Detection method of interception network and related attachments based on high resolution multibeam acoustic imaging

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Abstract. Aiming at the blocking problem of the interceptor network at the intake of the nuclear power plant, a detection method of interceptor network and related attachments based on high-resolution multi beam acoustic imaging is proposed. The high-frequency multi beam detection pool test of interceptor network and related attachments is carried out, in which the attachment is selected from the kelp, and the echo characteristics test of interceptor network and interceptor Network + kelp are analyzed. During the experiment, clear intercepting net and intercepting net + kelp acoustic image are obtained, which verifies the feasibility of using high-resolution multi beam acoustic imaging method to detect intercepting net and related attachments. Through the comparison of the detection results of the interception network and the interception network + kelp, it is known that the echo highlights of the interception network will be enhanced after the kelp is attached. Therefore, the echo highlights can qualitatively describe the existence state of the attachments on the interception network.

1. Introduction
A large amount of "domestic waste" is easy to collect on the sea surface of the cold source water intake of nuclear power plant, and "the explosive growth of algae", "a large number of fish and shrimp suddenly gather" block the trash net, resulting in the decrease of the water intake flow, resulting in the shutdown or power reduction operation of the unit due to the lack of cooling water. At present, many nuclear power plants have experienced serious incidents of marine organisms blocking the cold source water intake of nuclear power plants, such as the invasion of marine organisms and marine garbage in Hainan nuclear power plant, the invasion of wheat straw, Enteromorpha, laver and shrimp in Tianwan nuclear power plant, the invasion of jellyfish in Hongyanhe power plant, and the invasion of thallus in Ningde nuclear power plant. [1]In order to ensure the safety of water intake of nuclear power plant, it is urgent to improve the cold source water intake project of Binhai nuclear power plant. Among them, the monitoring technology of the anti sea biological interception network at the water intake is an important measure for the improvement of the cold source water intake project of the nuclear power plant. The monitoring and early warning system is set up at the water intake interception network to monitor the interception of marine organisms in real time, so as to reduce or avoid the economic loss caused by the shutdown or power reduction of the unit caused by the invasion of marine organisms. [2-4] In this paper, a detection method based on high-resolution multibeam acoustic imaging for interceptor network and related attachments is proposed. The echo characteristics of interceptor network and related attachments are tested and studied. Clear interceptor network and interceptor...
Network + kelp acoustic image are obtained by detection. The feasibility of detecting interceptor network and related attachments with high-resolution multibeam acoustic imaging is verified. It is the cold source water of subsequent nuclear power plants, providing the basis for field measurement and analysis for the early warning and disposal of marine organisms in this area[5].

2. Principle

The so-called beamforming technology refers to the method of forming spatial directivity by processing the output of each element of the array with a certain geometry (line, cylinder, arc, etc.) through processing (such as weighting, time delay, summation, etc.). The beamforming processing method in underwater acoustic engineering is to properly process the channel data of underwater multiple acoustic array, so that the output of the whole array has the required response to the sound waves in some spatial directions. Therefore, a beamformer can be regarded as a spatial filter, which can filter out the signals of certain directions in space and only let the signals of specified directions pass through. There are many methods of beamforming, especially in practical application. With the rapid development of microelectronics technology and computing technology, digital signal processing technology makes time-domain and frequency-domain beamforming methods run through each other[6].

Plane array is a rectangular array placed horizontally in the horizontal plane, which is composed of m X n elements. The geometric relationship is shown in the figure below. Taking the array element at the upper left corner of the array as the reference point, there are n uniform linear arrays with a spacing of d on the X axis. In addition, assuming that the incident azimuth of the signal is \( \theta \) and the pitch angle is \( \phi \), where the azimuth represents the angle between the signal and the X axis, the time delay between the signal and the reference array element caused by the incident on the k-th array element is[7]:

\[
\tau = \frac{1}{c} \left( x_k \cos \theta \cos \phi + \sin \theta \cos \phi \right) \quad (1)
\]

Where C is the propagation speed of sound wave. Therefore, the output amplitude of the normalized array is:

\[
R(\theta) = \sum_{i=1}^{m} g_i e^{-j(\gamma_i \cos \theta \cos \phi + \gamma_i \sin \theta \cos \phi) \frac{2\pi}{\lambda}} = \sum_{i=1}^{m} \sum_{k=1}^{n} e^{-j(\gamma_i - \gamma_k) \frac{2\pi d}{\lambda} \sin \theta \cos \phi - j(k-1) \frac{2\pi d}{\lambda} \sin \theta \cos \phi} = \sum_{i=1}^{m} e^{-j(\gamma_i - \gamma_k) \frac{2\pi d}{\lambda} \sin \theta \cos \phi} \sum_{k=1}^{n} e^{j(k-1) \frac{2\pi d}{\lambda} \sin \theta \cos \phi} = G_{row}(\theta) G_{col}(\phi) \quad (2)
\]

