Multi-beam Line-finding Problem Based on Geometric Model

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Abstract. In this paper, a geometric model is established to study the problem of multi-beam sounding line deployment. In this paper, the index of multi-beam sounding is calculated firstly. The geometric model of the path of the acoustic signal transmitted by the measuring ship and the transducer of the measuring ship, the seabed slope and the plane perpendicular to the direction of the measuring line are established. The mathematical relationship between the coverage width W of multi-beam sounding and the overlap rate between adjacent strips is obtained, and the overlap rate between adjacent strips is calculated. Finally, the model is tested to meet the robustness and the model is correct. Secondly, this paper studies the coverage width W of multi-beam sounding. According to the two cases that the coverage width W has nothing to do with the slope of the seabed and the coverage width W has something to do with the slope of the seabed, the geometric models of the measurement ship, the path of the acoustic signal emitted by the transducer of the measurement ship, the seabed slope and the plane perpendicular to the direction of the survey line are established respectively, and the geometric model is tested. The model is correct.

Keywords: Multibeam line, geometric model, coverage width.

1. Introduction

1.1. Problem background

Multibeam bathymetry and single-beam bathymetry principle is the same, are the use of acoustic waves in a homogeneous medium along the straight line of uniform propagation characteristics to measure the depth of the water column, but it is not a single point of continuous measurement, but the use of multiple beams along the perpendicular to the plane of its sailing trajectory to generate a return beam for measurement, so multibeam bathymetry to avoid the single-beam bathymetry data is dense, no measurement of the distance between the lines of the shortcomings and can measure the full-coverage bathymetric strips over flat seafloor areas[1-4]. In the undulating real seabed terrain, the use of multibeam bathymetry is characterized by poor measurement quality (omission of shallow water depths) and low measurement efficiency (high overlap rate at deeper water depths), so it is of great significance to improve multibeam bathymetry in order to improve the quality and efficiency of the measurements [5-7].

1.2. Problem restatement

(1) Assuming that α (slope) is the angle between the seafloor slope and the plane perpendicular to the direction of the survey line, a mathematical model is established to explore the relationship between the coverage width W of the multibeam bathymetry and the overlap rate between adjacent strips. Assuming that the opening angle of the multibeam transducer is 120°, the slope is 1.5°, and the depth of seawater at the center point of the sea area is 70 m, the established model is used to calculate the index values of the positions listed in Table 1.

(2) β is the angle between the direction of the survey line and the normal direction of the seafloor slope projected on the horizontal plane, to establish a mathematical model of the width of the multibeam bathymetry coverage of a rectangular sea area to be tested. Assuming that the opening angle of the multibeam transducer is 120°, the slope is 1.5°, and the depth of seawater at the center...
of the sea area is 120 m, the established model is used to calculate the coverage width of multibeam bathymetry at the positions.

2. Problem analysis

(1) Firstly, establish the geometrical model of the measuring ship, the path of the acoustic signal emitted by the transducer of the measuring ship, the slope of the seabed and the plane perpendicular to the direction of the measuring line, use the geometrical relationship to get the required angle, and get the formula of the coverage width W according to the sine theorem, and then establish the geometrical model of the measuring ship, the path of the acoustic signal emitted by the transducer of the measuring ship, the slope of the seabed, the plane perpendicular to the direction of the measuring line, with the distance of the measuring line at the center point at 0 and the distance of the moving. The geometric model of the perpendicular to the direction of the measurement line, using similar triangles to find out the formula for calculating the depth of seawater D from the center point, according to the calculated formula, first find out the depth of seawater D from the center point, and then find out the width of the coverage W, and then finally calculate the overlap rate between the neighboring strips by substituting into the given formula, and calculate a number of groups of results to test the model.

