

Simulated Research on Passive Sonar Range Using Different Hydrographic Conditions

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Abstract. As an example using the passive sonar, it calculated the quality factor of passive sonar using the sonar equation. The sound field was calculated under different depth and range using multiform hydrographic conditions. The isoline of passive sonar quality factor was marked out on the sound field. The isoline also represented the passive sonar range. The simulation results showed that hydrographic conditions had important effect on passive sonar range. At the same hydrographic conditions, the permissible drawdown of passive sonar had important effect on passive sonar range. Thus, according to the hydrographic character, the passive sonar range could be improved by selecting suitable passive sonar permissible drawdown.

1 INTRODUCTION

The acoustic wave can transmit very far distance and it is very important physical field in the ocean[1,2,3]. The work of sonar based on the acoustic wave[4]. The oceanic ambient has important effect on acoustic wave transmission[5,6,7]. The vertical change of the temperature and salinity of the sea water created the acoustic wave refraction. Sonar can detect and identify underwater target using the acoustic wave. It can also locate or communicate in the ocean using the acoustic wave. Sonar equation correlated the acoustic ambient and target and the sonar. Sonar equation was used to design sonar and estimate the sonar range. Passive sonar equation can be expressed using the followed formula[8].

$$SL - TL = NL - DI + DT \quad (1)$$

SL is the source level and the NL is noise level. TL is the transmission loss of acoustic wave. [1,2,3] is the receiving directional factor. DT is the threshold of detectability. The sonar quality factor can be expressed using the followed formula.

$$TLO = SL - NL + DI - DT \quad (2)$$

TLO is the sonar quality factor. It calculated the sound field under different conditions of sound speed profile. The isoline of sonar quality factor was marked out on the sound field. Thus, it could analyze the effect of ambient character on sonar range and it could also give the method for improving the sonar performance using the ambient character.

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2 METHODOLOGY AND RESULTS

2.1 Calculating the passive sonar range under different hydrographic conditions

The assumed frequency was 2000Hz. The hydrographic conditions were winter and summer sound speed profile. The assumed parameters such as SL , NL , DI and DT were substituted to the equation (2). The passive sonar quality factors were 74dB, 79dB, 71dB and 77dB corresponded to spring, summer, autumn and winter. The sound speed profiles for different seasons were expressed in Figure.1. The blue solid line, green '+' line, red 'o' line and black dash dot line denoted the sound speed profile of spring, summer, autumn and winter. There was a shallow sound speed jump layer in spring. Sound speed presented weak positive gradient distribution under the jump layer. During the summer, there was temperature jump layer in sea water. The sound speed profile was complex. The upper layer of sea water was jump layer. Lower part of the jump layer was negative gradient. It was iso sound speed distribution in summer sound speed profile under 45m. The jump layer became deeper in autumn. Sound speed profile presented weak negative gradient distribution under the jump layer. Sound speed presented weak positive gradient in winter because of the isothermal distribution. The sound speed increased following the depth.

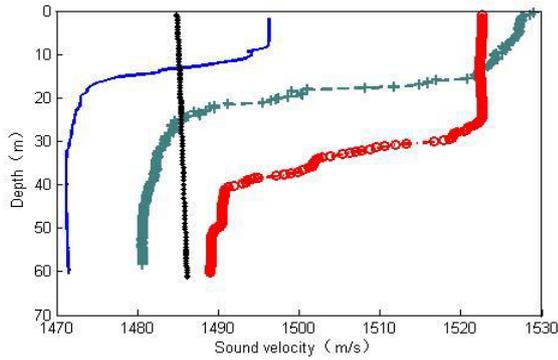


Figure.1 The sound speed profile for different seasons

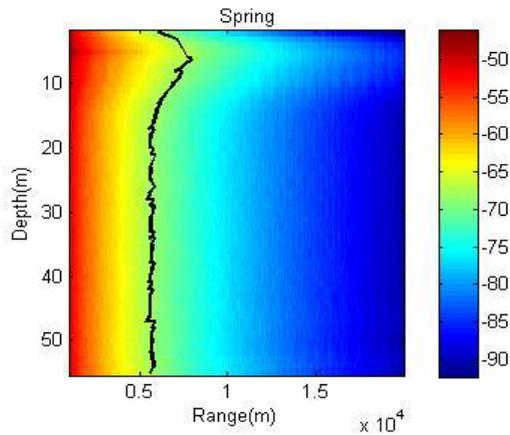


Figure.2 Passive sonar range for spring hydrographic conditions, the black solid line was isoline of sonar quality factor

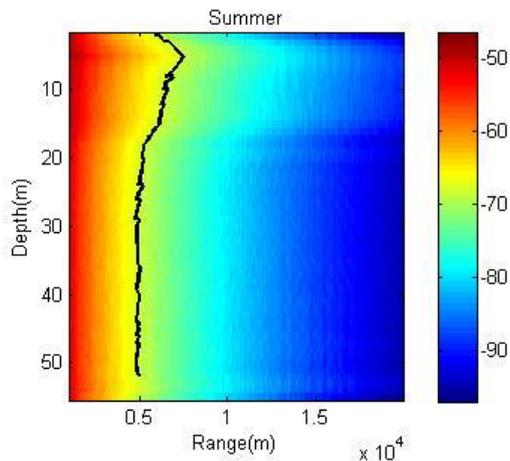


Figure.3 Passive sonar range for summer hydrographic conditions, the black solid line was isoline of sonar quality factor

