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Analysis of Broadband Interference in Deep Water

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1. Introduction

Broadband interference in ocean waveguide is widely studied topic in recent years by many researchers. Interference phenomena are influenced by the property of the medium in which the acoustic wave propagates. In deep water, the interference pattern is mainly controlled by the sound speed of water. This paper reports a feature of broadband interference in deep water measured when the source and receiver are near the axis of the deep sound channel.

2. Data

Fig. 1 shows the schematic of the experiment conducted in the East/Japan Sea. The acoustic signals were received at the 10 hydrophones lowered between 270 m and 360 m. The MK 64 SUS, detonated at 244 m, were used as acoustic sources. The temperature fields of the site were acquired by AXBT. The SUS and AXBT were dropped following the circular path from the receiver ship using the aircraft.

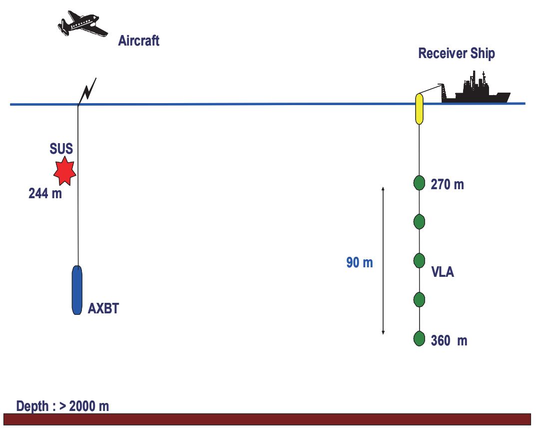

Fig. 1 Schematics of the measurement.

Fig. 2 shows the depth-averaged spectra of the received signals from two different azimuths. The range of the azimuth 1 is 27.65 km and that of the azimuth 2 is 27.75 km. Occurrence and shift of the frequency of intensity peak could be seen. The shift is more pronounced as the frequency increases.

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Fig. 3 represents the sound speed profiles of the two azimuths based on the data measured at the source and receiver positions. It could be seen that the sound speeds of the azimuth 2 are faster than the azimuth 1 between 75~ 300 m depths.

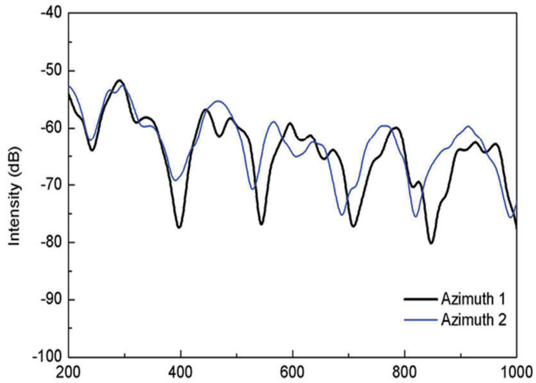

Fig. 2 Spectra of the explosive charges received from the sources having different azimuth and same range.

Fig. 2 and 3 imply that the shift of peak frequency might have caused by the sound speed variation above the sound channel.

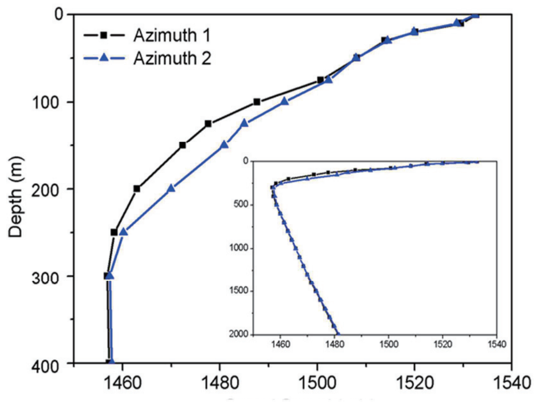

Fig. 3 Sound speed profile of Fig. 2.