(2) Firstly, we categorize and discuss (as in Fig. 2) the two cases of coverage width W is not related to seafloor slope α and coverage width W is related to seafloor slope α. We also categorize the cases of coverage width W is related to seafloor slope α into three subcategories (the angle β between the direction of the survey line and the normal direction of the seafloor slope projected on the horizontal plane is 90° or 270°, 135° or 315°, and 45° or 225°), and then set up the measurement vessel and the measurement vessel, respectively. Then the geometrical models of the measuring ship, the path of the acoustic signal emitted by the transducer of the measuring ship, the seabed slope and the plane perpendicular to the direction of the measuring line are established respectively, and the depth of the seawater at the distance from the center point D is calculated firstly, and then the formula for the coverage width W is obtained. 45° or 225° can be classified into one category. Finally, the opening angle of the multibeam transducer is 120°, the slope is 1.5°, the depth of seawater at the center of the sea area is 120m, and the distance of the measuring vessel from the center of the sea area is substituted into the formula for calculating the coverage width W to obtain the coverage width.

3. Modeling and solving

3.1. Calculation of multibeam bathymetry indexes

Establish the geometric model of the measuring ship, the path of the acoustic signal emitted by the transducer of the measuring ship [8], the seafloor slope and the plane perpendicular to the direction of the measurement line, first calculate the coverage width W, then calculate the depth of seawater at the distance from the center D, and finally calculate the overlap rate between adjacent strips [9,10].

3.1.1 Geometric modeling

(1) Calculate the coverage width W

The assumptions are schematized, and the results are shown in Fig. 1. From Fig. 1, we know that point A is the position of the survey ship, and set the measurement line as AE. The path of the transducer of the survey ship transmitting acoustic signals vertically to the seafloor is intersected with the seafloor slope at two points, point B and point C. Set BE = W1, CE = W2, extend the AB cross the horizontal plane at point H, extend the AE cross the horizontal plane at point F.
Figure 1. Geometrical modeling of the coverage width W

Model the geometry of the survey vessel, the path of the acoustic signal emitted by the transducer of the survey vessel, the slope of the seabed and the plane perpendicular to the direction of the survey line.

It is known that AE bisects $\angle BAC$, so $\angle BAE = \angle CAE = \theta/2$. $\Delta AHF$ is a right triangle, so $\angle AHF = \pi/2 - \theta/2$, $\angle ABE = \pi/2 - \theta/2 - \alpha$. In the middle of the equation, by the sine theorem, we get

$$\frac{AE}{\sin \angle ABE} = \frac{BE}{\sin \angle BAE}$$  \hspace{1cm} (1)

i.e.

$$\frac{D}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} - \alpha \right)} = \frac{W_1}{\sin \frac{\theta}{2}}$$  \hspace{1cm} (2)

In $\Delta ABC$, $\angle ACE = \pi/2 - \theta/2 + \alpha$.

In $\Delta ACE$, by the sine theorem, we have

$$\frac{AE}{\sin \angle ACE} = \frac{CE}{\sin \angle CAE}$$  \hspace{1cm} (3)

i.e.

$$\frac{D}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} + \alpha \right)} = \frac{W_2}{\sin \frac{\theta}{2}}$$  \hspace{1cm} (4)

From Eq. (2) and Eq. (4) we have

$$W_1 = \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} - \alpha \right)}$$  \hspace{1cm} (5)

$$W_2 = \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} + \frac{\theta}{2} + \alpha \right)}$$  \hspace{1cm} (6)

Coverage width $W = W_1 + W_2$

i.e.

$$W = \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} - \alpha \right)} + \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} + \frac{\theta}{2} + \alpha \right)}$$  \hspace{1cm} (7)

(2) Calculate the depth of seawater from the center point D

Measuring line from the center of the distance of 0m, set the position of the measurement ship at this time for the A', the measurement line for the A'E', the measurement ship transducer perpendicular to the seafloor transmitting acoustic signals to the bottom of the path and the seafloor slope intersected with the point B', point C'two points. The depth of seawater is 70m, i.e., $D'=70m$, which is brought into Equation (7) to get W1 and W2 at this time.
Establish the geometrical model of the measuring ship at point A' and point A, the path of the acoustic signal emitted by the transducer of the measuring ship, the seabed slope and the plane perpendicular to the direction of the measuring line, as in Fig. 2, make B'N perpendicular to the AE at point N over point B', and extend A'E' to intersect B'N at point M. In \( \triangle B'E'M \), the 
\[ E'M = W'_1 \sin \alpha \]  
(8)

