The effect of ocean turbulence on acoustic propagation in shallow water

Jing Han¹, Xuegang Zhang¹, Zhongpeng Wu¹*, Feng Cao¹

¹Science and Technology on Underwater Test and Control Laboratory, Dalian, China, 116013
*Corresponding author’s email: 937642385@qq.com

Abstract: This work devoted to research the temperature and salinity distribution in ocean turbulence. The sound velocity when ocean turbulence presented was calculated by the function relation between temperature, salinity, depth and sound velocity. The sound transmission loss was calculated when the ocean turbulence was presented or not and compared them. The sound field fluctuation resulted by ocean turbulence was analyzed. It was very significant to comprehend the mechanism and variation rule of ocean turbulence. Thus it was further study the effect of ocean turbulence on acoustic propagation. As an example, there was thermocline in the ocean water. The sound transmission loss was calculated when present ocean turbulence or not. It analyzed the effect of ocean turbulence on acoustic propagation. The sound field fluctuation caused by ocean turbulence could reach 8dB.

1. Introduction
Ocean water generated mixture end to end under different ocean dynamics factors synthesis action. The ocean water mixture was a general motion format in ocean.[1] Turbulence mixture exchanged with adjacent water as ocean water micelle.[2] It had intimate relation with ocean water movement. Turbulence had important contribution on ocean water momentum, heat quantity and mass transport. It also had important effect on ocean water movement velocity, temperature-salinity character and dissolved matter distribution. Ocean turbulence had important action on ocean wave breaking, bubble formation, circulation flow, ocean internal diffusion, jump layer formation and decay and internal wave breaking[3][4][5]. The perturbation of ocean turbulence could intensify sound scatter and rapid modify local sound intensity. Thus, it would impact the transmission performance of ocean sound channel.[6][7]The sound transmission path would more complex. The ocean turbulence mentioned above was natural turbulent current and it was an expression formation of ocean dynamics course. On the other hand, when the ship navigated in the ocean, ship body would damage the original waters structure. The rotation of screw propeller would format weak current which included spiral vortex, turbulence and air bubble. The waters change must cause temperature, salinity alternation and the sound velocity would modify as a function of temperature and salinity. The distribution of temperature and salinity had intimate relation with sound wave and light wave transport in the ocean. The related research of sound field fluctuation caused by internal wave and vortex had many reporting in journal. R. L. Field et al[8] had studied the acoustic propagation in turbulent layers. The objective of their work was to determine the extent to which acoustic propagation varies in the vicinity of topographic features where the flow oscillates between laminar and turbulent states. In a recent experiment by Moum and Nash, oceanographic measurements were made around a small bank off the western continental shelf. Temperature, salinity, and turbulent dissipation rate measurements were obtained from this experiment...
and broadband (9-11kHz) acoustic simulations done to determine the impact of the turbulentsound speed field on acoustic propagation. Acoustic simulations show an overall increase in transmission loss of about 10-15dB within the 10-11kHz band. The object of this paper was to study the effect of ocean turbulence on acoustic propagation and analyzed the sound field fluctuation caused by turbulence.

2. Simulated conditions
Temperature, salinity and sound velocity profile figures without ocean turbulence were denoted in Figure 1. Ocean turbulence was distributed on the assumption that from water surface to underwater 10m. The horizontal change of ocean turbulence was no think about in this paper. The present of ocean turbulence altered the temperature and salinity. And then, the sound velocity was changed. It was postulated that the temperature and salinity tended to homogeneous after the ocean turbulence disturbance.

![Figure 1 Temperature, salinity and sound velocity profile without turbulence](image1)

![Figure 2 Temperature, salinity and sound velocity profile with turbulence](image2)

The temperature, salinity and sound velocity profile after disturbance were expressed in Figure 2. These pictures showed that there was temperature jump layer in the water and the upper bound depth was 10m. The temperature jump layer thickness was 20m. Under the action of ocean turbulence, temperature tended to equal from water surface to underwater 10m. Thus, the sound velocity was also as equal in this zone.

3. Simulated results
The sound source depth was 5m and the frequencies were 1kHz and 5kHz. The vertical array was used to receive the sound wave which came from the sound source. The horizontal distance between sound source and vertical array was 10km. The acoustic propagation loss and sound field fluctuation were calculated with and without ocean turbulence.