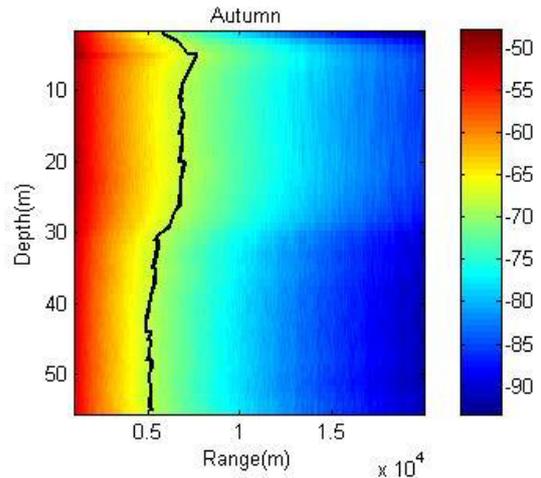


Figure.4 Passive sonar range for autumn hydrographic conditions, the black solid line was isoline of sonar quality factor

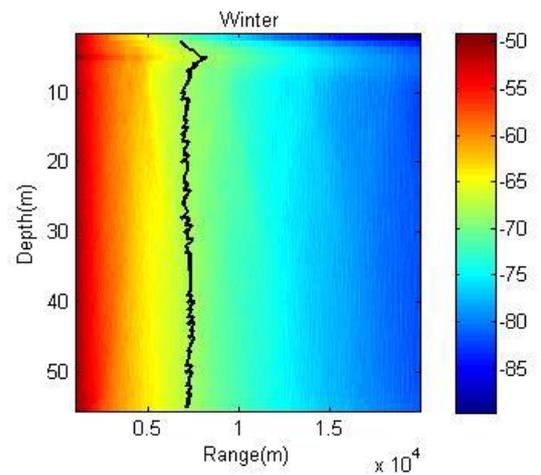


Figure.5 Passive sonar range for winter hydrographic conditions, the black solid line was isoline of sonar quality factor

The depth of the sea water was 60m. The permissible drawdown of the passive sonar was 5m. It was 2-55m permissible drawdown for the sound source and the step length was 1m. The sound field was calculated using software under different sound speed profiles. The isoline of sonar factor was marked out in the sound field, such as figure.2 to figure.5. These four pictures corresponded to the simulated results on different seasons. The black solid line was isoline of sonar quality factor in these figures. For example, the water depth was 25m. These pictures showed that the passive sonar range was 6.5km, 5.8km, 7.7km and 8.4km corresponded to spring, summer, autumn, and winter. Thus, acoustic wave could transmit far more distance in winter. There were sound speed jump layer in other seasons. The jump layer would induce the refraction loss of sound ray which limited the transmission of the acoustic wave. The hydrographic conditions were most complex in summer and the sonar range was least distance. The sonar performance fell down 31% in summer compared to winter. The sonar range was far bigger in winter than summer. So, the hydrographic conditions had important effect on passive sonar range. The passive sonar range would greatly fall

down when the jump layer was presence. In the next section, it would talk out the method for improving sonar range using acoustic ambient character.

2.2 Improving the sonar range under the same hydrographic conditions

The frequency was assumed as 2000Hz. The permissible drawdown of passive sonar was 5m, 15m, 25m, 35m and 45m. The sound source depth was from 2m to 55m and the step was 1m. Under the hydrographic conditions of winter and summer, sonar range isoline was calculated in different sonar permissible drawdown. It was showed in figure.6 to figure9. The solid line, “-+” line, “-o” line, “-*” line and “-.” line separately represented the isoline of sonar range for sonar permissible drawdown 5m, 15m, 25m, 35m and 45m. Fig.6 corresponded to simulated results on spring and summer seasons. And Fig.7 corresponded to the results on autumn and winter seasons.

