Matched Field Processing for a Short Vertical Array in Shallow Water Using the Geoacoustic Parameters Inversed from Short Range Source Data

ZHU Xian, WANG Zhongkang, GE Huiliang
Science and Technology on Sonar Laboratory
Hangzhou Applied Acoustics Research Institute,Hangzhou, P. R. China
sklzhuuxian@163.com

Introduction

In shallow water ocean, the multi-path structure information of acoustic signals received by a vertical array is useful for target localization. The environment knowledge mismatch restricts matched field processing localization performance. A method of matched field localization for a short vertical array in shallow water based on the geoacoustic parameters inversion with short-range co-operative source data is presented in this paper. This can be used to target localization when the knowledge of geoacoustic parameters of the seabed is unknown.

Geoacoustic Parameters Inversion Theory

Let us consider that a receiver receives data from a short range point source, as shown in figure 1. Four paths will be considered here: the first-path is a direct-arrival wave; the second-path is a surface reflected wave; the third-path is a bottom reflected wave; and, the fourth-path is a surface-bottom reflected wave. Where $\theta_3$ and $\theta_t3$ are the third path incidence and refracted grazing angles. From (2), we can find the solutions of $p_2$ and $c_2$, they are given as equation(1).

$$\begin{align*}
\theta^2 + \sin^2 \theta & = \frac{1}{\rho^2} \\
\theta_t^2 + \sin^2 \theta_t & = \frac{1}{\rho_t^2}
\end{align*}$$

(1)

Fig.1 Multi-path rays sketch.

$$\begin{align*}
\theta \cos \theta - \theta_t \cos \theta_t & = \frac{1}{\rho} \\
\theta_t \cos \theta + \theta \cos \theta_t & = \frac{1}{\rho_t}
\end{align*}$$

(2)

Broadband Coherent Matched Field in Beam Domain

The broadband coherent matched field processor can be expressed as

$$b(r,z) = \sum_{n=1}^{N} \sum_{\alpha=1}^{n} X_{\alpha n}(\alpha, \theta, r, z) X_{\alpha n}^*(\alpha, \theta, r, z)$$

(3)

where

$$X_{\alpha n}(\alpha, \theta, r, z) = A_{\alpha n}(\alpha, \theta, r, z)$$

are cross-spectrum of measured data and cross-spectrum of copied field respectively.

Geoacoustic Parameters Inversion Simulation

The Bellhop ray model will be used to produce the simulated data. The arrival time and grazing angles for the selected four paths are shown in Fig.2. Some parameters of (2) and the measurement results of the density and sound speed of seabed are given in TABLE II. Form the results, the measured density and sound speed are very close to the real value.

Analysis of the Experimental Data

The data used for geoacoustic parameters measurement was obtained in a shallow water sea experiment. The sea depth at the experiment site is 32m, the density in the water column is 1.0g/cm3, and the water column sound speed profile data is given in Fig.3. The received vertical array which has 8 elements spaced 1m apart is 106m distant from the source, and spaced evenly from 8m to 15m in the shallow water waveguide. The source transmits a 200Hz-800Hz LFM signal with 250ms at depth of 10m.

The ambiguity surface output after conventional beamforming and matched filtering is given in Fig.4. Fig.5 is the arrival time and grazing angles for the selected four paths extracted from Fig.4. Some parameters of (2) and the measurement results of the density and sound speed of seabed are given in TABLE II. From TABLE II, we can get $\rho c = 26.3^\circ$, so the usable condition of (6) can be satisfied. Fig.6 is the MFP output which uses the measured results in TABLE II as the environment parameters. From Fig.6, we can know the target’s range is 2300m and depth is 12m, which are very close to the real range (1000m) and depth (10m). Fig.7 is the RTR (Range-Time Record) outcome of MFP for 150s data. The target at 2300m can be identified clearly.

Summary

A method of matched field localization for a short vertical array in shallow water based on the geoacoustic parameters inversion with short-range cooperative source data is presented.

Through real experimental data analysis, the range estimation error of the presented method is 5%, and the depth estimation error is 2 meters using the data recorded by a 7-meter vertical received array, when the SNR of array element output is 2 dB, and the target distance is 2.2 kilometers away from the received array.

Table I. Geoacoustic Parameters Inversion Results in Simulation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>$E_1$</td>
<td>1.796e-004</td>
</tr>
<tr>
<td>$E_2$</td>
<td>3.37e-004</td>
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<tr>
<td>$E_3$</td>
<td>4.74e-005</td>
</tr>
<tr>
<td>$E_4$</td>
<td>2.32e-005</td>
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<tr>
<td>$\rho c$</td>
<td>26.3</td>
</tr>
<tr>
<td>$\rho(\text{g/cm}^3)$</td>
<td>1.025</td>
</tr>
<tr>
<td>$c(\text{m/s})$</td>
<td>1532.5</td>
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</table>

Table II. Geoacoustic Parameters Inversion Results in Experimental Data

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_1$</td>
<td>0.1925</td>
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<tr>
<td>$E_2$</td>
<td>0.8477</td>
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<tr>
<td>$E_3$</td>
<td>0.8942</td>
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<tr>
<td>$E_4$</td>
<td>0.89753</td>
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<tr>
<td>$\rho c$</td>
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<tr>
<td>$\rho(\text{g/cm}^3)$</td>
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<tr>
<td>$c(\text{m/s})$</td>
<td>1473.5</td>
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</tbody>
</table>

Fig.2 Arrival time and grazing angles for four paths in simulation.

Fig.3. Water column sound speed profile.

Fig.4. The ambiguity surface output after conventional beamforming and matched filtering.

Fig.5. The arrival time and grazing angles for four paths extracted from Fig.4 in experiment data.

Fig.6. The MFP output uses the measured results as the environment parameters.

Fig.7. The waveform of one channel data (left) and the RTR (Range-Time Record) outcome of MFP (right) for 150s data.

Fig.8. The ambiguity surface output after conventional beamforming and matched filtering.