frontiers | Frontiers in Marine Science

TYPE Editorial
PUBLISHED 15 June 2023
DOI 10.3389/fmars.2023.1212840

OPEN ACCESS

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RECEIVED 27 April 2023
ACCEPTED 05 June 2023
PUBLISHED 15 June 2023

CITATION
Zhang X, Sun H and Kaneko A (2023) Editorial: Ocean observation based on underwater acoustic technology. *Front. Mar. Sci.* 10:1212840. doi: 10.3389/fmars.2023.1212840

Editorial: Ocean observation based on underwater acoustic technology

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KEYWORDS

underwater, detection, identification, communication, submarine

Editorial on the Research Topic
Ocean observation based on underwater acoustic technology

1 Introduction

The world's military powers have always attached great importance to the collection of Marine environment and hydroacoustic data. Marine monitoring technology plays an important role in promoting the development of economic, military and ecological protection. The performance of underwater communication and target detection algorithms is influenced by the nonlinear interference of underwater communication noise, speed of water surface ripples, weather changes, and geological structure of the seabed. To address the problems of environment interference, professionals and technical personnel propose corresponding technical solutions to address these issues. These solutions aim to improve and enhance the detection and identification capabilities when encountering such challenges. The use of sound waves as information carriers for long-distance transmission in the ocean is necessary, making the research and development of sound wave technology crucial in ocean exploration. Nevertheless, the extensive application of acoustic wave technology in ocean exploration relies on signal processing foundations and sensor support.

2 Underwater communication

Underwater communication is susceptible to various interfering factors. As a result, ensuring high efficiency and speed in underwater communication has become significantly important, leading to increased attention towards communication network protocols (Ahmed and Eltawil, 2015). On the other hand, due to realistic constraints, such as extreme spatiotemporal variations in the underwater acoustic channel, long transmission delays, and limited bandwidth, the application of mature network protocols in underwater communication often fails. Consequently, it is crucial to address the problem of improving system information throughput and network frequency spectrum efficiency in underwater acoustic communication with limited bandwidth (Lu et al). Addressing this challenge, a proposed method aims to overcome the limitations of previous self-interference cancellation (SIC) method, known as spatial self-interference cancellation (SSIC). This method effectively inhibits interference from array and direction-related aspects while also preventing distortion of desired signals over long distances. The implemented in-band full-duplex underwater acoustic communication (IBFD-UWAC) system utilizes improved constant beamwidth beamforming (ICBBF) (convex optimization theory), and a variable step-size least-squares algorithm is proposed for spatial noise threshold in the digtal self-interference cancellation (DSIC) method. Compared to the traditional variable step-size least mean square (VSS-LMS) method, this algorithm demonstrates a more effective elimination effect and achieves faster convergence (Wei et al).To address the hidden terminal problem caused by the unique channel characteristics of underwater sound, including long delay hidden terminals and multi-channel hidden terminals, a multichannel medium access control (MAC) solution is proposed. The channel allocation scheme is determined based on the physical transmission model, and graph coloring theory is utilized to improve channel utilization. Additionally, a channel selection rule method is proposed for graph coloring-based multichannel MAC protocol (GCMAC) data negotiation to enhance efficiency. Experimental results demonstrate that the designed multi-channel MAC protocol not only exhibits a higher success rate of receiving packets compared to single-channel protocols.

3 Underwater acoustic wave propagation

In shallow environments, several factors significantly interfere with the propagation characteristics of sound waves, including the unique structure of the seafloor, sound wave propagation, and attenuation in the ocean (Zhu et al). In their study on the inversion method of acoustic parameters in the marine environment, Bayesian theory was employed to verify the attenuation, sound velocity, seabed structure, and sound velocity density in the seabed. The focus was on matching the characteristic impedance of the vertical waveguide. The inversion results offer valuable insights for the application of existing underwater sensors. Accurate measurement of tidal currents in complex shallow sea environments is also crucial. Researchers have employed tools such as coastal acoustic tomography and mutual acoustic transmission for detecting tidal currents. Data assimilation techniques, specifically the use of the ensemble Kalman filter (EnKF), have been utilized to enhance measurement efficiency (Taniguchi et al). The experimental data used in their study were obtained from path average current results from Japanese researchers in a completed reverse acoustic transmission experiment in the Seto Inland Sea. By redesigning four acoustic station detection points, the EnKF was applied to observe temporal and spatial changes in tidal currents. Various combinations, including location values, the number of system members, and different inflation values, were employed during the implementation of EnKF. The study also identified the cause of high variation in the mean current of the path, attributing it to temporal and spatial variations produced by eddies associated with island wakes. Additionally, EnKF's mutual acoustic transmission capability allowed for the capture of short-period changes within long periods. These findings contribute to the understanding and development of coastal physical processes across different time scales.

