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Noise Directionality Estimated by Using the Ship Track Data in the Southern Sea of Korea

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1. Introduction

A major contributor to marine background noise in the low-frequency band (< 1 kHz) is ship-radiated sound, which is especially noticeable in coastal areas around harbors and shipping lanes.[1)] The number and tonnage of vessels operating globally has increased significantly in recent decades with the expansion of international trade.[2)] As interest in protecting marine ecosystems around the world has increased, several studies are underway to observe and predict ship noise in the oceans. As an example, the National Oceanic and Atmospheric Administration (NOAA) has been working on creating noise maps around the world using navigational information on global shipping, aimed at addressing noise impacts on marine life.

In this paper, we studied the prediction of underwater noise directionality of ships using ship-track data observed in the southern sea of Korea. An Automatic Identification System (AIS) was used to observe ship navigation information. This is a device adopted by the International Maritime Organization (IMO) to monitor ship specifications between ship-to-ship and land-to-ship for the purpose of enhancing the safety and security of navigation.[3)]

2. Field Measurements

The AIS was installed near the coast to record both dynamic and static information of each ship passing through the study area, including Maritime Mobile Service Identity (MMSI), time, heading, position, length overall, and speed. Approximately 364 unique vessels were identified during the measurement period. The movement patterns of each ship extracted from the dynamic information of the AIS data were very complex (blue solid line in **Fig. 1**).

While observing ship navigation information with the AIS, the noise directionality was measured using a horizontal line array (HLA) at the point of the red circle shown in Fig. 1. The HLA is a nested line array consisting of 21 sensors with a length of 70 m, and this was moored on the sea floor (**Fig. 2**).

Figure 1 shows the measured maritime movement patterns. It can be seen that there are small vessels sailing around the coast, fishing vessels operating in shallow water, vessels anchoring around the port, and large vessels sailing from China and Southeast Asia to Korea and Japan.

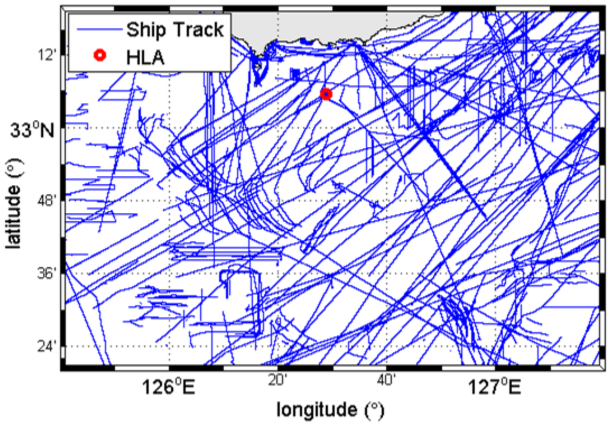

Fig. 1 Measured ship-track (blue solid line) and HLA moored location (red circle).

Large vessels, including merchant, cargo, and passenger ships, are required to have an AIS on board for safety navigation at sea, but for small vessels, such as fishing boats, it is not required. Thus, there may have been ships in the experimental area that were not observed with the AIS. Additionally, the AIS antenna used in the experiment was small and portable, and it is not easy to measure navigation data for a ship over 50 nautical miles away.

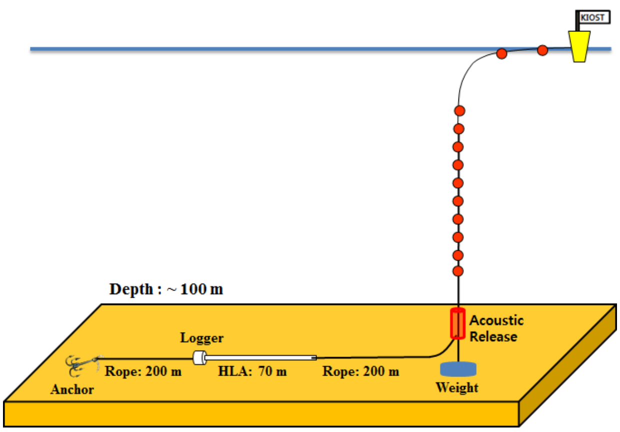

Fig. 2 Schematic of the HLA deployed on the sea floor.

