Abstract

Oral session I-1 (Thursday, Afternoon)

6149-Study on Driving Methods of Magnetostrictive/Piezoelectric Hybrid Janus-Helmholtz Transducer*

Wenzhao Liu, Yong Chai, Xiping Mo
Institute of Acoustics Chinese Academy of Sciences

Abstract—A study on driving methods of magnetostrictive/ piezoelectric hybrid Janus-Helmholtz (JH) transducer is carried out. Modal analysis of the hybrid Janus transducer is done at first. It is proved that two effective characteristic modes could be generated, which could be designed to expand the working bandwidth by multiple-mode-coupling technique. The hybrid transducer can be driven in four ways by one driving element while the other driving element is in short circuit state or open circuit state. On this basis, change regularities of the performance of hybrid Janus and JH transducer driven in four ways are studied in detail. Besides, corresponding physical interpretations are also given why the performance changing with different circuit state of driving element. It is confirmed by the predicted results that at least three working modes of the hybrid JH transducer could be used to achieve effective mode coupling and the -6dB working bandwidth could be over two octaves. This new hybrid JH transducer has a series of advantages such as low frequency, wide band and high power.

6145-Broadband transmitting transducer composed of spherical transducer and copper tube

Jie Li, Rongrong Zhao, Xianglong Yu
Shanghai Marine Electronic Equipment Research Institution

Abstract—Through simulation and actual measurement analysis, after installing a copper tube with an inner diameter of 71mm, an outer diameter of 75mm and a length of 35mm outside the spherical transducer with a diameter of 65mm and a wall thickness of 2mm, the vertical through-hole axial transmission voltage response -3dB bandwidth has been increased from 16kHz to The bandwidth of 24kHz and -6dB has been increased from 24kHz to 31kHz, and the range of the directivity of the transducer is small, which has achieved the effect of broadening the transmitting frequency band of the transducer.

6125-Research on Nonlinear Driving Manner of Fe-Ga Alloy Transducer

Jiaheng Zhao, Xiping Mo, Yong Chai, Yongping Liu
Institute of Acoustics, Chinese Academy of Sciences

Abstract—A nonlinear driving manner of transducer driven by the Fe-Ga Alloy material known as Galfenol is developed based on the magnetostrictive equation. The Galfenol driving element of transducer which works under the condition without magnetic bias field is designed. A larger driving magnetic field could be gained under the same working current. The optimal operating point of the driving element is studied by numerical analysis software. The simulation results show that when the driving current is 7A, the prestress of the optimal operating point is 37.5MPa. Then a nonlinear driving technique called half-frequency-driving method is introduced through linear simplification under low driving magnetic field. When the driving magnetic field reaches middle to high level, the input electrical signal function is designed to match the magnetostrictive nonlinear constitutive relationship based on the magnetostrictive equation inversion theory. The output of the transducer is assumed to be a simple harmonic wave at first. Then the linear simple harmonic wave is substituted into the nonlinear equation. At last the input electric signal function needed is obtained through inversion. Thus the simple harmonic output of the transducer is realized. A series of advantages including clear model, simple calculation and easyto- obtain parameters are confirmed by this method. It could be used for the study of nonlinear control of other magnetostrictive transducers.

6123-Research on Temperature Characteristics of Circular Tube Underwater Acoustic Transducer Based on Air Environment

Mingyu Zhang, Yan Wang, Jia Liu, Hui Zhao, Mingrui Li, Rui Zhang
Shanghai Marine Electronic Equipment Research Institute

Abstract—The temperature characteristics of underwater acoustic transducer include temperature variation characteristics, temperature balance characteristics, temperature influence characteristics and other factors. During the long time and high power use of underwater acoustic transducer, the temperature characteristics have become one of the main factors affecting the normal work of the transducer. Since the air environment and water environment are both stable free fields, it is of great scientific significance and engineering value to study the temperature characteristics of the underwater acoustic transducer based on the air environment for improving the long time and high power working ability of the underwater acoustic transducer. The research on the temperature characteristics of the tube underwater acoustic transducer based on the air environment is carried out. The research results are of certain value by means of theoretical analysis, simulation calculation and experimental verification. The formulas for calculating the heating power and cooling power of the tube transducer are obtained. The heat balance temperature of the tube transducer in air environment is simulated. The temperature characteristics and temperature balance characteristics of the tube transducer in the air environment are measured. The heat dissipation technology is used to reduce the temperature equilibrium temperature of the tube transducer in the air environment. It lays a certain technical foundation for the analysis of the temperature characteristics of the tube transducer in multiple environments and the effective realization of the heat dissipation technology of the transducer.

6048-High-Sensitivity Miniaturized Fiber-Optic Hydrophones

Yingsong Huang, Liqiu Wang, Xiaojun Chen, Da Zhang, Wei Sun, Huiliang Ge
Hangzhou Applied Acoustics Research Institute

Abstract—This article introduces the design and experimental verification of a fiber-optic hydrophone. This kind of optical fiber hydrophone is composed of a Michelson interferometer, and the sensitivity enhancement structure is optimized through finite element analysis to improve sensitivity. The developed hydrophone has the characteristics of small size and high sensitivity. In the case of reduced diameter, high sound pressure sensitivity can still be ensured. In the frequency band below 2 kHz, the sensitivity of the hydrophone sample is -140 dB, and the sensitivity fluctuation does not exceed 4 dB.

