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Measurements of breaking wave noise in the sea-cliff zone

Sungho Cho‡, and Jee Woong Choi
(Dept. of Environmental Marine Sciences, Hanyang University, Ansan, Korea.)

1. Introduction

The noise generated by waves breaking on the sea shore is a major contribution of ambient noise in coastal waters, which was reported to be measured up to 9 km from the shore [1]. There have been several efforts to investigate the breaking wave noise in the surf zone [1-5]. However, there has been much less study for the breaking wave noise in the sea-cliff area. In this paper, measurements of the ambient noise generated by breaking waves in the sea-cliff zone are presented.

Ambient noise was recorded on two hydrophones deployed at depths of 3 m and 8 m and positioned ~50 m away from the cliff. The video recording of breaking events were simultaneously made with the acoustic measurements.

In this paper, the spectrogram analysis of breaking wave noise in the cliff zone is carried out in frequency range of 100 Hz-5 kHz, and compared to those in the surf zone reported in the literature. In addition, source level per unit area is estimated from the received level and transmission loss predicted using the parabolic equation (PE) code, based on the range-dependent acoustic model (RAM) [6].

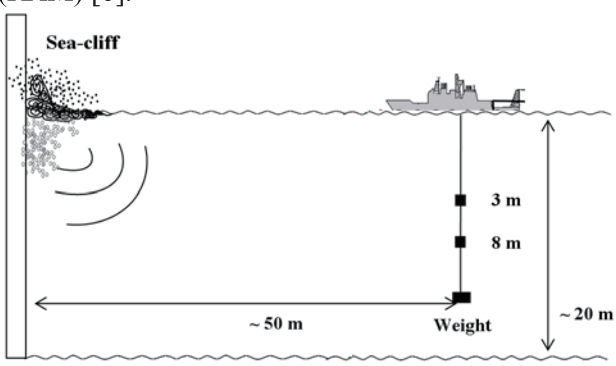

Fig. 1 Experimental geometry for ambient noise measurements.

2. Field measurements

Measurements were made in April 20, 2007, in waters 20 m in depth. Breaking wave noise was received by two hydrophones deployed from the small fishing boat while it was holding station via anchor (**Fig. 1**)

Correspondence to choijw@hanyang.ac.kr

Wind speed was varied from 7 to 12 m/s during the acoustic measurement. The sound speed structure was very stable in the range of 1495 m/s (near the sea surface) and 1493 m/s (near the bottom).

3. Results

Fig. 2 shows a spectrogram (in dB relative to 1μPa^2/Hz) of the ambient noise for 60 seconds measured by a hydrophone at depth 3 m. Each red vertical band is the sound of individual wave breaking against the sea-cliff, which persists for a few seconds with the dominant frequency band less than 3 kHz.

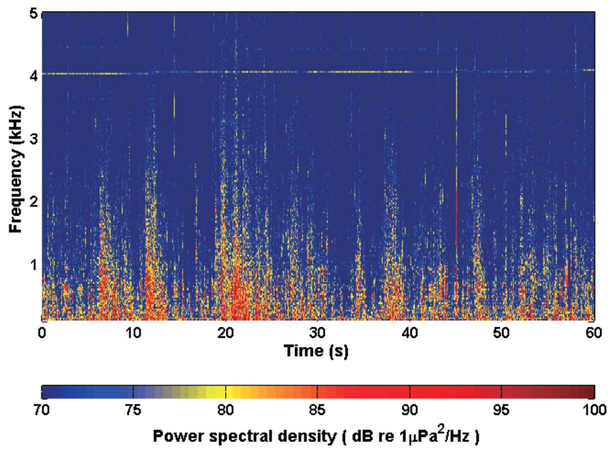

Fig. 2 Spectrogram of noise generated by waves breaking against the sea-cliff.

The measured ambient noise for 15 wave breaking events from each hydrophone were selected through the comparison with the video measurements synchronized with the acoustic measurements.

Fig. 3 shows the power spectral densities for individual breaking event (thin lines) and their averaged power spectral densities (thick lines). The extracted time series is divided into time segments having 20 ms and each spectal estimate represents their average. There are many sound sources of the ambient noise in the cliff-zone. The primary sources of noise include the pounding of sea-cliff, single and collective bubble oscillations in bubble plumes.

In order to estimate the spectral source level, the effective sound generation region having a sheetlike shape is assumed of which the size was determined based on the video recording data synchronized with the acoustic measurements (**Fig.**

4). Then, the effective source regions are divided into M by N patches, which is assumed to be individual incoherent point sources (as used in Ref. 4).