The width band acoustic propagation loss with frequency 1kHz were showed in Figure 3 and the receive depth were 5m and 20m corresponded to upside and inside of the temperature jump layer. These pictures showed that the maximum difference of acoustic propagation loss with or without ocean turbulence was 2dB with 5m receive depth. The effect of ocean turbulence on acoustic
propagation decreased as the range increasing. The maximum difference of acoustic propagation loss with or without ocean turbulence was 1dB with 20m receive depth. And the effect of ocean turbulence on acoustic propagation decreased as the range increasing. The width band acoustic propagation loss with frequency 1kHz were showed in Figure4 and the receive depth were 40 corresponded to downside of the temperature jump layer. The maximum difference of acoustic propagation loss with or without ocean turbulence was not exceeding 1dB. And the effect of ocean turbulence on acoustic propagation decreased as the range increasing. Because of the effect depth of ocean turbulence was 10m and the 5m receive depth was in the turbulence zone. Thus, the acoustic propagation fluctuation was bigger in 5m receive depth than 20m and 40m receive depth. The sound field fluctuation on different range and depth was showed in Figure5. The sound field fluctuation was biggest in turbulence zone and the fluctuation was not exceeding 3dB. The sound field fluctuation was weak outside of turbulence zone and the effect of ocean turbulence on acoustic propagation decreased as the range increasing. The sound field fluctuation was not exceeding 0.5dB when the range exceeded 5km.

Figure.3 Acoustic transmission loss difference with and without turbulence (1kHz, 5m and 20m)

The width band acoustic propagation loss with frequency 5kHz were showed in Figure6 and the receive depth were 5m and 20m corresponded to upside and inside of the temperature jump layer. These pictures showed that the maximum difference of acoustic propagation loss with or without ocean turbulence was exceeding 6dB with 5m receive depth. The effect of ocean turbulence on acoustic propagation loss tended to increase as the range increasing. The maximum difference of acoustic propagation loss with or without ocean turbulence was 4dB with 20m receive depth. And the effect of ocean turbulence on acoustic propagation loss increased as the range increasing. The width band acoustic propagation loss with frequency 5kHz were showed in Figure7 and the receive depth were 40 corresponded to downside of the temperature jump layer. The maximum difference of acoustic propagation loss with or without ocean turbulence was 4dB. And the effect of ocean turbulence on acoustic propagation loss increased as the range increasing. Because of the effect depth of ocean turbulence was 10m and the 5m receive depth was in the turbulence zone. Thus, the acoustic propagation fluctuation was bigger in 5m receive depth than 20m and 40m receive depth. The sound field fluctuation on different range and depth was showed in Figure8. The sound field fluctuation was biggest in turbulence zone and the fluctuation was not exceeding 8dB. The sound field fluctuation was bigger outside of turbulence zone than low frequency (1kHz) and the effect of ocean turbulence on acoustic propagation increased as the range increasing.
The effect of ocean turbulence on acoustic propagation for different frequencies was generalized in Table.1. The acoustic propagation loss difference with and without ocean turbulence increased as the frequency increasing. The effect of ocean turbulence on acoustic propagation was bigger in high frequency than low frequency. The acoustic propagation loss difference was bigger in ocean turbulence zone than no turbulence. The sound field fluctuation was biggest for 5kHz.

Table.1 The acoustic propagation loss difference with and without ocean turbulence

| Frequency(kHz) | 0.9-1.1 | 4.5-5.5 |
|----------------|---------|---------|
| Receiver Depth(m) | 5 | 20 | 40 | 5 | 20 | 40 |
| Maximum TL difference(dB) | 1.9 | 0.9 | 0.8 | 6.7 | 4.0 | 4.4 |
| Sound field fluctuation(dB) | -2~3 | -6~8 |   |   |   |   |

4. Conclusion
Ocean turbulence had significant effect on acoustic propagation and the effect was bigger in high frequency. The effect of ocean turbulence consisted of bigger acoustic propagation loss difference and range of influence. The influence of turbulence concentrated within horizontal range 5km for low frequency (1kHz) and concentrated in the range of influence for ocean turbulence. The effect of ocean turbulence on acoustic propagation tended to from weak to strong in horizontal range and depth domain for high frequency. The influence depth of ocean turbulence was 10m in this paper and the temperature and salinity were homogeneous in the turbulence zone. The sound field fluctuation caused by ocean turbulence could reach 8dB. However, the practical situation was not in this way. The effect of turbulence on acoustic propagation was more complex and the sound field fluctuation could not be ignored.

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