Assuming A'A=d, so MN=d, from similar triangles \( \triangle B'EN \) and \( \triangle B'EM \) we get
\[ \frac{B'M}{B'M} = \frac{E'M}{EN} \]
(9)
i.e.
\[ \frac{W'_1 \sin \alpha}{EN} = \frac{W'_1 \cos \alpha}{W'_1 \cos \alpha + d} \]
(10)
solve for
\[ EN = \frac{\sin(\alpha W'_1 \cos \alpha + d)}{\cos \alpha} \]
(11)

Depth of the sea at the center from A'M=AND = AE = AN - EN = A'M - EN

i.e.
\[ D = D' + W'_1 \sin \alpha - \frac{\sin(\alpha W'_1 \cos \alpha + d)}{\cos \alpha} \]
(12)

(3) Calculate the overlap rate \( \eta \) between neighboring strips

According to Eq. (12) the seawater depth \( D \) at the distance from the center point can be calculated, and then the coverage width \( W \) can be obtained according to Eq. (7), and the overlap rate \( \eta \) between adjacent strips can be calculated by substituting into the given Eq. \( \eta = 1 - \frac{d}{W} \)

\[ \eta = 1 - \frac{d}{D \sin \theta_1 + D \sin \theta_2} \]
(13)

3.1.2 Geometric model solution

From the distance of the measuring line from the center point, we can get d=200m, and when the distance of the measuring line from the center point is 0m, the depth of seawater \( D' = 70 \)m, and get the corresponding \( W'1 \). According to the formula (13), the depth of seawater \( D \) at the distance from the center point is calculated, and the coverage width \( W \) is obtained according to the formula, the opening angle of the multibeam transducer \( \theta \) is 120°, and the slope \( \alpha \) is 1.5°. Substituting the known data into Eq.1, we got the overlap rate \( \eta \) with the previous survey line. We used MATLAB to get the calculation results, which are shown in Table 1.

<table>
<thead>
<tr>
<th>Distance between measuring line and center point</th>
<th>-800</th>
<th>-600</th>
<th>-400</th>
<th>-200</th>
<th>0</th>
<th>200</th>
<th>400</th>
<th>600</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom depth/m</td>
<td>90.95</td>
<td>85.71</td>
<td>80.47</td>
<td>75.24</td>
<td>70.00</td>
<td>64.76</td>
<td>59.53</td>
<td>54.29</td>
<td>49.05</td>
</tr>
<tr>
<td>Coverage width/m</td>
<td>315.81</td>
<td>297.63</td>
<td>279.44</td>
<td>261.26</td>
<td>243.07</td>
<td>224.88</td>
<td>206.70</td>
<td>188.51</td>
<td>170.33</td>
</tr>
<tr>
<td>Overlap rate with the previous measurement line/%</td>
<td>———</td>
<td>32.80</td>
<td>28.43</td>
<td>23.45</td>
<td>17.72</td>
<td>11.07</td>
<td>3.24</td>
<td>-6.09</td>
<td>-17.42</td>
</tr>
</tbody>
</table>

According to Table 1, the greater the distance between the survey line and the center point, the seawater depth, the coverage width, and the overlap rate with the previous survey line show a decreasing trend.
3.1.3 Test of geometric model

Suppose d = 100m, the measurement ship, the path of the acoustic signal emitted by the transducer of the measurement ship, the geometric model of the seabed slope and the plane perpendicular to the direction of the survey line are established. Similar to the first problem, the formula is used to calculate the seawater depth D at the center point. The formula is used to obtain the coverage width W, and the overlap rate η between adjacent strips is calculated by substituting the formula. The calculation results are shown in Table 2.

