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Variation of Underwater Ambient Noise Observed at IORS Station as a Pilot Study

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Abstract – The Ieodo Ocean Research Station(IORS) is an integrated meteorological and oceanographic observation base which was constructed on the Ieodo underwater rock located at a distance of about 150 km to the south-west of the Mara-do, the southernmost island in Korea. The underwater ambient noise level observed at the IORS was similar to the results of the shallow water surrounding the Korean Peninsula (Choi *et al*. 2003) and was higher than that of deep ocean (Wenz 1962). The wind dependence of ambient noise was dominant at frequencies of a few kHz. The surface current dependence of ambient noise showed good correlation with the ambient noise in the frequency of 10 kHz. Especially, the shrimp sound was estimated through investigations of waveform and spectrum and its main acoustic energy was about 40 dB larger than ambient noise level at 5 kHz.

Key words – oceanic ambient noise, shrimp sound, wind speed, surface current, Ieodo Ocean Research Station

1. Introduction

In the ocean, ambient noise always exists due to water surface agitation, biological activity and shipping traffic. Studies on underwater ambient noise have been performed by Knudsen (Knudsen *et al.* 1948) and Wenz (Wenz 1962). From these studies, ambient noise characteristics are famously described as the Knudsen spectra and Wenz curve. Nevertheless, these are limited to the deep sea. The underwater ambient noise is used as an input parameter of sonar equation (Urick 1983) to improve the signal-to-noise ratio of underwater acoustic instruments such as sonar. The ambient noise is also utilized as basic data for monitoring of rainfall and wind speed (Lemon *et al.* 1984; Nystuen 1986) on the sea surface. According to Lemon (1984) and Nystuen (1986), the sound from the whitecaps generated by wind can be used to quantitatively measure wind speed as the number of whitecaps is proportional to wind speed. The sound of rain and drizzle contains relatively more high frequency tones than the sound from wind-only conditions. Recently, a study of ambient noise in the sea around the Korean Peninsula, with a focus on this sea as a shallow water, has been carried out by Kim and Choi. (Kim *et al.* 1996; Choi *et al.* 2003). They report the ambient noise level is higher than that of the deep water as Wenz curve.

In this study the ambient noise was measured at the Ieodo Ocean Research Station (IORS) (Shim *et al.* 2004). The goal of this study is to collect the ambient noise data at the IORS and to estimate what the noise sources are. Wind speed and surface current speed as surrounding environment parameters were measured. In section 2, we introduce the measurement technique at the IORS station. In section 3, the statistical properties of ambient noise are described. Finally, we analyze the environmental effect to the ambient noise level and special signals such as the shrimp sound in sections 4 and 5. The goals of this study are as follows. Firstly, we acquire the ambient noise data of the IORS station and compare the data from the shallow water of the Korean Peninsula and the deep ocean ambient noise level. Secondly, we attempt to match the environmental parameters of wind, shipping and water current with the ambient noise spectrum levels. Here, we analyzed the

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relation between current and the ambient noise. Thirdly, we captured the special sound presumed to be the shrimp sound and compared this to other papers' results.

2. Underwater Noise Measurement at IORS Station

The IORS is an integrated meteorological and oceanographic observation base which was first constructed in Korea. It was constructed on the Ieodo underwater rock located at a distance of about 150 km to the south-west of Mara-do as shown in Fig. 1. The structure is a fixed jacket type installed at a water depth of 40 m. In order to understand the characteristics of oceanic ambient noise at the station, the ambient noise was measured for about 70 hours on July 2004. A hydrophone was used to catch the ambient noise at a depth of 20 m as shown in Fig. 2(a). The ambient noise levels at each center-frequency of one-third octave band from 25 Hz to 12.5 kHz were analyzed and processed in order to get average and standard deviations of noise levels. The Bruel & Kjaer model 8101, model 2636 and model 7006 were used as a hydrophone, a measuring amplifier and a tape recorder, respectively. The spectrum analysis was conducted by using a signal analyzer, the Bruel & Kjaer model 2035. Dependences of wind speed, current speed and biological effects on the noise levels were investigated (Fig. 2(b)). The wind speed was measured by wind speed sensor (Vaisala, WAA151) at 12 m above sea surface every 10 minutes. The current speed was measured using Wave Radar (Miros, SM-050) at 20 minutes average value.

