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Source Level Estimation of the Snapping Shrimp Sound Observed in the Coastal Sea

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1. Introduction

The ambient noise in the ocean shows very different dependences on marine life as well as wind, rainfall, and shipping. The sources of ambient noise in the deep ocean are clearly identified from the summary of a large amount of data measured in the 1940s[1)]. According to this summary, the main sources of ambient noise are distant shipping and ocean surface wind. The ambient noise in the coastal sea is more complex than the noise in the deep ocean owing to the breaking waves in the surf zone and the marine life as well as the shipping and wind. Since the biological noise due to the marine life has very high diurnal dependence and seasonal variation, it has a greater effect on ambient noise than others[2)]. In particular, it is well known that the sounds of dolphins and snapping shrimp affect sonar ping signals[2, 3)]. In the coastal sea, where snapping shrimps live, their sounds always exist with ambient noise such as the noise due to shipping and wind. Therefore, the sound of snapping shrimps can effect ambient noise and sonar detection performance more than the sound of dolphins. For this reason, many researchers have measured and analyzed the snapping shrimp sound[4-8)]. In this study, we estimated peak to peak sound pressure source level of the snapping shrimp sound observed in the coastal sea.

2. Theory on Source Position Estimation

Figure 1 shows a schematic diagram to estimate the source level of snapping shrimp sound. As shown in **Fig 1**., when the sounds emitted from a snapping shrimp at a point S is received by three hydrophones at points P_x, P_y, and P_z, the sound traveling distances R_x, R_y, and R_z, are given in the forms

$$R_x = \sqrt{(x-1)^2 + y^2 + z^2}\,, \tag{1}$$

$$R_y = \sqrt{x^2 + (y-1)^2 + z^2}\,, \tag{2}$$

$$R_z = \sqrt{x^2 + y^2 + (z-1)^2}\,. \tag{3}$$

If arrival times of the snapping shrimp sound at points P_x, P_y, and P_z are measured, equations (1), (2), and (3) can be expressed as follows:

$$\sqrt{(x-1)^2 + y^2 + z^2} = \frac{(x-y)}{c(T_2+T_3)} - \frac{c(T_2+T_3)}{2}\,, \tag{4}$$

$$\sqrt{x^2 + (y-1)^2 + z^2} = \frac{(y-z)}{c(T_1+T_3)} - \frac{c(T_1+T_3)}{2}\,, \tag{5}$$

$$\sqrt{x^2 + y^2 + (z-1)^2} = \frac{(z-x)}{c(T_1+T_2)} - \frac{c(T_1+T_2)}{2}\,, \tag{6}$$

where c is sound speed in a medium, arrival time differences T_1, T_2, and T_3 are $T_1 = t_x - t_y$, $T_2 = t_y - t_z$, and $T_3 = t_z - t_x$, and t_x, t_y, and t_z are arrival times of the snapping shrimp sounds at the points P_x, P_y, and P_z.

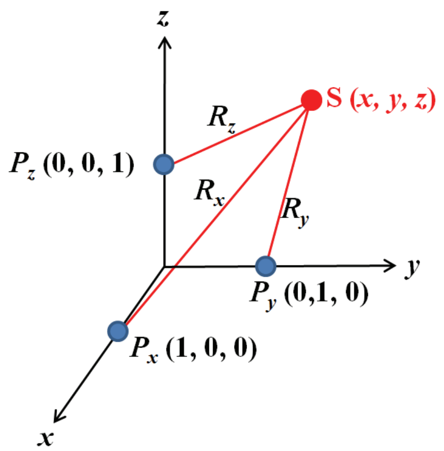

Fig. 1. Schematic diagram to estimate the source level of snapping shrimp sound.

When the arrival time differences T_1, T_2, and T_3 are known, x, y, and z in Eqs. (4), (5), and (6) can be obtained through numerical calculations of these equations. Then, the peak to peak source level of the snapping shrimp sound can beexpressed by

$$SL = 20\log P + 10\log R\,, \tag{7}$$

where P is peak to peak sound pressure amplitude of the snapping shrimp sound, R is the sound traveling distance between the hydrophone and the snapping shrimp. Since the snapping shrimps are distributed on the sea bottom in the coastal sea, z in **Fig. 1** is a constant value.