Table 2. Calculation results for d = 100

<table>
<thead>
<tr>
<th>Distance between the measuring line and the center point/m</th>
<th>-800</th>
<th>-700</th>
<th>-600</th>
<th>-500</th>
<th>-400</th>
<th>-300</th>
<th>-200</th>
<th>-100</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea water depth/m</td>
<td>90.95</td>
<td>88.33</td>
<td>85.71</td>
<td>83.09</td>
<td>80.47</td>
<td>77.86</td>
<td>75.24</td>
<td>72.62</td>
<td>70</td>
</tr>
<tr>
<td>Coverage width/m</td>
<td>315.81</td>
<td>306.72</td>
<td>297.63</td>
<td>288.53</td>
<td>279.44</td>
<td>270.35</td>
<td>261.26</td>
<td>252.16</td>
<td>243.07</td>
</tr>
<tr>
<td>Overlap rate with the previous measurement line/%</td>
<td>———</td>
<td>67.39</td>
<td>66.4</td>
<td>65.34</td>
<td>64.21</td>
<td>63.01</td>
<td>61.72</td>
<td>60.34</td>
<td>58.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance between the measuring line and the center point/m</th>
<th>0</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea water depth/m</td>
<td>70</td>
<td>67.38</td>
<td>64.76</td>
<td>62.14</td>
<td>59.53</td>
<td>56.91</td>
<td>54.29</td>
<td>51.67</td>
<td>49.05</td>
</tr>
<tr>
<td>Coverage width/m</td>
<td>243.07</td>
<td>233.98</td>
<td>224.88</td>
<td>215.79</td>
<td>206.7</td>
<td>197.61</td>
<td>188.51</td>
<td>179.42</td>
<td>170.33</td>
</tr>
<tr>
<td>Overlap rate with the previous measurement line/%</td>
<td>58.86</td>
<td>57.26</td>
<td>55.53</td>
<td>53.66</td>
<td>51.62</td>
<td>49.39</td>
<td>46.95</td>
<td>44.26</td>
<td>41.29</td>
</tr>
</tbody>
</table>

According to Table 2, when d = 100m, it also satisfies the law when d = 200m: the greater the distance between the survey line and the center point, the seawater depth, the coverage width, and the overlap rate with the previous survey line show a decreasing trend. The model satisfies the robustness, so the model is correct.

3.2. Coverage width W problem of multi-beam sounding

The geometric model of the survey ship, the path of the acoustic signal emitted by the transducer of the survey ship, the seabed slope and the plane perpendicular to the direction of the survey line are established, classified and discussed, and the calculation formula of the corresponding coverage width W is obtained.

3.2.1 Establishment of geometric model

The data is illustrated, and the spatial rectangular coordinate system is established with the center point of the horizontal plane as the origin point. The graphical result is shown in Figure 3 (cube). The intersection point of the z-axis and the sea level is the center point C of the sea area, and the left side of the section perpendicular to the direction of the survey line of the survey ship is the positive direction.

In the first case, the angle β between the direction of the survey line and the normal direction of the seabed slope projected on the horizontal plane is 0° or 180°, and the coverage width W has nothing to do with the seabed slope.
Figure 2. The cross-section of the angle $\beta$ between the direction of the survey line and the normal direction of the seabed slope on the horizontal plane is 0° or 180°.

Its cross section is shown in Figure 3, from which it is known that the seawater depth $D$ at the distance from the center point is a fixed value, and

$$\frac{W}{D} = \tan \frac{\theta}{2}$$  \hspace{1cm} (14)

Therefore

$$W = 2D\tan\frac{\theta}{2}$$  \hspace{1cm} (15)

The second case: the coverage width $W$ is related to the seabed slope $\alpha$.

Assuming that the angle between the intersection line and the horizontal plane of the cross section of the survey line direction and the seabed surface is $\alpha_1$, the cross section is shown in Figure.3. Similar to problem 1, the survey ship, the path of the acoustic signal emitted by the survey ship transducer, the geometric model of the seabed slope and the plane perpendicular to the survey line direction are established.

![Cross-sectional view](image)

Figure 3. Cross-sectional view

(1) Calculate the seawater depth from the center point $D$.

![Calculating the D-geometric model of seawater depth at the center of the distance.](image)

Figure 4. Calculating the D-geometric model of seawater depth at the center of the distance.