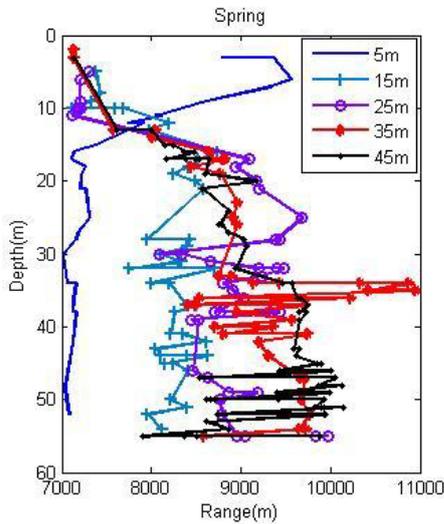


Figure.6 The isoline of passive sonar range on different depth for spring

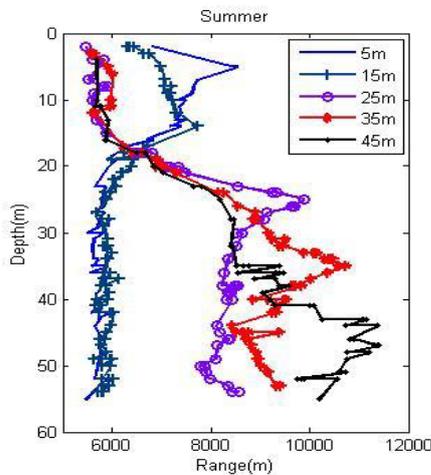


Figure.7 The isoline of passive sonar range on different depth for summer

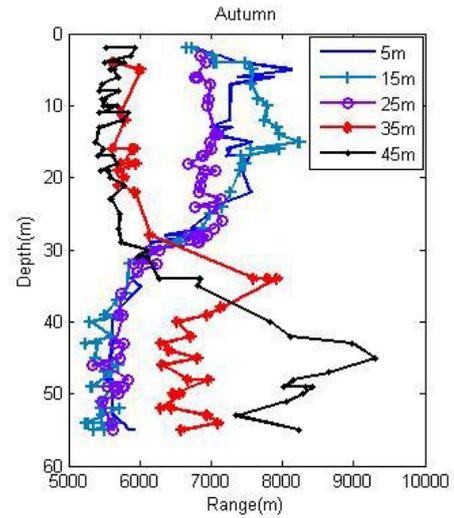


Figure.8 The isoline of passive sonar range on different depth for autumn

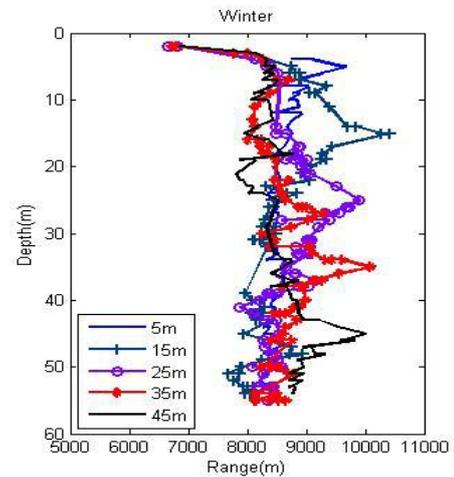


Figure.9 The isoline of passive sonar range on different depth for winter

Figure.6 to figure.9 showed that passive sonar range was biggest when the passive sonar permissible drawdown was the same as the sound source. The depth of sound speed jump layer was shallow in spring and it was about 10~20m. The sound speed had little change under the jump layer. It assumed that the passive sonar was put on the jump layer. The passive sonar range had far more distance when sound source was also put on the jump layer. As the depth change of sound source from shallow to deep, passive sonar range decreased gradually. When the sound source was put under the jump layer, the passive sonar range had least distance.

In summer, passive sonar permissible drawdown had important effect on sonar range. Sonar worked in the jump layer when it's permissible drawdown between 5~15m. When the permissible drawdown of the sound source was also in the jump layer, sonar range was about 7km. Sonar range decreased as the sound source permissible drawdown becoming deeper. When the sound source worked under the jump layer, sonar range was least distance and was about 6km. To other sonar permissible drawdown, the sound velocity profile was

negative gradient distribution. When the sound source worked under the jump layer, sonar range was far more distance and was not less than 8km. When the sound source worked on the jump layer, sonar range was not more than 6km.

In autumn, the sound speed jump layer distributed between the depth of 25~40m. When passive sonar and the sound source were put on the same side of the jump layer, the sonar range had far more distance. Contrarily, the passive sonar range had least distance. When passive sonar and sound source were all put in the jump layer, the sonar range had medium distance.

In winter, the passive sonar range was about 8~9km and the sonar permissible drawdown had little effect on the sonar range. Because of the sound velocity profile was weak positive gradient distribution, thus the acoustic wave could transmit far more distance.

Thus, the jump layer had bad effect on acoustic wave transmission. Passive sonar range was least distance when passive sonar and sound source worked on different sides of the jump layer. Sonar range was most distance when passive sonar and sound source worked under the jump layer.

CONCLUSIONS

It obtained some conclusions from these simulated results. The hydrographic conditions had important effect on passive sonar range. Passive sonar range had near distance when there was sound speed jump layer in water. Passive sonar range had far more distance when there was no sound speed jump layer in water. It assumed that the hydrographic condition was definite. The permissible drawdown of passive sonar had important effect on sonar range. Especially there was sound speed jump layer in water. When passive sonar and the sound source were put on the same side of the jump layer, the passive sonar range had far more distance. Contrarily, the passive sonar range had least distance. When passive sonar and sound source were all put in the jump layer, the sonar range had medium distance. Thus, in order to improve the sonar range, it could change the permissible drawdown of passive sonar according to hydrographic condition.

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