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Influence on Sound Field by Propagation Angle of Internal Wave
内部波の伝搬角度による音場への影響

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1. Introduction

In shallow water, an internal wave is generated. Internal wave (IW) is a wave generated on the thermocline by the tidal force. Many studies has been performed in the field of geophysics for a physical property of IWs[1)]. And the interest in the influence of IW on the sound wave propagation has been increasing in the field of underwater acoustics[2)]. Tsurugaya et al. examined the sound field by the position between turning ray and IW and by the width of IW, and reported[3,4)]. These studies were examined by 1-IW in two dimensions (depth and range). Observing IW from the sky, it is propagated like the line. Then, when one-IW has the right angle to the sound source, the characteristic of the sound field caused by each angle was examined. The azimuth coupling is not considered here.

2. Parameters in Simulation

The parameters used to examine the angular characteristic of IW are shown in **Fig. 1**. FOR3D[5)] is used for the calculation of the sound field. A sound speed profile is shifted in the direction of depth according to the shape of IW, and IW is input to FOR3D. The bottom depth is 200m, and the shape of IW is approximated by sech^2. The frequency is a continuous wave of 600Hz. Sound source depth is 50m shown in this figure by △ sign.

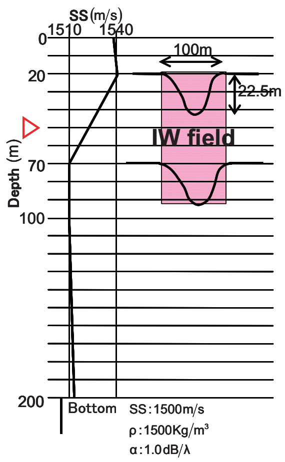

Fig. 1 Sound speed (SS) profile and parameters.

The propagation of IW has the angle to the sound source as shown in **Fig. 2**. IW approaches to the sound source by the right angle, that is, θ=0°. When IW is in 2000m, the range from the sound source to IW and the width of IW at the angle θ are shown in Table 1. Naturally, the range between sound source and IW doubles at θ=60°, and the width of IW doubles, too.

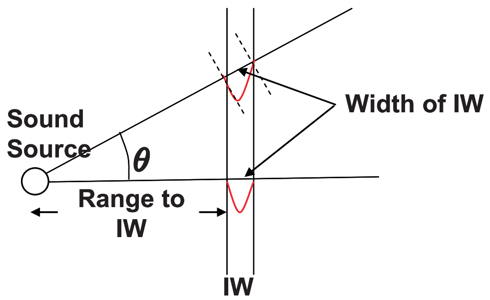

Fig. 2 Relation between sound source and IW.

Table 1 Range and IW width to the Angle

Angle θ (degrees)	Range to IW (m)	Width of IW (m)
0	2000.00	100.00
10	2030.85	101.54
20	2128.35	106.41
30	2309.40	115.47
40	2610.01	130.54
50	3111.44	155.57
60	4000.00	200.00

3. Sound scattering by internal wave

For IW in 2000m, the subtracted sound fields (SSF) at the angle θ is shown in **Fig. 3**. When IW is in 2000m, SSF to the angle is shown in Fig. 3. The sound fields without IW is 0dB in SSF, as shown in the right-side scale. Figure is shown SSF of θ=5°, 40°, 55°, and 60° from the upper. The curve in this figure shows the turning ray of the source depth in 50m. The ray radiated from the source between 0 degrees and +9.715 degrees becomes the turning ray. The influence of IW on the sound wave propagation appears strongly in the backward and the lower side. In θ=5°, because the IW fields is outside of the turning ray, IW is influenced only to the sound wave propagating in the bottom reflection and the surface reflection. In θ=40°, IW is overlapped with the turning ray radiated at +9.715 degrees from the sound source. Therefore, the influence by the overlapped with the turning ray and IW appears greatly. The depth of the turning ray changes

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from the upper interface of thermocline to the sound source depth. In θ=55°, IW field is overlapped with the turning ray radiated from the sound source by 0 degrees. The overlap of the turning ray and IW fields is small, and the range between the sound source and IW increases. But the influence appears greatly because of the increased the width of IW[4]. In θ=60°, although IW doesn't overlap with the turning ray, the influence of width appears strongly because of the twice width.

