal with frequency of 600 Hz and 20 cycles. Target is 10 m in depth, 100 m in length and 3000 m/s in sound speed. Sound speed for water column is 1500 m/s. In the following, the display of the figure is used the first separated signal.

3.1 Difference between old processing and new processing

The comparison between the case where the sound wave radiated from 3 sound source are added at the receiving point (old processing) and the case where they are added in TR sound field (new processing) is shown Figure 1. Figure a is old processing, and b is the output from this processing. TGT position is same position, and is indicated by a circle. In the old processing, the influence of sea surface / bottom reflection is appeared strongly. Therefore, the convergence at TGT is hidden by the reflection. In new processing, the effect of reflection is reduced and the separability of TGT is improved.

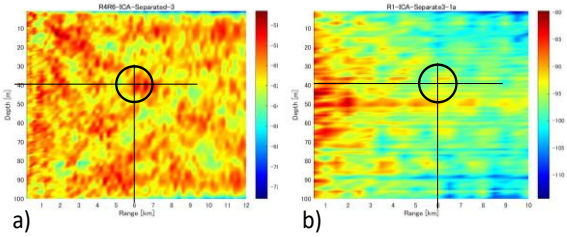

Fig. 1 Comparison of difference for TR processing
a) old processing b) new processing

3.2 TR sound field due to difference target depth

TGT and the environmental parameters are the same as in Figure 1. TR sound field when TGT depth is different is

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shown in Figure 2. The distance is 6 km, TGT depth is 25 m in Figure a, 40 m in figure b, and 85 m in figure c. In each case, the convergence of TR sound field can be seen at TGT position. The deeper the depth is the higher strength.

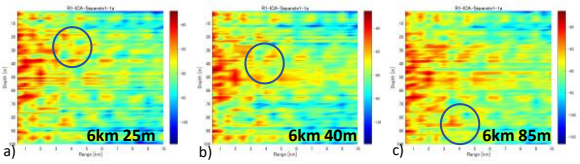

Fig. 2 Comparison of TR sound field for TGT depth
a) The target depth is 25 m b) 40 m c) 85 m
○is denoted TGT position

3.3 TR sound field caused by difference in distance

TR sound field when TGT distances are different is shown in Figure 3. TGT depth is 40 m. The distance in figure a is 2 km, 4 km in figure b, and, 6 km in figure c. The pattern of TR sound field does not change significantly. Convergence is became clear at distances far from sound source.

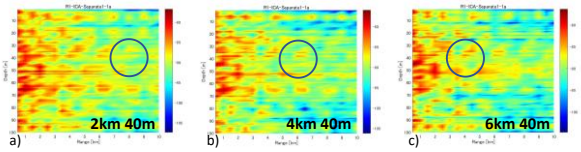

Fig. 3 Comparison of TR sound field for Target distance
a) 2 km b) 4 km c) 6 km
○is denoted TGT position

4. Difference in TR sound field cause by TGT sound speed

TR sound field when TGT sound speed are different is shown in Figure 4. TGT distance is 4km and the depth is 40 m. Figure a is showed 3000 m/s which is faster than that of water column., and Figure b is 950 m/s, slower than that of water column. The pattern of TR sound field does not change significantly. The convergence where sound speed is slower than that of water column is appeared strongly.

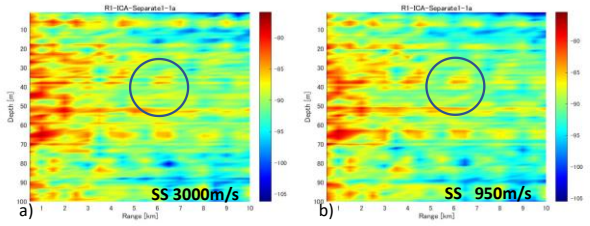

Fig. 5 Comparison of TR sound field for target sound speed
a) 3000 m/s b) 950 m/s

5. Difference in TR sound field cause by TGT sound speed

TR sound field for the difference in TGT shape is shown in Figure 6. TGT distance and depth is the same. Figure a is the same rectangular shape as before, and Figure b is the rectangular shape with a convex part added. The pattern of TR sound field does not change, significantly, but the strength of TR sound field in the added convex shape is increased.

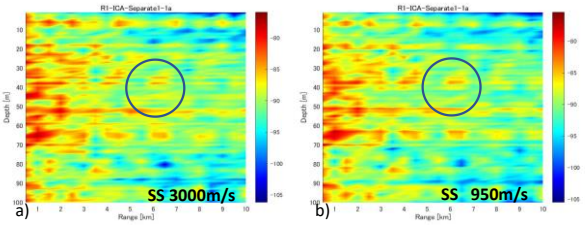

Fig. 6 Comparison of TR sound field for target shape
a) rectangular TGT b) rectangular with convex

6. Summary

By changing the method of adding signals from the three sound sources, the difference in the convergence of TR sound field with respect to TGT position is obtained. The separation state and intensity of convergence for TGT position are better in this processing.

The convergence strength of TR sound field is increase when TGT sound speed is slower than that of the water column. The scattering intensity is increased when TGT is not rectangular and has a convex portion. When the sound speed is slower than that of water column, and the convex shape is changed the reflection at TGT. Therefore, the scattering at TGT is emphasized.

TR sound field is also affected by the sea surface and the seafloor reflection. Therefore, by reducing the effect of surface reflection and bottom reflection, the convergence to TGT position is became clear.

References

1. Y. Tsurugaya, T. Kikuchi, and K. Mizutani, Proc. Marine Acoust Soc. Jpn (2021) 61. (in Japanese)
2. Y. Tsurugaya, T. Kikuchi, and K. Mizutani, Proc. The 42nd of symposium on Ultrasonic Electronics (2021) 1Pa6-1
3. Y. Tsurugaya, T. Kikuchi, and K. Mizutani, Proc. Marine Acoust Soc. Jpn (2022) 63. (in Japanese)
4. D. Lee *et al.*, "*Numerical Ocean Acoustic Propagation in Three Dimension*", World Scientific, (1995)