3P-61

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Sound scattering by the second internal wave in internal wave train
内部波列における 2 番目の内部波による音波散乱

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1. Introduction

In shallow water, the internal wave (IW) is primarily generated by the tidal force. Because the isopycnic surface fluctuates by the internal wave, it strongly influences to the sound propagation. Therefore, the report of research concerning the underwater acoustic field has been increased[1)]. Tsurugaya et al. investigated the scattering mechanism by IW, and clarified the positional relationship of the turning ray and IW[2)]. However, this study is an investigation of the sound scattering by one IW. IW usually forms the train[3)]. Then, in the case when two IWs were consecutive, the sound scattering by the second IW was investigated.

2. Parameters used for examination

The parameters used to examine IW is given in **Fig. 1.** Layer depth (LD) is 20m. Under LD, there is thermocline, and the depth that is deeper than 70m is an isothermal layer. The bottom is 200m in depth. Absorption coefficient in the bottom is 1.0dB/λ though the sediment is sandy silt. IW is 100m in width, and the amplitude 22.5m. The shape of the IW was approximated by sech^2. The model used to calculation is FOR3D[4)]. IW is input to the model by the shape of IW at intervals of 10m. The frequency used to calculation is 600Hz. The second IW is the same shape.

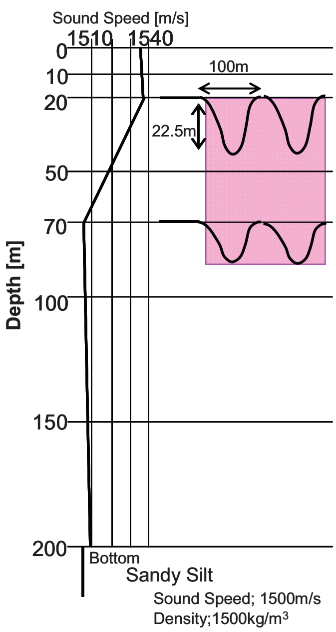

Fig. 1 Sound speed profile and IWs

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3. Sound scattering by one IW

In the scattering by one IW, the strongscattering is generated when the turning ray and IW was overlapped. The subtracted sound field by one-IW is shown in **Fig. 2**. The subtracted sound field is a result of subtracting the sound field without IW from the sound field of one-IW. The width of IW is 100m (center), twice width (200m;upper), 1/2 width (50m,lower). The scattering pattern doesn't change even if the width of IW is widened, but the strength of scattering increases by the width. And, even if the amplitude of IW changes, the same tendency is demonstrated. Next, the scattering pattern do not change by varying in the temperature gradient of thermocline though the strength level is changed. That is to say, the scattering by the internal wave is changing in mode excitation, and the change by mode excitation originates in the wave motion of the upper surface of the thermocline[5)]. In other wards, the scattering by IW is the result that the mode having the antinode in the thermocline is depressed in the direction of depth by the wave motion of IW.

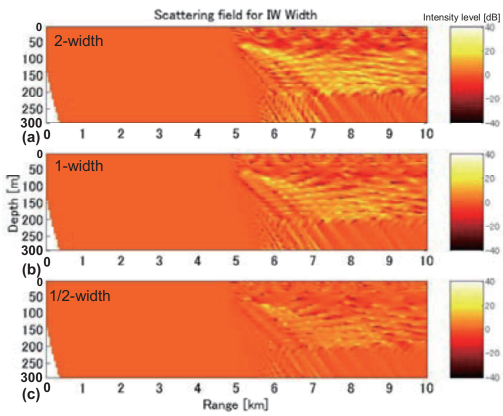

Fig. 2 Comparison of the subtracted sound field for width of one-IW (a) twice widths of one-IW (200m), (b) one width (100m), (c)1/2 widths (50m).