Fig. 1. Location of the Ieodo Ocean Research Station (IORS).

3. Environmental Effects of Ambient Noise and Their Temporal Variation

We analyzed the ambient noise level variation due to wind speed on water surface and surface current speed of water. The wind speed was observed at 12 m height above the sea surface and the surface current was measured by using a current meter installed at the middle-roof deck of the IORS. The variations of wind speed, surface current and ambient noise level for 70 hours are shown in Fig. 3. Here the ambient noise was expressed by the overall level on frequency band of 20 Hz to 12.5 kHz.

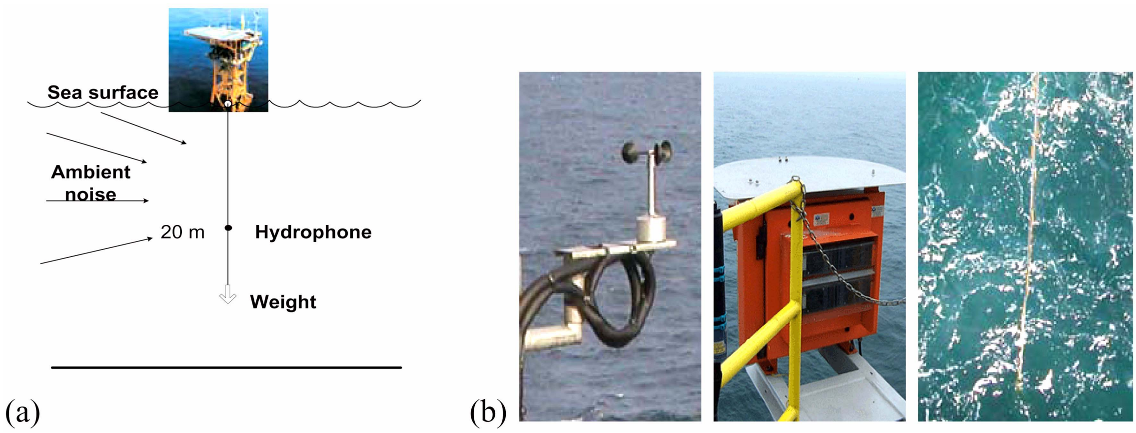

Fig. 2. (a) Schematic diagram of ambient noise measurement, (b) Left: wind speed sensor (Vaisala, WAA151), Middle: Wave Radar (Miros, SM-050), Right: hydrophone cable (hydrophone: Bruel & Kjaer 8101).

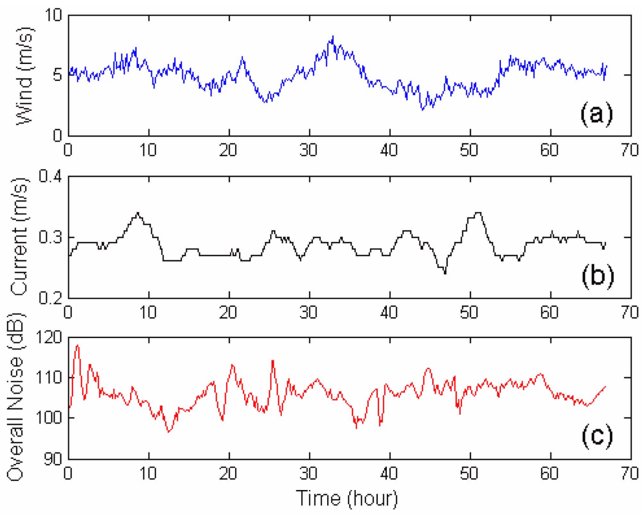

Fig. 3. Variations of wind speed, current speed and ambient noise level for 70 hours. (a) Wind speed (m/s), (b) current speed (m/s), (c) Ambient noise overall level (dB).