The EK at point E is perpendicular to AE to point K, as shown in figure 4. If the distance between the measuring line and the center point is $x$, the $E'K=A'A=x$ can be obtained from the geometric relationship. In $E'EK$
Therefore

\[ \frac{E_K}{E_K} = \tan \alpha_1 \]  

(16)

Because \(^{\wedge}E^{\wedge} = AK= D', \) so \(D'=AE=AK-EK = A'E'-EK\)

i.e.

\[ D = D' - x \tan \alpha_1 \]  

(18)

(2) calculate the coverage width \(W.\)

Measure the path of the acoustic signal emitted by the ship's transducer, the geometric model of the submarine slope and the plane perpendicular to the direction of the line, as shown in figure 6. It is known from figure 6 that point An is the position of the measuring ship and the measuring line is AE. The path of the acoustic signal emitted by the transducer of the measuring ship vertically intersects with the submarine slope at point B and point C. Let \(BE=w_1, CE=w_1\) prolong the horizontal plane of AB intersection at point H and extend the horizontal plane of AE intersection at point F. Suppose that \(AE\) is divided equally into BAC, so that \(BAE=\) is equal to \(CAE= \theta / 2.\) \(AHF\) is a right triangle, so \(AHF= \pi / 2-\theta / 2, ABE= \pi / 2-\theta \) / 2 - \(\alpha_1.\)

In \(ABE,\) it is determined by the sine.

\[ \frac{AE}{\sin \angle ABE} = \frac{BE}{\sin \angle BAE} \]  

(19)

i.e.

\[ \frac{D}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} - \alpha_1 \right)} = \frac{w_1}{\sin \frac{\theta}{2}} \]  

(20)

In \(\Delta ABC, ACE= \pi / 2-\theta / 2 + \alpha_1.\)

In \(\Delta ACE,\) it is obtained from the sine.

\[ \frac{AE}{\sin \angle ACE} = \frac{CE}{\sin \angle CAE} \]  

(21)

\[ \frac{D}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} + \alpha_1 \right)} = \frac{w_2}{\sin \frac{\theta}{2}} \]  

(22)

Obtained from formula (20) and formula (22)

\[ W_1 = \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} - \alpha_1 \right)} \]  

(23)

\[ W_2 = \frac{D \sin \frac{\theta}{2}}{\sin \left( \frac{\pi}{2} - \frac{\theta}{2} + \alpha_1 \right)} \]  

(24)

Coverage width \(W=w_1+w_2\)
i.e.

\[ W = \frac{D \sin \theta}{\sin \left( \frac{\pi}{2} - \alpha \right)} + \frac{D \sin \theta}{\sin \left( \frac{\pi}{2} + \alpha \right)} \]  \hspace{1cm} (25)

Replace the formula (19) into the formula (26).

\[ W = \frac{(D' - x \tan \alpha_{1}) \sin \theta}{\sin \left( \frac{\pi}{2} - \alpha \right)} + \frac{(D' - x \tan \alpha_{1}) \sin \theta}{\sin \left( \frac{\pi}{2} + \alpha \right)} \]  \hspace{1cm} (26)

(1) the angle between the direction of the survey line and the normal projection of the submarine slope on the horizontal plane is 90° or 270°.

At this time, the same problem 1, the angle between the cross section of the measuring line and the sea floor and the horizontal plane \( \alpha_{1} = \alpha \), and the coverage width \( W \) can be obtained by substituting it into the formula.

(2) the angle between the direction of the survey line and the normal projection of the submarine slope on the horizontal plane is 135° or 315°.

Let the side length of the cube in figure 3 be \( a \), then the length of the corner line of the bottom plane is square \( 2a \), and the height of the sea floor and the horizontal plane \( h = \tan \alpha \).

Therefore

\[ \tan \alpha_{1} = \frac{\tan \alpha}{\sqrt{2}} \]  \hspace{1cm} (27)

Therefore

\[ \alpha_{1} = \arctan \frac{\tan \alpha}{\sqrt{2}} \]  \hspace{1cm} (28)

The coverage width \( W \) can be obtained from the above formula.

