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Vertical coherence measurements of broadband signals in shallow water

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1. Introduction

As underwater sound propagates through the ocean waveguide, it interacts with the ocean boundaries as well as ocean medium itself. The acoustical properties of ocean waveguide environment can thus be estimated from the signals received after propagation through the waveguide. Measurement of vertical coherence is one of the useful tools to understand the effect on sound propagation. [1-5)]

This paper presents the measurement results of the vertical coherence estimated using the broadband signals recieved from a vertical line array (VLA) in shallow water.

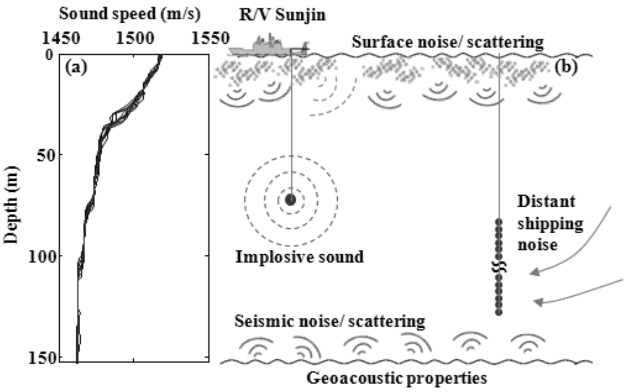

Fig. 1 Experimental layout for measuring the vertical coherence.

2. Field Measurements

The acoustic measurements were made in the East Sea in July 2009 using a light bulb as an acoustic source, deployed from the R/V Sunjin. The signals were received by a 24-channel VLA within the source-receiver range of 100 to 2500 m. Over the acoustic measurement period, XBT (expendable bathythermograph) casts were frequently made to measure the sound speed profile, which was stable during the experiment and has a negative gradient [Fig. 1(a)]. Bottom properties including mean grain size and sediment layering structure were collected by the grab sampling and chirp sonar operation. The experimental site was surveyed using a depth sounder. The bottom was almost flat and the surficial sediment consisted of sand having a grain-size range of 3 to 5 (75 %) in waters approximately 150 m.

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3. Results

Fig. 2 shows a spectrogram (in dB relative to 1μPa^2/Hz) of the signal for 60 s measured by a hydrophone which was deployed at a depth of 96 m and at a range of 130 m from the source.

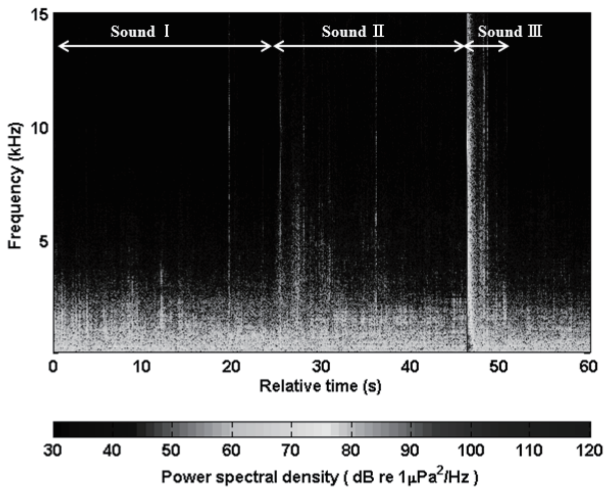

Fig. 2 Spectrogram of the signal received by a top hydrophone of the vertical line array. The strong peak near ~47 s is the arrival of the bulb-implosive signal.

Each arrow in **Fig. 2** represents the three types of signals generated by different acoustic sources. The dominant noise of the portion marked by ‘Sound I’ is the noise generated by auxiliary generator of another research vessel, which was opereated near the R/V Sunjin and was holding station. The portion of ‘Sound II’ is corresponding to the propeller noise of that research vessel, which was moving away from VLA. The portion of ‘Sound III’ is the sound arrvial of an light bulb implosion.