From Fig. 3, the correlations among the wind speed, current speed and overall level of ambient noise are not obvious. Therefore, these correlations are individually analyzed as such: the correlation to each center-frequency of one-third octave band as shown in Fig. 4. The linear regression trends and correlation coefficients of the ambient noise for wind speed and current speed are shown in Fig. 4. In Fig. 4(a), we can see that the ambient noise is highly correlated with the wind speed at around 3-5 kHz. This is similar to previous results reported by other authors (Wenz 1962; Kim *et al.* 1996; Choi *et al.* 2003). The correlation between ambient noise level and current speed was analyzed for the first time here as shown in Fig. 4(b). The current can make water agitation and it can be a significant underwater noise source, which is termed a flow noise (Urick 1983). The relatively high correlation between ambient noise and current speed is shown to be around 10 kHz. The flow noise can be formed by a flow agitation of the sea bottom and nearby hydrophone in the water. The variation of ambient noise level of specific frequency band of 100 Hz, 5 kHz and 10 kHz is represented in Fig. 5. The trend of noise variation of 5 kHz is similar to wind speed variation as shown in Fig. 3(a). The trend of noise variation of 10 kHz is similar to current speed variation as shown in Fig. 3(b). But the correlation coefficient values of 5 kHz and 10 kHz is barely around 0.4. Therefore, the variation trend is not exactly same in Fig. 5.

4. Spectra of Underwater Ambient Noise

To see the variation of ambient noise to time, frequency spectra were obtained with one-third octave band interval from 25 Hz to 12.5 kHz during 70 hours. The spectrogram of the ambient noise is shown in Fig. 6(a). Here, the x-axis indicates the time and the y-axis represents the frequency.

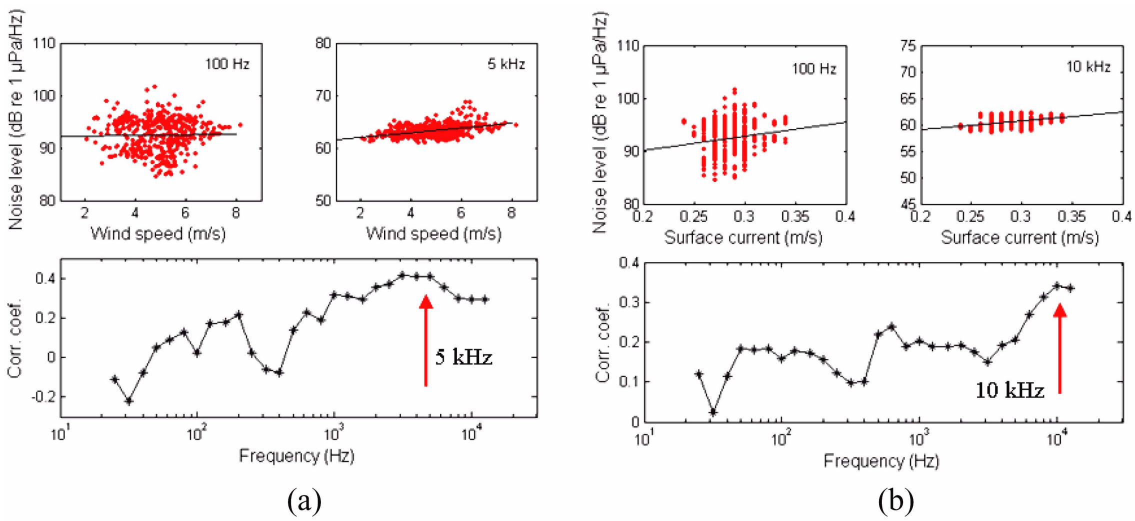

Fig. 4. Linear regression trends and correlation coefficients of the ambient noise for wind speed and current speed. (a) Linear regression fits (upper) between wind speed and noise level of 100 Hz (left) and 5 kHz (right), respectively, and their correlation coefficients (lower). (b) Linear regression fits (upper) between the current speed and noise level of 100 Hz (left) and 10 kHz (right), respectively, and their correlation coefficients (lower).