The high frequency multi beam acoustic imaging technology is based on the acoustic plane array. The detection results are output in the form of acoustic image through the plane array beamforming, and the detection of weak targets is realized by using its high signal-to-noise ratio gain.
3. Test survey

In order to explore the feasibility of high-resolution multi beam acoustic imaging method to detect interceptor network and related attachments, the high-frequency multi beam detection pool test of interceptor network and related attachments was carried out, in which the attachment was selected as kelp. The test contents are the echo characteristic test of interceptor network and the echo characteristic test of interceptor Network + kelp. The detection target kelp and interception network are shown in Figure 2.

The experiment was carried out in the pool of Key Laboratory of underwater measurement and control technology of Dalian Institute of measurement and control technology. The length of the pool is 2m, the width is 1.5m, and the height is 0.8m. Among them, the pool is fresh water. The test pool is shown in Figure 3. During the test, the sonar deck unit and data acquisition computer are installed, and the sonar is placed in the middle of the water side. After the system is connected, power on commissioning shall be carried out to collect background noise; the intercepting net shall be placed in the pool, about 1 meter away from sonar, and sonar shall be used to detect the intercepting net in water; the kelp shall be hung on the intercepting net, and sonar shall be used to detect the intercepting net + kelp in water; the system shall be recovered and the test shall be ended. The test layout is shown in Figure 4.
4. Test result

4.1. Echo data processing and analysis of interception network

In this pool test, due to the small size of the pool, the echo signal of the pool wall and water surface will be measured in the test. Figure 5 is the screenshot of the sonar detection results in the test, Figure 6 is the location mark of the echo signal of the pool wall and water surface, and the data in the middle part of the image is the main data concerned.

After removing the interference of pool wall and water surface, the echo image of interceptor network is extracted as shown in Figure 7. The bright spot in the picture (called bright spot) is the underwater target detected by sonar. The darker the bright spot color is, the stronger the echo is. In the picture, there are strong highlights on both sides and above, while weak highlights in the middle. Due to the large area of the intercepting network and the lack of counterweight in the test, and the low density of the intercepting network, there are many intercepting networks near the water surface and the pool walls on both sides in a folded state, resulting in strong echo. The middle part of the interception network is in a flat state, with less folding, so the echo is weak. In addition, due to the small size of the pool, only the interference of the pool wall and water surface can be removed as much as possible, and there will still be some residual signals.
4.2. Data processing and analysis of interception network + kelp echo

During the test, many kelps are placed on the intercepting net. Because of the small density of kelps, most of them are floating near the water surface, while only a few are in the water. The sonar detection results are shown in Figure 8, which can find obvious strip highlights in the figure.

After removing the interference of pool wall and water surface, the echo image of intercepting net + kelp is extracted as shown in Figure 9. Compared with the detection results of the above interceptor network, there are many bright spots in the sea belt, that is, the bright spots produced by the sea belt in water. And the intensity of bright spots produced by kelp is greater than that produced by intercepting net. It can be seen that when intercepting the attached kelp on the Internet and using sonar for detection, the bright spot will be enhanced.

5. Conclusion

In this paper, the underwater acoustic high-resolution multibeam detection method is used to detect the interception network and the interception network + kelp, respectively, to obtain their echo characteristics. Through the comparison of the results, it is found that the echo highlights of the interception network will be enhanced after the attachment of kelp. Therefore, the echo highlights can qualitatively describe the existence of the attachments on the interception network, and also preliminarily verify the feasibility of high-resolution multi beam acoustic imaging method to detect the interception network and its related accessories. Because of the small size of the test tank, the test is easy to be interfered by the tank wall and interface. Therefore, the larger test pool or sea area will be selected to reduce the interference of pool wall and interface. At the same time, the high-resolution multi beam acoustic imaging method is further studied for the detection of interception network and related attachments. The research contents include: echo characteristics test and feature extraction of different attachments, detection and identification of attachments of interception network, quantitative description of the attachment of interception network.

Acknowledgments

First of all, I would like to extend my sincere gratitude to my supervisor, Xuegang Zhang, for her instructive advices on my thesis. I am deeply grateful of her help in the completion of this thesis.

I am also deeply indebted to all the other tutors and teachers in Translation Studies for their direct and indirect help to me.

Special thanks should go to my friends who have put considerable time and effort into their comments on the draft.

Finally, I am indebted to my parents for their continuous support and encouragement.

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