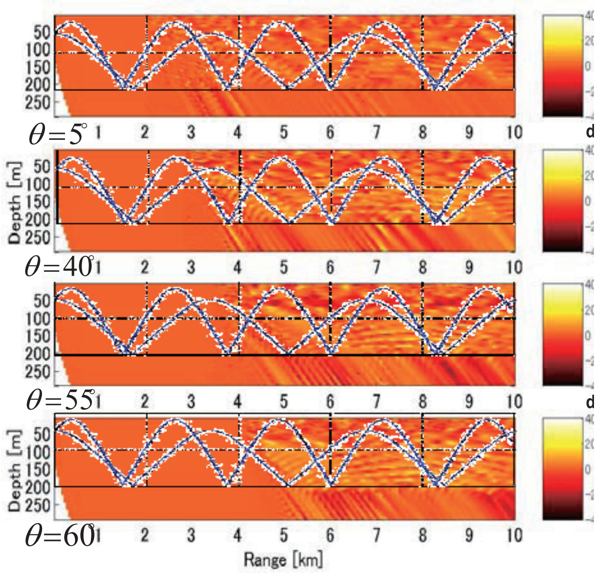

Fig. 3 Subtracted sound field in angle θ

4. Transmission loss by the angle of IW

To examine the characteristic on the angle, the transmission losse of the sound field scattered by IW are compared in each angle. In 2000m of IW, the transmission loss in each angle (△) is shown in **Fig. 4**. A vertical axis is transmission loss (dB) and a horizontal axis is the angle. The range between the sound source and IW is 2000m in 0 degrees, and 4000m in 60 degrees. The position of the turning ray in the upper interface of the thermocline is about 2500m, and the angle is about 37 degrees. The position of the turning ray radiated at 0 degrees is about 3500m, and the angle corresponds to about 56 degrees. The range increases from 0 to 30 degrees in the angle. Therefore, the transmission loss increases if the width of IW is the same. However, the influence of IW increases because the width of IW increases. In a word, the influence of the increase of the range and the increase of the width of IW is superimposed in the entire transmission loss. The transmission loss decreases because the turning ray and the internal wave overlap at 37 degrees. However, the variation of the level from 37 to 57 degrees in the angle is generated by the interference of the consecutive turning ray. In 60 degrees, IW is outside of the turning ray, and the range from the source is twice. However, because the width of IW doubled, the transmission loss becomes small. When IW is in 4000m, the same tendency is shown though it doesn't show here. Therefore, as a result of the change of the IW position according to the angle, the influence of the relation of the turning ray and IW, the width of IW, and the change of the range is superimposed in the transmission loss.

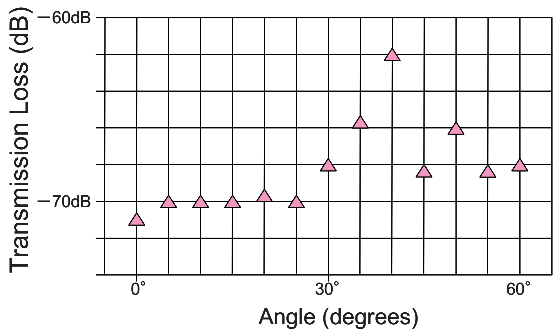

Fig. 4 Variation of transmission loss by the angle
IW : 2000m

5. Summary

When IW was at the position of the right angle to the source, the variation of the transmission loss by the angle was examined. The following two points are important to consider the influence of IW on the sound scattering;

1. Increasing of propagation range and IW width by increasing angle.
2. The overlapping degree of the turning ray and IW field.

The influence by the angle of the source and IW becomes the superposition of the above-mentioned two components. This time, the influence by the angle was examined without the azimuth coupling.

References

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