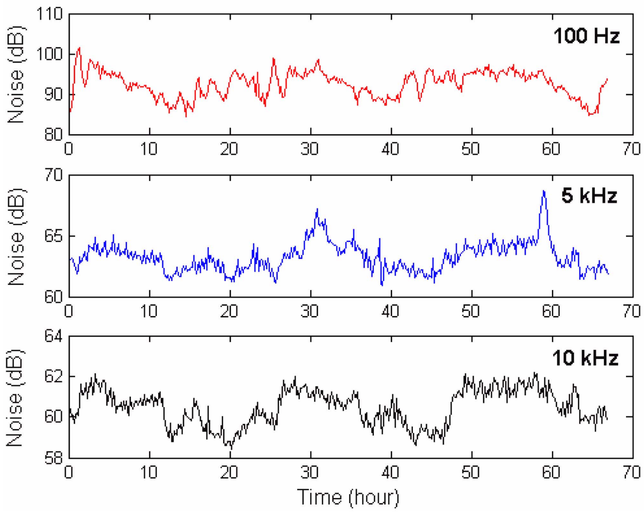

Fig. 5. Variations of ambient noise level about specific frequency band for 70 hours. (a) 100 Hz, (b) 5 kHz, (c) 10 kHz.

The box and the circle marks indicate the wind-dominated noise and the shipping-dominated noise, respectively. The averaged spectrum level of the ambient noise is shown in Fig. 6(b). The ambient noise in the frequency band from 25 Hz to 400 Hz in Fig. 6(b), appears to be dominated by distant ship traffic. In the frequency band from 400 Hz to 12.5 kHz, the noise having a slope of –6 dB/octave mainly seems to be generated by wind on the sea surface (Wenz 1962). The two peaks in low frequency band(32 Hz and 80 Hz) are assumed to be due to wave break at the IORS. The slight increasing noise level around 5 kHz is considered the snapping shrimp sound that is corresponding to Fig. 7 (Kim *et al.* 2003; Versluis *et al.* 2000).

5. Snapping Shrimp Sound

In the coastal sea where the snapping shrimp lives, its noise always coexists with ambient noise such as shipping noise and wind noise. The IORS is located on rock base of 40 m water depth and the snapping shrimps can live there. Bertilon *et al.* tried to investigate a detection of weak snapping shrimp signal under ambient noise environment (Bertilone *et al.* 2001). Versluis *et al.* carried out an experiment to investigate the source of snapping shrimp noise (Versluis *et al.* 2000). They demonstrated that during the rapid snapper claw closure, the noise was emitted by the collapse of cavitation bubble (< 3.5 mm in size) and not by the claw closure. Also, Kim *et al.* measured the snapping shrimp sound in the coastal sea around the Korean Peninsula (Kim *et al.* 2003). The measured waveform and spectra of the snapping shrimp sound at the IORS are shown in Fig. 7. Figure 7(a) shows the typical temporal waveforms of snapping shrimp sound. Figure 7(b) shows the one click sound and its spectra of Fig. 7(a). The snapping shrimp sound (solid line) is compared to the usual ambient noise (bold solid line). The main acoustic energy concentrates at around 5 kHz. This spectrum characteristic is similar to that demonstrated in other papers (Bertilone *et al.* 2001; Versluis *et al.* 2000; Kim *et al.* 2003). Furthermore, the sea bottom material near the IORS consists of rock with sand (Cheong and Shim 2001). The condition of the bottom is similar to that of coastal waters of the Korean Peninsula where the snapping shrimp characteristically live. Therefore snapping shrimp can

