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Passive Sonar Performance Analysis Employing the Concept ‘Robustness of Detection’

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1. Introduction

Normally, a military platform searching for underwater targets has multiple sonars of both active and passive types. The platform uses passive sonars for long-range detection and identification against hostile targets. For maeasuring the performance of passive sonar, we usually consider detection range (DR) under the environment and system parameters in operation. When we have multiple sonars, however, we have to adopt a combined performance instead of the single one. In shallow water, where sound enevitably touches sea surface and bottom, detection normally maintains up to the maximum range. In deep water, however, sound may not interact with sea surface or/and bottom, and thus there may exist shadow zones in which sound can hardly reach. In this situation, DR alone can not completely define the performance of each sonar. For complete description of sonar performance, we employ the concept ‘Robustness of Detection (ROD)’.

This paper presents the two concepts: (1) combined performance for multiple sonars, (2) ROD for applying in deep water environment. We give some results specially focused on the relations among environment, DR and ROD in a water of Korean Peninsula. Finally, we conlude with confirming the effectiveness of ROD as one of the parameters measuring sonar performance in deep waters.

2. Sonar Detection Performance

2.1 Combined Performance

We can define detection performance of each passive sonar using its parameters and environment in which it operates against targets. Sonar parameters include directivity index (DI) and detection threshold (DT). The typical environment includes transmission loss (TL) between target and sonar, and ambient noise (AN) at each frequency. The target is defined as its source level, the degree of radiated noise. With these variables, we can compute signal excess (SE) of each sonar as following. Further detection probability could be calculated assuming the normal distribution of signal excess.

$$SE = SL - TL - AN + (DI - DT) \qquad (1)$$

When we have multiple sonars of which frequency bands are different, we have to consider a combined performance index in which all the sonar performances are merged. The combining may be done in two phases. First, at one grid point of the study area, we compute the maximum DR for selected frequency and each bearing of equally divided in 360°. If multiple sonars share their frequency, we select the sonar which has the maximum DR and regard it as representing combined performance of the bearing considered. Fig. 1 shows the concept.

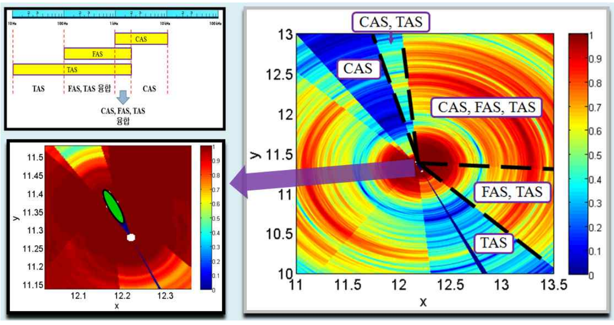

Fig.1 Combined performance of multiple sonars.

Based on the combined performance, we can compute DR at each grid point of all sonars considered as following.

$$DR = \sum_{i=1}^{N} D_i \Big/ N \qquad (2)$$

Here, D_i and N represent the maximum DR at the i-th bearing and number of bearings equally divided in 360°, respectively.

2.2 Robustness of Detection (ROD)

The concept ‘Maximum DR’ is incomplete definition to measure the performance of a sonar specially in deep water because there may exist shadow zones in horizontal and vertical directions. To complete the performance of a sonar, we adopt another definition ‘ROD’ as following.[1]

$$ROD = \frac{D_B - D_A}{D_B} \times 100\ (\%) \quad (3)$$

Here, D_A and D_B denote shadow zone and maximum DR, respectively. Fig. 2 shows definitions.

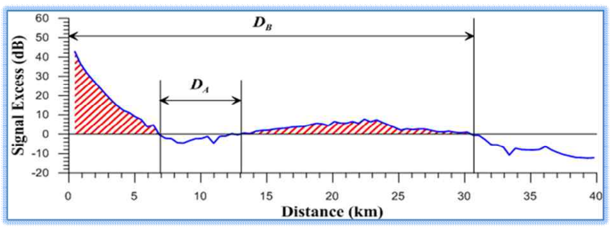

Fig.2 Shadow zone(D_A) and detection range(D_B).

3. Results

We select a Northeastern area of Korean Peninsula which has about 80 grid points. Figure 3 presents bathymetry and horizontal slices of 60m depth. The slices are temperature, DR (ratios relative to the maximum) and ROD (%) based on the re-analyzed environment at 28 October, 2007. We employ a model of Gaussian beam tracing scheme.[2]

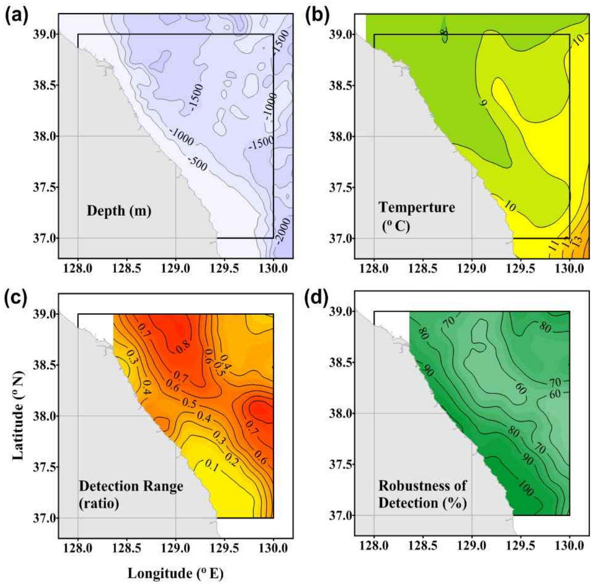

Fig.3 Horizontal distributions of (a) bathymetry, (b) temperature, (c) DR and (d) ROD.

The DR (Fig.3c) shows high values in the Northwestern direction (315°), where North Korean Cold Water develops along the bathymetry.[3] Extremely low DR in lower part is due to relatively shallow flat bathymetry (Fig.3a) where sound energy quickly decays by frequent interactions with the sea surface and bottom. When we look into the ROD variation (Fig.3d), we can see that it shows reverse patterns to the DR variation. The ROD gives low values in the Northwestern direction (315°), where DR does high values. Meanwhile, in the regions along the coastline and upper right (Fig.3d), ROD shows high values when DR does low values (Fig.3c). In this example, DR and ROD variations show exactly negative phases, and this fact suggest we should consider DR and ROD at the same time for complete description of sonar performance in deep water of complicated environment.

Fig. 4 gives one-year variation of DR in the study area. We get the DR every 10 days by taking average over 80 grid points.

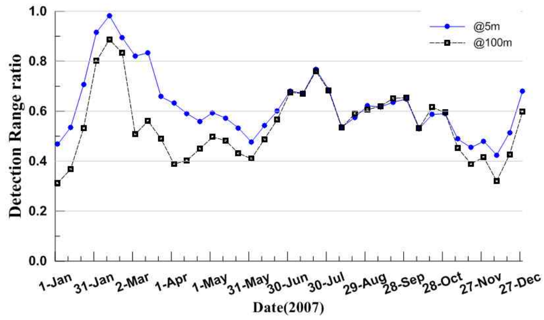

Fig.4 One-year variation of DR in the study area.

From the figure, we can see big variation in a year at the two receiver depths of 5m and 100m, the variations being assumed to be highly related to relative changes of water masses in the area. The two curves show same trend but do difference specially from November to May.

4. Conclusions

We confirm the ROD is efficient as one of the parameters measuring sonar performance in deep waters. In the environment like the study area, the variation of ROD is exactly reverse to that of DR, implying that we have to employ the two concepts simultaneously for complete measurement of sonar performance.

References

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