4 Underwater imaging

Obtaining clear and accurate information about the natural distribution of underwater environments is particularly important in the study of the ocean, highlighting the significance of underwater imaging (Huang and Yang). Researchers have designed a technique that surpasses traditional imaging methods in terms of producing higher-resolution images. They employ the subblock processing method in the cross-trajectory dimension, leveraging the analysis of cross trajectory variance of super-resolution convolution (SRC). This approach yields similar high-resolution results to the back projection (BP) algorithm benchmark tests while significantly reducing processing time, resulting in improved efficiency (Li et al).Furthermore, a method based on a convolutional recursive neural network (CRNN) has been proposed to enhance underwater imaging performance. The underwater direction of arrival (DOA) estimation utilizes the acoustic array method. The results demonstrate that the proposed CRNN method achieves higher accuracy and faster processing times, making it suitable for broader applications.

5 A marine mobile device

In complex shallow water environments, a marine mobile device is essential for collecting experimental data for scientific research (Totland et al). Drawing on design concepts inspired by the appearance of a two-person kayak used for adventurous activities, researchers developed an unmanned surface vehicle (USV) known as the kayak drone. The primary objective was to construct the kayak drone using existing open-source software and hardware. Previous field experiments have demonstrated that the noise generated by the kayak drone is negligible, allowing it to record the data from fish echo-sounders in the surrounding waters without disturbing fish activities or the natural environment. Additionally, the kayak drone can be employed for baseline-free survey estimations of fish populations in shallow water, which is crucial for the management and assessment of various fish populations. The kayak platform finds applications beyond the aforementioned aspects and can be widely utilized in experiments involving different silent platforms.

6 Marine animal protection

With the passage of time and advancements in science and technology, various technologies utilized in marine research have become increasingly mature. Among these technologies, the protection of the marine environment and the well-being of sea-dwelling animals require dedicated attention and research (Rorstadbotnen et al).

In a study, researchers examined five hours of data from two fiber-optic telecommunication cables and successfully detected 1,808 fin whale vocalizations. This breakthrough opens up new possibilities for accurately mapping the presence and location of whales over large areas, spanning at least 60 km in length and 20 km in width, in near real-time. The simultaneous tracking of multiple whales also offers the potential for gaining new insights into their behavior and interactions within a corridor of approximately 10 km on either side of the cable. By utilizing two fiber cables separated by a few kilometers, the usual left-right ambiguity of a single straight-line array is resolved. The demonstrated capabilities present an opportunity for near-real-time whale tracking that can be implemented worldwide wherever whales are present. Furthermore, by incorporating fused data from other sources such as the Automatic Identification System (AIS), a real-time collision avoidance system, it becomes feasible to develop measures for reducing ship strikes. Successful examples of underwater acoustic systems include passive acoustic monitoring systems, which are not only stable, reliable and cost-effective, but have been widely used to estimate the location and seasonal presence of some animals.

7 Conclusion

Significant progress has been achieved in the study of coastal physical processes and underwater acoustic communication. The application of the GCMAC protocol and the IBFD-UWAC system with DSIC method has greatly enhanced the frequency and efficiency of underwater communication networks. In coastal surveillance and navigation, underwater acoustic array processing techniques, such as Synthetic Aperture Sonar and DOA estimation based on deep learning algorithms, have proven to be vital. These techniques contribute to improved capabilities for monitoring coastal regions and facilitating navigation tasks. Furthermore, advancements in underwater exploration technology are continuously improving. The development of innovative tools and methods enables more effective and efficient exploration of the underwater environment. Further research on underwater acoustic technology is needed in the future so as to be more familiar with the Marine environment.There is much room for future advances in underwater acoustic technology, such as enhancing the reliability and efficiency of underwater communication systems, and improving the accuracy of environmental monitoring so that the ocean can be observed and studied more comprehensively.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Acknowledgments

The authors would like to thank the support from the teachers and students in the Underwater Acoustic Communication Lab of Xiamen University.

Conflict of interest

XZ is employed by the R&D Department, Whale Wave Technology Inc., China.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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