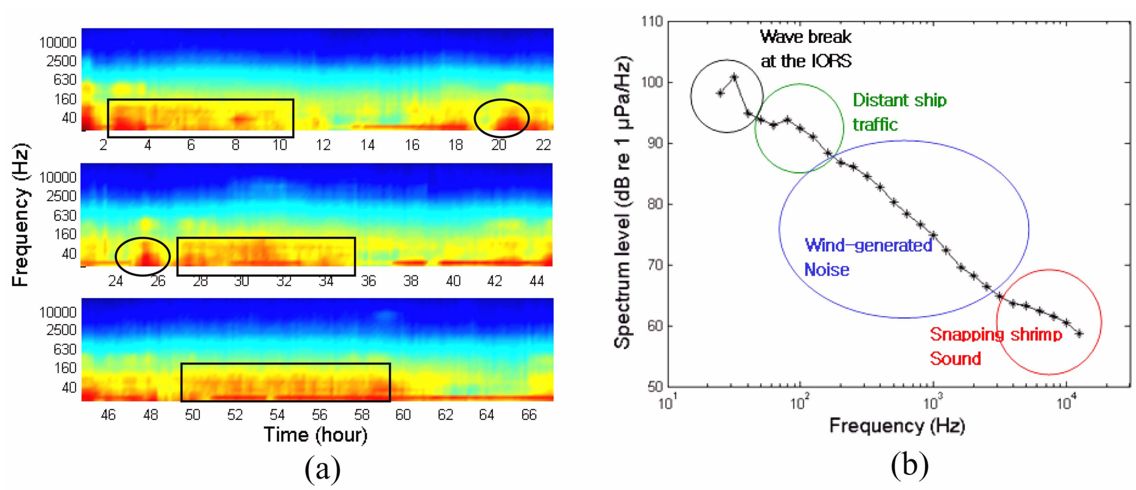

Fig. 6. (a) Spectrogram of ambient noise measured for 70 hours, (b) Averaged spectrum level of ambient noise measured for 70 hours. In (a) the box and the circle marks represent the wind effect and the shipping effect, respectively.

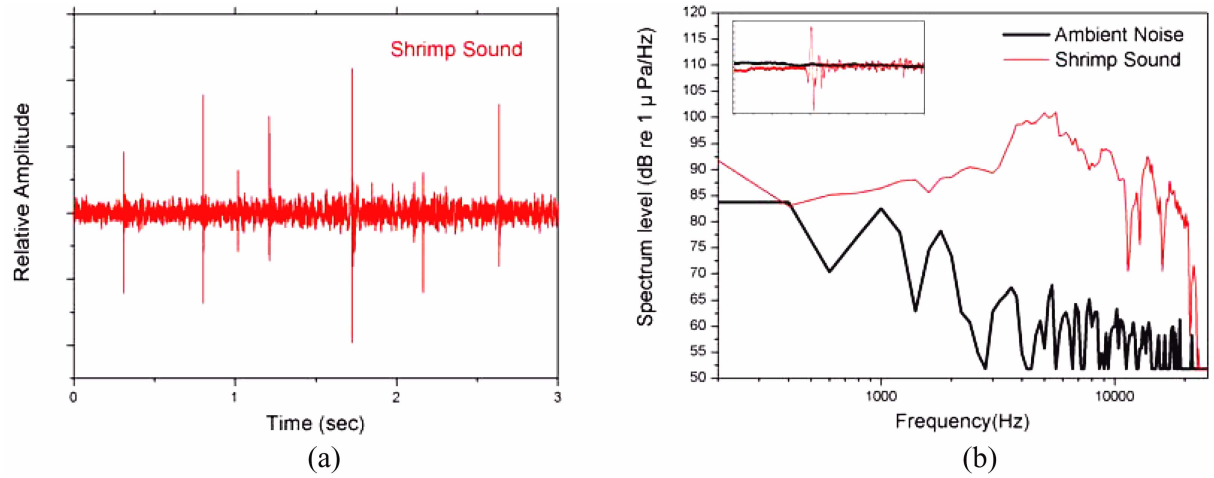

Fig. 7. (a) Typical temporal waveforms of snapping shrimp sound, (b) One click sound and its spectrum. The snapping shrimp sound (solid line) is compared to the usual ambient noise (bold solid line).

well occur around the IORS station. Therefore, these signals can be assumed to be the snapping shrimp sound.

6. Conclusion and Future Works

The ambient noise at the Ieodo Ocean Research Station (IORS) was observed for 70 hours. The wind dependence of the ambient noise is dominant at frequencies of a few kHz. The surface current dependence is shown by the relatively high correlation with the ambient noise in the frequency of 10 kHz. We also measured the snapping shrimp sound and its main acoustic energy at about 40 dB larger than ambient noise level at 5 kHz. In the future, an automatic system for measuring the ambient noise will be installed at the IORS. The long-period characteristics of ambient noise will be examined from the data, including such environmental variations as oceanic storm, whale activity and so on.

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