4. Sound scattering by the second IW

A sound field in the waveguides is represented by the product of the excitation

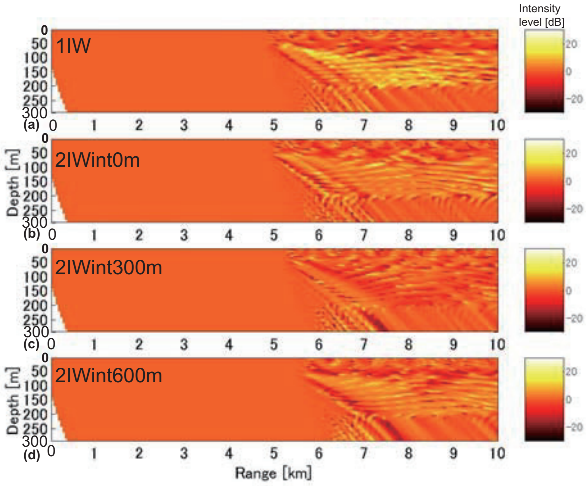

Fig. 3 Comparison of the subtracted sound field by IW(4800m) (a);1-IW (b);2-IWs (spacing 0m) (c);2-IWs (300m) (d);2-IWs (600m)

coefficient of the mode and the eigenfunction of the waveguide[6]. Therefore, it can be considered that the influence by IW train is a superimposition of the influence by each IW. Then, the internal wave train that consists of two IWs is considered. To clarify the influence by 2-IWs, the spacing between 2-IWs has been changed from 0 to 1000m. The influence by the second IW is shown in **Fig. 3**. In this figure, the subtracted sound field is represented. This sound field is a result of subtracting the sound field in one-IW from those of two IWs. But, top figure is the subtracted sound field in the sound field not-including IW from those of one-IW. The difference of gradations is a difference from scattered field by the first IW as indicated in the right scale. Top figure is the subtracted sound field by one-IW, and below figures are the scattering sound field by 2-IWs. The spacing between two IWs is 0m, 300m, and 600m from 3-(b). Compared with the scattering patterns, the intensity level of subtracted sound field is strong in 0m and 600m, but is weak in 300m. Next, the intensity distribution in receiving depth 80m is shown in **Fig. 4**. A horizontal axis is a spacing between two IWs, and the case in 0m is consecutive one. The intensity level is high when the spacing is 0m and around

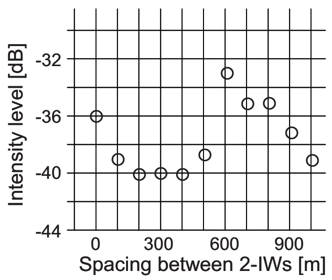

Fig. 4 Comparison of intensity level for the spacing between IWs. IW;4800m

600m. In this case, IW is in 4800m, and IW overlaps with the turning ray. This turning ray is turned in the upper surface of the thermocline. Then, the case that IW do not overlap with turning ray is considered. The intensity distribution on the spacing between IWs is shown in **Fig. 5**. The receiving depth is also 80m. IW position is in 4200m. The intensity level is high in the spacing around 300m and 900m. In both cases, the strong and weak strength level is yielded in 600m space. That is, the scattering sound fields of each IW interacts constructively and/or destructively. Therefore, it is considered that the sound field by 2-IWs is the results of interacting the scattered sound field in 1st IW and 2nd one. In other words, the strong scattering is yielded in the case of which two scattering sound fields interacts constructively.

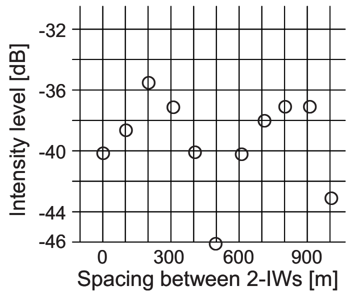

Fig. 5 Comparison of intensity level for the spacing between IWs. IW;4200m

5. Summary

The influence of the second IW in IW train was investigated. In the overlapped with IW and the turning ray, a strong scattering was yielded at 0m and 600m in the spacing of 2-IWs. Moreover, it was at 300m and 900m when IW and the turning ray did not overlap. That is, the influence of the second IW was yielded at spacing of 600m. Therefore, the scattering of the sound wave by 2-IWs is the superimposition of the scattering sound field by each IW.

References

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