2. Experimental Measurements

Figure 2 shows schematic and block diagrams of experimental setup for acoustic measurements of the snapping shrimp sound in the coastal sea. Individual hydrophone in **Fig. 2(a)** was located at a distance of 1 m from a center point(O)

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of stainless frame. The Hydrophones 1, 2 (B&K, Type 8106), and 3 (B&K, Type 8101) are used to measure the snapping shrimp sound. The hydrophone 4 (B&K, Type 8106) is used as a auxiliary to estimate bearing of the snapping shrimp sound. The stainless frame with four hydrophones are deployed in Jukbyeon Harbour. The water depth was about 6 m. The distance between the center point of the frame and the sea bottom was about 1.45m. As shown in **Fig. 2(b)**, the snapping shrimp sounds received from the hydrophones were amplified through the acoustic measuring amplifiers((B&k, Type 2636), and then they were digitazed by the A/D converter (National Instrument, DAQCard-6062E).

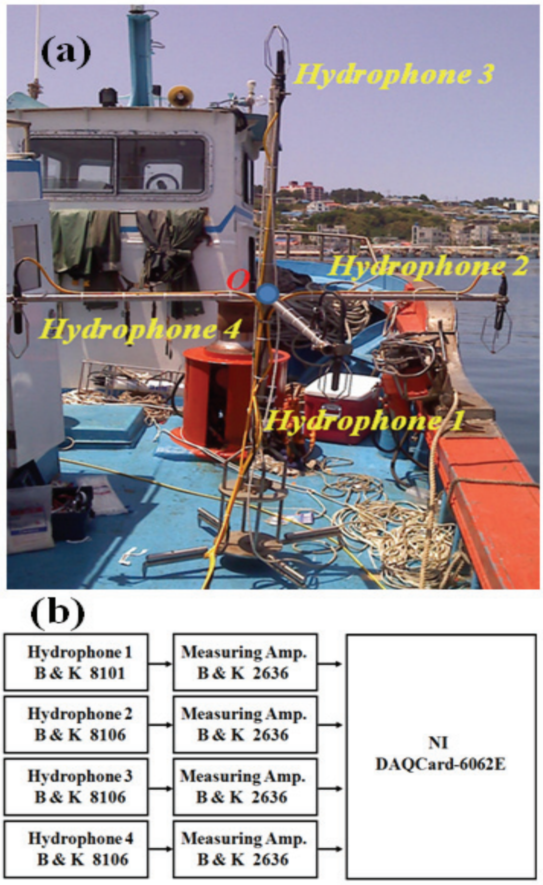

Fig. 2. (a) Schematic and (b) block diagrams of experimental setup for acoustic measurements of the snapping shrimp sound in the coastal sea.

3. Results

Figure 3 shows the typical temporal waveforms of sounds produced by the snapping shrimp in the coastal sea. The first pulses in **Fig. 3** are directly received signals in the hydrophones. The second pulses are signals reflected signals.

When the arrival time of the snapping shrimp sound received at each hydrophone in **Fig. 3** is measured, the peak to peak source level of the snapping shrimp sound can obtained by Eq. (7). **Figure 4** shows mean peak to peak source level of snapping shrimp sound measured by three hydrophones 1, 2, and 3. The median source level is 170 dB (*re* 1μPa) with lower quartile (164 dB *re* 1μPa) and upper quartile (176 dB *re* 1μPa).

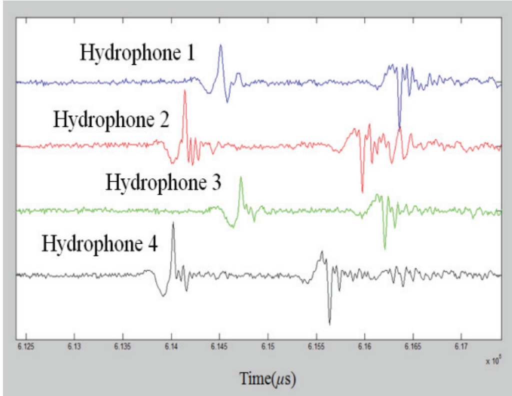

Fig. 3. Typical temporal waveforms of sounds produced by the snapping shrimp in the coastal sea.

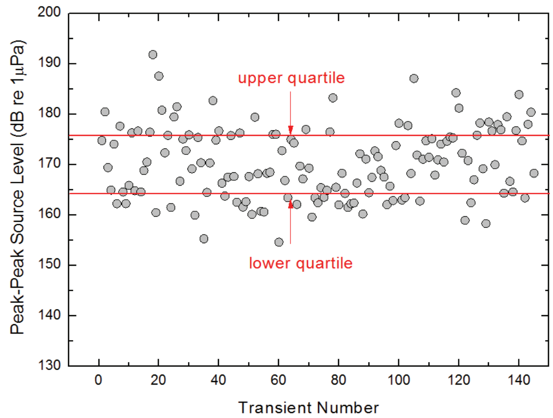

Fig. 4. Mean peak to peak source level of snapping shrimp sound measured by three hydrophones 1, 2, and 3.

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