DOI: 10.37102/1992-4429_2023_44_02_06

PECULIARITIES OF ATTENUATION OF LOW-FREQUENCY SOUND IN THE COURSE OF PROPAGATION IN A 2D ARCTIC-TYPE WAVEGUIDE WITH RANDOM BATHYMETRY

O.E. Gulin, I.O. Yaroshchuk

For a low-frequency sound signal propagating in a two-dimensionally inhomogeneous shallow-water waveguide, the influence of random bathymetry (fluctuating bottom boundary) is considered based on the local-mode approach and statistical modeling. The study was carried out for shallow sea conditions corresponding to the coastal waveguides of Russian Arctic seas. A feature here is the presence of an almost homogeneous water layer with various characteristics of bottom sediments. For conditions of a bottom boundary that is strongly penetrable, calculations predict a very weak effect of bathymetry fluctuations on the average sound intensity. A feature of these coastal areas is the presence of an almost homogeneous water layer lying on weakly consolidated bottom sediments with various characteristics, including those with a high degree of gas saturation. Model calculations were performed for the conditions of a strongly penetrable statistically rough bottom boundary with different scales of random inhomogeneities. It is shown that the effect of bathymetry fluctuations on the average sound intensity has its own characteristics compared to the effect of random volumetric inhomogeneities of the speed of sound. In particular, a decrease in the characteristic scale of bottom roughness fluctuations leads to an increase in scattering and a decrease in the sound signal, while similar large-scale inhomogeneities of the bottom boundary change the propagation pattern a little. At the same time, in the presence of volume fluctuations in the speed of sound in the water layer and sediments, it was previously shown that it is large-scale inhomogeneities that significantly affect the propagation of a sound signal, changing the intensity decay law.

Keywords. Two-dimensional shallow-water waveguide, randomly rough bottom boundary, method of local modes.

References

1. Isakovich M.A. Scattering of waves from a statistically rough surface. J. Exper. Theor. Phys. 1952. Vol. 23. P. 305–314.

2. Tamoikin V.V., Fraiman A.A. The statistical properties of a field scattered by a rough surface. Radiophys. Quantum Electron. 1968. Vol. 11. P. 31–36. https://doi.org/10.1007/BF01033538.

3. Kravtsov Y.A., Fuks I.M., Shmelev A.B. Successive application of the Kirchhoff method to the problem of the scattering of a sound wave by a surface having random roughness. Radiophys. Quantum Electron. 1971. Vol. 14. P. 672–679. https://doi.org/10.1007/BF01033177.

4. Bass F., Fuks I. Waves Scattered from Statistically Rough Surfaces. Pergamon: Oxford, Great Britain, 1979.

5. Brekhovskikh L., Lysanov Yu. Fundamentals of Ocean Acoustics. Springer-Verlag: Berlin, Germany, New York, USA, 1982.

6. Kuperman W.A., Schmidt H. Rough surface elastic wave scattering in a horizontally stratified ocean. J. Acoust. Soc. Amer. 1986. Vol. 79. P. 1767–1777.

7. Ogilvy J.A. Wave scattering from rough surface. Rep. Prog. Phys. 1987. Vol. 50. P. 1553–1608.

8. Tracey B.H. and Schmidt H. Seismo-acoustic field statistics in shallow water. IEEE J. Ocean. Eng. 1997. Vol. 22, No. 2. P. 317–331.

9. Stotts S.A., Knobles D.P. and Koch R.A. Scattering in a Pekeris waveguide from a rough bottom using a two-way coupled mode approach. J. Acoust. Soc. Am. 2011. Vol. 129, No. 5. EL172–178.

10. Darmon M., Dorval V., Baque F. Acoustic scattering models from rough surfaces: a brief review and recent advances. Appl. Sci. 2020. Vol. 10 (22), 8305. https://doi.org/10.3390/app10228305.

11. Gulin O.E. Vector characteristics in statistically inhomogeneous waveguides. Sov. Phys. Acoust. 1984. Vol. 30, No. 4. P. 276–279.

12. Jensen F.B., Kuperman W.A., Porter M.B., Schmidt H. Computational Ocean Acoustics. Springer: New York, USA; Dordrecht, The Netherlands; Heildelberg, Germany; London, UK, 2011.

13. Brekhovskikh L.M., Godin O.A. Sound Fields in Layered and Three-Dimensional Inhomogeneous Media. In Acoustics of Inhomogeneous Media. Vol. 2. Nauka: Moscow, Russia, 2009.

14. Yaroshchuk I.O., Gulin O.E. Statistical Modeling Method for Hydroacoustic Problems. Dalnauka: Vladivostok, Russia, 2002.

15. Gulin O.E., Yaroshchuk I.O. Simulation of underwater acoustical field fluctuations in shallow sea with random inhomogeneities of sound speed: depth-dependent environment. J. Comp. Acoust. 2014. Vol. 22, 1440002. https://doi.org/10.1142/S0218396X14400025.