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3. Modeling

The Range-dependent Acoustic Model (RAM), which is an acoustic propagation model, was used to calculate the spatio-temporal noise distribution using the positions of vessels measured with the AIS. We used databases of bathymetry (ETOPO1) and water column sound speed (GDEM), provided by NOAA, to construct the input parameters of the acoustic model. The attenuation and density of the bottom were estimated using the geoacoustic properties measured by Korea Institute of Ocean Science and Technology (KIOST).

As shown in **Fig. 3**, the spatial distribution of transmission loss for the study area was calculated from the location where the HLA was deployed. Using the distribution of spatio-temporal ship noise and the transmission loss, the intensity of the noise according to the azimuth angle can be calculated from the location of HLA, which will be compared with the measured noise directionality.

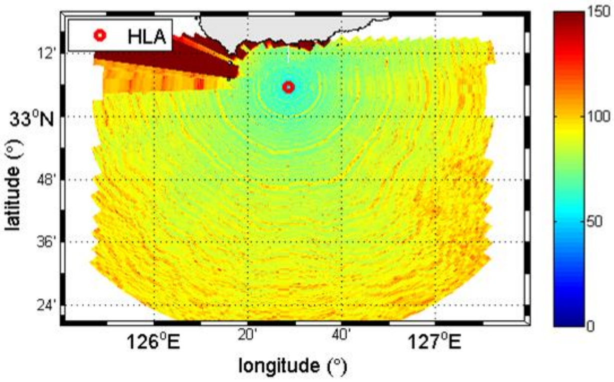

Fig. 3 Transmission loss in the ocean from the location where the horizontal line array was moored (frequency: 410 Hz, HLA depth: 99 m, ship source depth: 6 m).

4. Results

Figure 4 shows the estimated noise directionality during the measurement time at frequencies of 195 Hz and 410 Hz. The HLA used in the experiment was deployed in the direction of -103°, where an azimuth of 0° indicates north. The directional noise was measured continuously between 50 to 100 and -50 to -150° for the whole measuring time. It can also be seen that the directional noise changed intermittently in a short time, with several vessels passing quickly near the moored HLA.

The noise directionality averaged over time is plotted in **Fig. 5** at both frequencies, where the noise intensities coming from the port direction are higher than those from other directions. This is thought to be due to the continuous impact of vessels anchoring or operating at the port. There may also be an effect of small fishing vessel data that were not received by the AIS. As shown in Fig. 5, the noise directionality was symmetrical with respect to the direction in which the HLA was deployed. Thus, beam-pattern ambiguity will be considered when analyzing the directional noise using the measured shipping noise.

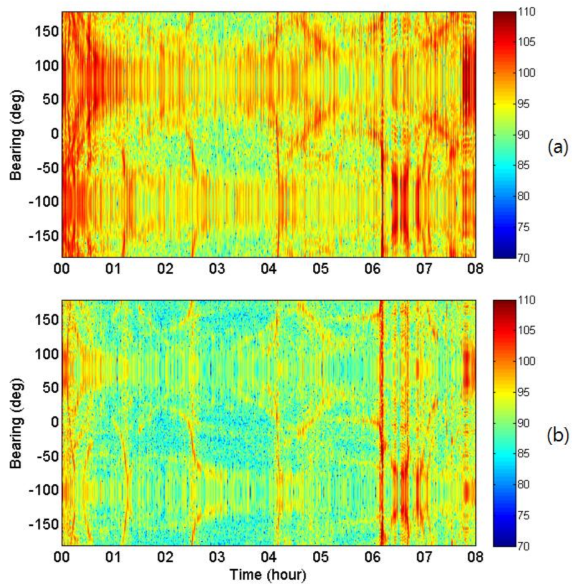

Fig. 4 Noise directivity calculated using conventional beam-forming at 10-s intervals (a) 195 Hz, (b) 410 Hz.

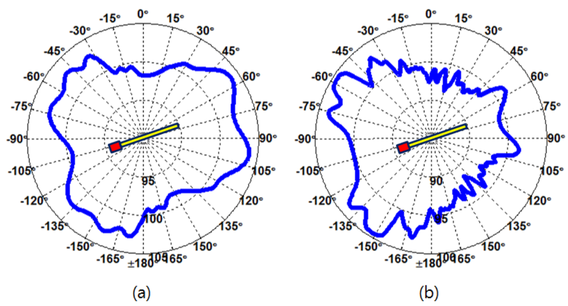

Fig. 5 Noise directionality calculated by averaging over the entire time using conventional beam-forming (a) 195 Hz, (b) 410 Hz.

Acknowledgment

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