3. Analysis

Using the normal mode theory, the sound intensity at large distances from the source may be represented as

$$I(\omega, r, z) = |p(\omega, r, z)|^2 = \sum_{l,m} B_l B_m^* \cos(\kappa_{lm}\, r)\ ,(1)$$

where $\kappa_{lm} \equiv \kappa_l - \kappa_m$.[1] κ_l is the horizontal wavenumber of mode l. If the frequency-dependence of mode amplitude $B_l B_m^*$ could be regarded as constant, the condition for maximum intensity for interference of modes l and m is

$$\kappa_{lm} r = 2\pi N, N = 1,2,... \quad (2)$$

The sound speed profile of deep sound channel having bilinear gradient could be represented as

$$c = \begin{cases} (\frac{1}{c_0^2} - qz)^{-1/2}, z > 0 \\ (\frac{1}{c_0^2} + q'z)^{-1/2}, z < 0 \end{cases} \quad (3)$$

and

$$q = \frac{1}{h}\left(\frac{1}{c_0^2} - \frac{1}{c_1^2}\right), \quad q' = \frac{1}{h'}\left(\frac{1}{c_0^2} - \frac{1}{c_1'^2}\right) \quad (4)$$

where z=0 correspond to the channel axis.[2] The depths are positive to the bottom.

In case of bilinear profile, the difference of horizontal wavenumber between neighboring two modes might be represented as

$$\kappa_{lm} = (m^{2/3} - l^{2/3})\mu\omega^{1/3} \quad (5)$$

where

$$\mu = \frac{c_0}{2}\left[\frac{3}{2}\frac{\pi}{(q^{-1}+(q')^{-1})}\right]^{2/3} \quad (6)$$

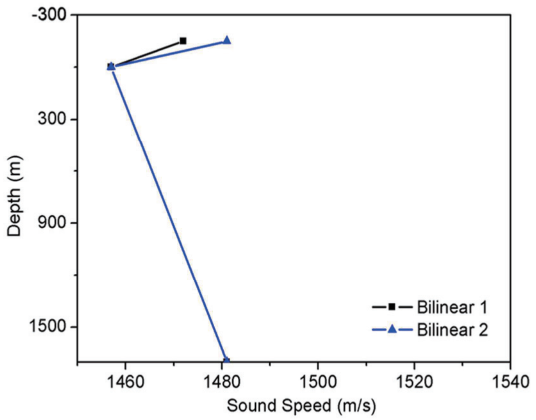

Fig. 4 Bilinear sound speed profile for analysis of interference.

To investigate the feature of broadband interference pattern of Fig. 2, the profiles of Fig. 3 were simplified to bilinear profiles using the values at 150 m, 300 m, and 2000 m depths. **Fig. 4** shows the simplified profiles. The bilinear 1 approximates the azimuth 1 of Fig. 2.

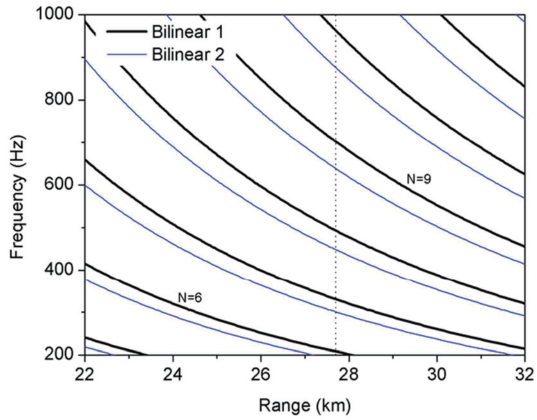

Fig. 5 Range-frequency interference pattern for the profile of Fig. 4.

Fig. 5 shows the lines of maximum intensity in range-frequency domain due to the interference between mode 1 and 4 of the bilinear profiles. At the source-to-receiver range of 27.7 km, the intensity maxima appear at five frequencies, which is similar with the measurement of Fig. 2. Also, it could be seen that the peak frequencies shift to lower frequencies if the sound speed gradient of the upper layer of the channel increases. Fig. 5 shows that the frequency shifts of Fig. 2 are originated from the difference of sound speed gradient above the sound channel axis.

Acknowledgment

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References

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