Fig. 3 shows the real and imaginary parts of the vertical coherence as a function of frequency and time. The spatial coherence of the broadband signals received at two receivers is defined as

$$\Gamma_{12}(f) = \frac{\left\langle S_1(f) \bullet S_2^*(f) \right\rangle}{\sqrt{\left\langle S_1(f) \bullet S_1^*(f) \right\rangle \left\langle S_2(f) \bullet S_2^*(f) \right\rangle}} ,$$

where, $S_1(f)$ and $S_2(f)$ denote the Fourier transforms of the signals received at hydrophones 1 and 2, respectively. The signs $*$ indicates the complex conjugate and <> means the ensemble average.

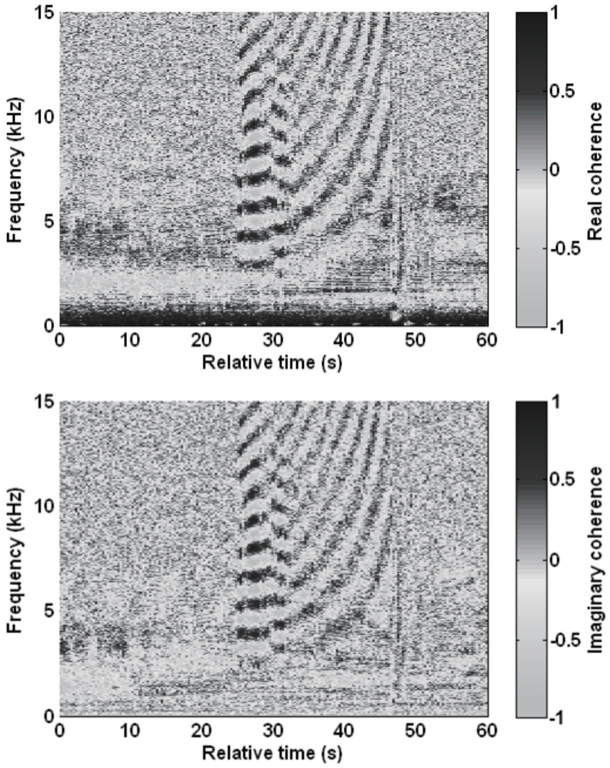

Fig. 3 Real (top) and imaginary (bottom) parts of the coherence received by uppermost two hydrophones with an array space of 187.5 cm.

The coherences calculated for three portions display the different characteristic features. However, for the frequency range lower than 1 kHz the coherence values for 60 s are stable except the portion of ‘Sound III’, showing that the auxiliary generator noise is a main contributor of coherence for the lower frequency range. For the portion of ‘Sound II’, very pronounced frequency dependence of coherence exists and it varied with time, implying that the research vessel was moving away. Finally, the rapid change of coherence with time is shown for the portion of ‘Sound III’. This is due to the multipath effect in shallow water waveguide.

Fig. 4 shows the vertical directionality of the received signals estimated from the braodband coherence. The characteristics of coherence for the three different portions discussed above are also well seen in Fig. 4.

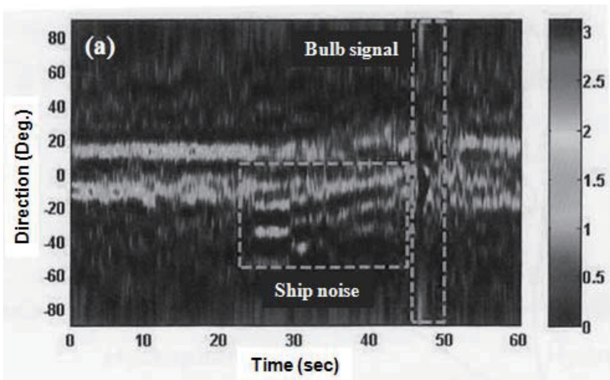

Fig. 4 The vertical directionality calculated from the coherence result.

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