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Array Gain Variation of Bulb Signals in Vertically Directional Noise Field

Dong-Gyun Han[1‡], Su-Uk Son[1], Young Geul Yoon[1], Jee Woong Choi[1], and Joung-Soo Park[2] ([1]Dep. of Marine Sci. & Convergence Eng., Hanyang Univ.; [2]Agency for Defense Development)

1. Introduction

Underwater ambient noise has temporal and spatial variations due to the contribution of various noise sources distributed in the ocean. One of dominant sources of ambient noise originates from distant ships, which is generally in the frequency range of 10-200 Hz and has strong horizontal directionality. On the other hand, wind-driven noise dominates at frequencies above 200 Hz and has vertical directionality [1]. Anisotropic noise can be a limiting factor for sonar array system because it causes array signal gain degradation(ASGD). Therefore, it is important to understand how anisotropic ambient noise affects the array performance [2,3].

In this paper, acoustic experiment using a light bulb as a source were made in eastern coast of Korea to investigate the array gain in vertically directional noise-field. The estimated array gain is compared with the simulation results predicted after considering the noise directionality.

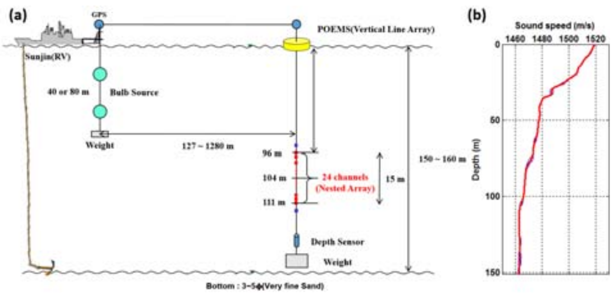

Fig. 1 (a) Experimental geometry for acoustic measurements and (b) sound speed profile measured by XBT cast.

2. Field measurements

Field experiments were performed in eastern coast of Korea in water depth of about 150-160 m in July 13, 2009 [4]. Acoustic data were acquired using a vertical line array, called Portable Ocean Environment System(POEMS), which was moored at about 104 m in depth (**Fig. 1**). It consisted of 4 sub-band arrays with total 24 hydrophones. The light bulbs were used as a broadband sound source, which were imploded about 40 or 80 m in depth.

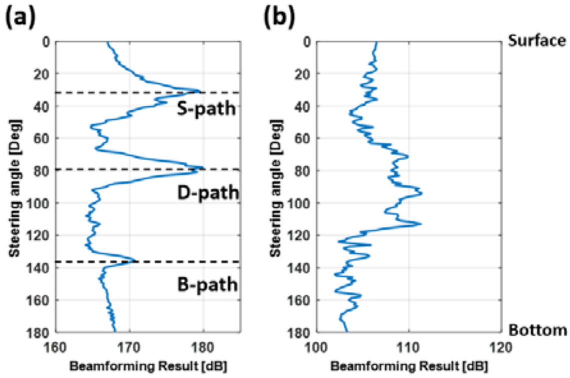

Fig. 2 Conventional beamforming results for (a) bulb signal and (b) ambient noise signal using sub-band 1 array of POEMS.

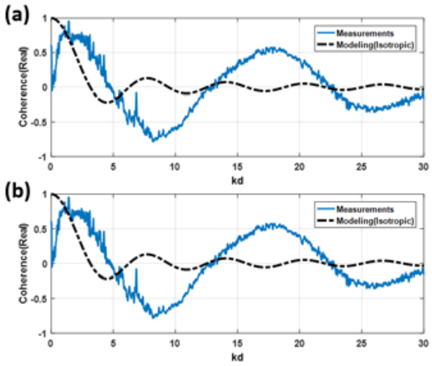

Fig. 3 Spatial coherences of the measured ambient noise and model predictions for isotropic noise-field; (a) real part (b) imaginary part.

Fig. 2 shows conventional beamforming results for bulb signals and ambient noise using sub-band 1 (with 9 elements and 1.875 m spacing) for the source depth of 80 m and the horizontal range between source and receiver of 127 m. The arrival angles of the direct path, surface bounced path, and bottom bounced path were estimated to be 78°, 31°, and 136°, respectively **[Fig. 2(a)]**. The beamforming results for ambient noise shows that the ambient noise power is concentrated in about 70-110°**[Fig. 2(b)]**. **Fig. 3** shows the spatial coherences of the measured ambient noise and its

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Correspondence to J. W. Choi : choijw@hanyang.ac.kr comparison to the simulation in isotropic noise field [5,6]. The measured coherence is not in agreement with the modeling results.

3. Simulation and results

Table I. shows the arrival angles for the direct, surface, and bottom paths predicted by a ray-based eigenray tracing and those estimated by beamforming method as well as the estimated array gains. Note that the array gain of the direct path is lower than that of surface path, although the beamforming output power of the direct path is higher than that of surface path. Because the noise field in the experimental site did not satisfy the isotropic condition, the array gains were not identical with the directivity index, and thus ASGD occurred except for the bottom path.

Table I. Estimated arrival angles and array gains for direct, surface, and bottom paths.

Path	Arrival Angle		Array Gain	Directivity Index
	Model (Numerical)	Beamforming Result		
Surface	34°	31°	7.7 dB	9.5 dB
Direct	80°	78°	4.6 dB	
Bottom	137°	136°	11 dB	

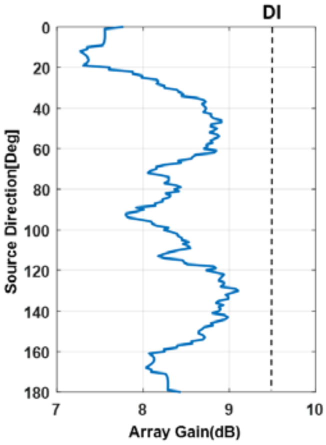

Fig. 4 The simulated array gain (solid line) as a function of angle. Dashed line is the directivity index for hydrophone number of 9.

To investigate the array gain variation due to the directional noise-field, the beamforming output for the noise-field seen in **Fig. 2(b)** is used as a weighting factor, which is multiplied by the simulated isotropic random noise signals. Then phase differences are compensated to simulate the noise signals received by each hydrophone element in the vertical line array, and it is repeated for every direction (with unit angle interval). Finally, the noise components for every direction were summed.

Fig. 4 shows the simulation result of array gain using the simulated anisotropic noise field. In this case, the same signal power for every direction was used. The results show that the array gain in the anisotropic noise field is always smaller than the directivity index, that is, ASGD occurs and it is inversely correlated with the directivity of the noise field.

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