16. Zhu F., Gulin O.E., Yaroshchuk I.O. Average intensity of low-frequency sound and its fluctuations in a shallow sea with a range-dependent random impedance of the liquid bottom. Appl. Sci. 2021. Vol. 11 (23), 11575. https://doi.org/10.3390/app112311575.

17. Gulin O.E. First-order equations to study acoustic fields in ocean with significant horizontal heterogeneities. Dokl. Earth Sci. 2005. Vol. 400, No. 1. P. 173–175.

18. Gulin O.E. Calculation of low-frequency sound fields in irregular waveguides with strong backscattering. Acoust. Phys. 2008. Vol. 54. P. 495–505. https://doi.org/10.1134/S106377100804009X.

19. Gulin O.E. Simulation of low-frequency sound propagation in an irregular shallow-water waveguide with a fluid bottom. Acoust. Phys. 2010. Vol. 56. P. 684–692. https://doi.org/10.1134/S1063771010050143.

20. Gulin O.E. The contribution of a lateral wave in simulating low-frequency sound fields in an irregular waveguide with a liquid bottom. Acoust. Phys. 2010. Vol. 56. P. 613–622. https://doi.org/10.1134/S1063771010050027.

21. Gulin O.E., Yaroshchuk I.O. Simulation of underwater acoustical field fluctuations in range-dependent random environment of shallow sea. J. Comp. Acoust. 2014. Vol. 22, 1440006. https://doi.org/10.1142/S0218396X14400062.

22. Gulin O.E., Yaroshchuk I.O. Features of the energy structure of acoustic fields in the ocean with two-dimensional random inhomogeneities. Acoust. Phys. 2017. Vol. 63. P. 168–174. https://doi.org/10.1134/S1063771017020051.

23. Gulin O.E., Yaroshchuk I.O. Dependence of the mean intensity of a low-frequency acoustic field on the bottom parameters of a shallow sea with random volumetric water-layer inhomogeneities. Acoust. Phys. 2018. Vol. 64. P. 186–189. https://doi.org/10.1134/S1063771018020069.

24. Zhu F., Gulin O.E., Yaroshchuk I.O. Statistical patterns of transmission losses of low-frequency sound in shallow sea waveguides with Gaussian and non-Gaussian fluctuations. Appl. Sci. 2019. Vol. 9 (9), 1841. https://doi.org/10.3390/app9091841.

25. Gulin O.E., Yaroshchuk I.O. On average losses of low-frequency sound in a two- dimensional shallow-water random waveguide. J. Mar. Sci. Eng. 2022. Vol. 10 (6), 822. https://doi.org/10.3390/jmse10060822.

26. Katsnelson B., Petnikov V., Lynch J. Fundamentals of Shallow Water Acoustics. Springer: New York, USA, 2012.

27. Grigor'ev V.A., Petnikov V.G., Roslyakov A.G., Terekhina Y.E. Sound propagation in shallow water with an inhomogeneous gas-saturated bottom. Acoust. Phys. 2018. Vol. 64. P. 331–346. https:// doi.org/ 10.1134/S1063771018030053.

28. Tang X., Tappert F.D., Creamer D.B. Simulations of large acoustic scintillations in the Straits of Florida. J. Acoust. Soc. Am. 2006. Vol. 120, No. 6. P. 3539–3552.

About the authors

GULIN Oleg Eduardovich, Doctor of sciences, physics and mathematics, Leading researcher
Pacific Oceanological Institute, Far Eastern Branch of the Russian Academy of Sciences
Address: 43, Baltiyskaya st., Vladivostok, 690041, Russia
Scientific fields: Scientific fields: ocean acoustics, theory and mathematical simulation of low-frequency wave processes in the layered, irregular, random media, method of local modes.
Phone: +7(423) 231-26-17. **Fax:** +7(423) 231-26-17
E-mail: gulinoe@poi.dvo.ru
https://orcid.org/0000-0002-1132-7354

YAROSHCHUK Igor Olegovich, Doctor of sciences, physics and mathematics, Senior researcher, Head of the Laboratory
Pacific Oceanological Institute, Far Eastern Branch of the Russian Academy of Sciences
Address: 43, Baltiyskaya st., Vladivostok, 690041, Russia
Scientific fields: statistical hydroacoustics, statistical modeling, seismoacoustics, oceanology
Phone: +7(423) 231-26-17. **Fax:** +7(423) 231-26-17
E-mail: yaroshchuk@poi.dvo.ru
https://orcid.org/0000-0002-3212-9752

Recommended citation:

Gulin O.E., Yaroshchuk I.O. PECULIARITIES OF ATTENUATION OF LOW-FREQUENCY SOUND IN THE COURSE OF PROPAGATION IN A 2D ARCTIC-TYPE WAVEGUIDE WITH RANDOM BATHYMETRY. Underwater investigations and robotics. 2023. No. 2 (44). P. 67–74. DOI: 10.37102/1992-4429_2023_44_02_06. EDN: TIAYKK.