(3) the angle between the direction of the survey line and the normal projection of the submarine slope on the horizontal plane is 45° or 225°.

\[ \tan \alpha_{1} = \frac{\tan \alpha}{\sqrt{2}} \]  \hspace{1cm} (29)

Therefore

\[ \alpha_{1} = \arctan \frac{\tan \alpha}{\sqrt{2}} \]  \hspace{1cm} (30)

The coverage width \( W \) can be obtained from the above formula.

According to the section view of figure 4 and the angle \( \alpha \_1 \) of the intersection line between the section and the bottom surface and the horizontal plane, it can be known that the angle between the line direction and the normal projection of the submarine slope on the horizontal plane is 135° or 315°, and the angle between the direction of the survey line and the normal projection of the submarine slope is 45° or 225°.

Therefore, these two situations can be classified as one situation.

### 3.2.2 solution of geometric model.

The open angle of the multi-beam transducer is 120°, the slope is 1.5°, the depth of the sea water at the central point of the sea area is 120m and the distance \( x \) between the measuring ship and the central point of the sea area is given. Using the geometric model established, the coverage width \( W \) of multi-beam sounding at the position listed in the table can be calculated. The calculated results are shown in Table 3.
It is known from Table 3 that when the angle between the measuring line direction is 0 ° and 180 °, the larger the distance between the measuring ship and the center point of the sea area, the coverage width W remains unchanged; when the angle between the measuring line direction is 45 °, 90 ° and 135 °, the larger the distance between the measuring ship and the center point of the sea area is, the coverage width W shows an increasing trend; when the angle between the measuring line direction is 225 °, 270 ° and 315 °, the larger the distance between the measuring ship and the center point of the sea area, the coverage width W shows a decreasing trend.

<table>
<thead>
<tr>
<th>Angle of measurement line direction/°</th>
<th>Measure the distance/nautical mile between the ship and the center point of the sea area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>415.69</td>
</tr>
<tr>
<td>45</td>
<td>416.19</td>
</tr>
<tr>
<td>90</td>
<td>416.69</td>
</tr>
<tr>
<td>135</td>
<td>416.19</td>
</tr>
<tr>
<td>180</td>
<td>415.69</td>
</tr>
<tr>
<td>225</td>
<td>416.19</td>
</tr>
<tr>
<td>270</td>
<td>416.69</td>
</tr>
<tr>
<td>315</td>
<td>416.19</td>
</tr>
</tbody>
</table>

3.2.3 Test of geometric model.

If the adjacent distance is 0.6 nautical miles, the open angle of the multi-beam transducer is 120 °, the slope is 1.5 °, and the seawater depth is 120 m at the center of the sea area. The coverage width W of the listed position multi-beam sounding can be calculated by using the geometric model established.

When the angle between the measuring line direction is 0 ° and 180 °, the larger the distance between the measuring ship and the center point of the sea area, the coverage width W remains the same; when the angle between the measuring line direction is 45 °, 90 ° and 135 °, the larger the distance between the measuring ship and the center point of the sea area is, the larger the coverage width W is; when the angle between the measuring line direction is 225 °, 270 ° and 315 °, the larger the distance between the measuring ship and the center point of the sea area is, and the coverage width W shows a decreasing trend.

This conclusion is the same as that obtained by using the distance x (that is, 0.3 nautical miles) between the measuring ship and the center of the sea area, so the model is correct.

4. Conclusions

In this paper, a geometric model is established to study the problem of multi-beam sounding line deployment. In this paper, the index of multi-beam sounding is calculated firstly. The geometric model of the path of the acoustic signal transmitted by the measuring ship and the transducer of the measuring ship, the seabed slope and the plane perpendicular to the direction of the measuring line are established. The mathematical relationship between the coverage width W of multi-beam sounding and the overlap rate between adjacent strips is obtained, and the overlap rate between adjacent strips is calculated. Finally, the model is tested to meet the robustness and the model is correct. Secondly, this paper studies the coverage width W of multi-beam sounding. According to the two cases that the coverage width W has nothing to do with the slope of the seabed and the coverage width W has something to do with the slope of the seabed, the geometric models of the measurement ship, the path of the acoustic signal emitted by the transducer of the measurement ship, the seabed slope and the plane perpendicular to the direction of the survey line are established respectively, and the geometric model is tested. The model is correct.
References