Transmission loss from a point source to the hydropone is predicted using the PE code, RAM. The used geoacoustic parameters were derived from the sediment core analysis.

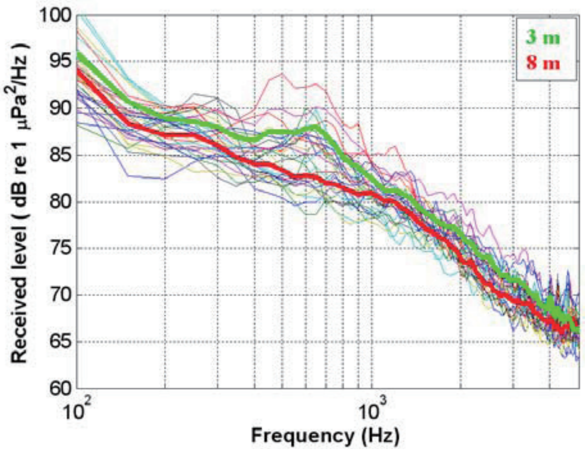

Fig. 3 Power spectral densities for individual breaking events (thin lines) and their averaged power spectral densities (thick green and red lines are spectra at depths 3 m and 8 m, respectively).

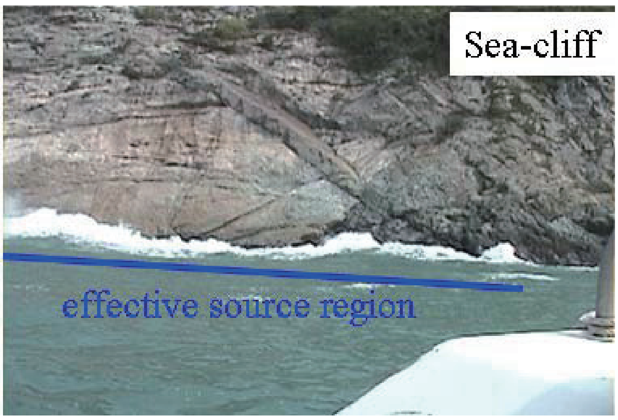

Fig. 4 Captured video image of the sea-cliff zone during the ambient noise measurements

Finally, spectral source level per unit area can be represented as follows,

$$SL = RL + 10\log \sum_{i=1}^{M} \sum_{j=1}^{n} g(r,f) - 10\log A,$$

where, SL is the source level in dB re $1\mu\text{Pa}^2/\text{Hz/m}^2$, RL is the received level in dB $1\mu\text{Pa}^2/\text{Hz}$. $g(r,f)$ is the spatial transfer function from a point souce to the receiver modeled using the RAM, and A is the source patch area.

Fig. 5 shows the estimate of averaged spectral source level per unit area. The decreasing slope of power sprectum for frequencies less than 1 kHz is slightly different from that for higher frequencies. For lower frequencies, the source spectral level drops off at about 20 dB for each decade increase in frequency (line A). Primary source of this frequency band is collective bubbles oscillations in bubble plumes [7]. For higher frequencies, the source spectral level decreases by approximately 30 dB for each decade increase in frequency (line B), and the primary source is hypothesized to be the resonance sound of individual bubbles [5].

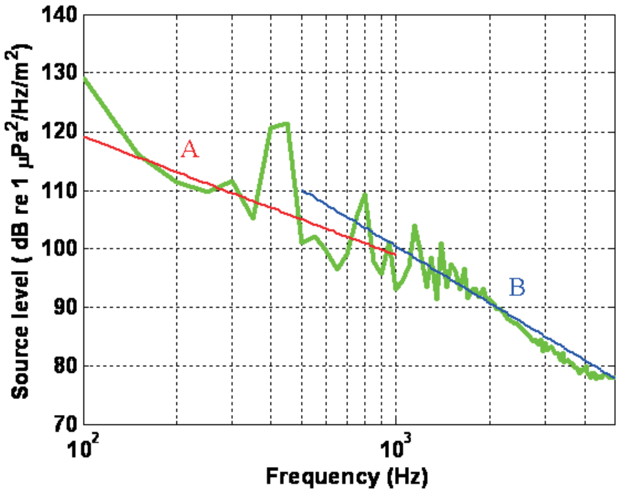

Fig. 5 Source level spectra per unit area for wave breaking sound in the sea-cliff zone.

Acknowledgment

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