6035-Probe Response of DFB Fiber Laser Hydrophone under Acoustic Vibration coupled Excitation

Wen-zhang SONG, Bo TANG, Jun-bin HUANG, Hong-can GU, Xuan ZHOU, Hong-lin ZHAO
Naval University of Engineering and No.91388 Troop"

Abstract—DFB fiber laser is cross sensitive to sound pressure signal and vibration signal. To the actual demand of the towed thin linear array based on DFB fiber laser hydrophone, the probe of symmetrical sensitized DFB fiber laser hydrophone was designed and packaged. In this paper, the sound sensitivity and acceleration sensitivity of the probe were calculated by finite element simulation respectively, and the experimental verification was carried out. Second, by acoustic vibration coupling experiment to simulate the actual working conditions, the probe was motivated by acoustic signal and acceleration signal, and the coupling experiment under acceleration sensitivity conform to the separate calculation of acceleration sensitivity. It preliminarily verified the sensor unit had both the high-pressure sensitivity and the low acceleration sensitivity. It was a foundation for the towed thin line array cable formation based on DFB fiber laser hydrophone.

5902-A Coherent Weak Target DOA Estimation Method Based on Target Features

You Shao, Guangyin Zheng, Fuchen Liu, Fuqing Jiang
Hangzhou Applied Acoustics Research Institute

Abstract—Conventional beamforming has become a classic algorithm for target detection because of its good tolerance, but the disadvantage is that its resolution is low and it cannot distinguish weak target signals well. The commonly used minimum variance distortion-free response (MVDR) algorithm is a classic high-resolution beamforming algorithm, but it cannot effectively resolve coherent signals, especially coherent weak target signals[1]. In this paper, a new DOA estimation method for coherent weak targets detection based on target features is proposed to solve the problems above.

4868-Using anti-acoustic baffle design to realize the directivity of transducers and arrays

zhao hui, Li haisen, zhu jianjun, Zhou Tian, Du Weidong
Harbin Engineering University

Abstract—Directivity is not only one of the important performance indicators of the transducer, but also determines the spatial characteristics of the acoustic system. The conventional directional angle and side lobe level parameters can be calculated by theoretical formulas. However, in actual engineering, the vibration characteristics of the radiation surface of the transducer, the coupling between the array elements, and the characteristics of the baffle etc. There will also be a large impact, especially the baffle effect, which will make the directivity of the transducer very complicated, and the angle will not be easily controlled. Studying the influence of baffle on the directivity of the transducer, using the reflection of the baffle reasonably to improve the directivity of the transducer, so that the directivity angle meets the design requirements, is a scientific problem often encountered in engineering and needs to be solved. This paper uses anti-acoustic baffles to improve the design and achieve the directivity of several commonly used underwater acoustic transducers and base arrays, including spherical transducers, cylindrical transducers, longitudinal vibration transducers, and linear array array elements. Using the virtual source method, through theoretical derivation and finite element simulation modeling, calculate the sound field, analyze the directivity factors that affect the transducer under the action of the anti-acoustic baffle, and theoretical calculations, simulation analysis and experimental verification show that the transducer or the basic The operating frequency of the element, the distance from the acoustic center to the baffle, and the size of the baffle are important factors that affect the directivity of the transducer. The paper obtains half-space radiation transducer, low axial beam cylindrical transducer, wide beam longitudinal vibration transducer and wide beam elementary line array by adjusting various influencing factors. The improvement measures obtained in this thesis have important guiding significance in the application of acoustic system or transducer engineering.

6237-Sound Speed Measurement Using Phase Estimation Method of Pulse Signal in Water

Liuqing Yang, Jun Zhang, Jiaheng Wang
Hangzhou Applied Acoustics Research Institute

Abstract—The sound speed is one of the indispensable parameters in underwater ranging, positioning, and navigation applications. The accurate measurement of the speed of sound can directly improve the performance of sonar. An accurate measurement method of sound speed in water based on phase estimation is proposed. An acoustic reflector with dual reflecting surfaces is designed, and the sound speed is obtained by measuring the distance between the dual reflecting surfaces and the arrival time delay of the echo signal from the reflecting surfaces. A quadrature phase detection method is proposed to accurately estimate the phase and time delay of the echo signal, and the dual-frequency transmission signal is used to solve the periodic wrapped of the phase estimation. A device for measuring the sound speed in seawater was developed to measure the sound speed of seawater at temperatures of -0.7 ° C and 20 ° C and a hydrostatic pressure range of 0 MPa to 30 MPa. The maximum standard deviation of the measurement results is 0.022 m/s. The measurement uncertainty of this device is evaluated, and its expanded uncertainty is 0.05 m/s.

6124-Research on Measurement Method of Underwater Transducer Acoustic Field Based on Laser Reflection Tomography

Weiyin Wang, Yi Chen, Shiquan Wang, Liuqing Yang
Hangzhou Applied Acoustics Research Institute

Abstract—The radiation acoustic field distribution of the transducer can directly reflect the acoustic performance of the transducer. If the radiation acoustic field distribution of the transducer cannot be accurately measured, it will have a serious impact on the diagnosis and evaluation of the transducer. The application of laser reflection tomography in the measurement of the acoustic field of the planar transducer is studied, and the measurement principle of the laser reflection tomography is analyzed. By combining the mathematical theory of the laser reflection tomography with the actual acoustic field measurement, acousto-optic effect, the fixed value formula of the absolute acoustic pressure value in the acoustic field is derived. On this basis, a planar transducer radiation acoustic field measurement system was built. The measurement experiment of the near-field radiation acoustic field distribution of the circular piston transducer was carried out, the acoustic field distribution and the absolute acoustic pressure value in the acoustic field was reconstructed. In order to verify the accuracy of the measurement results, a comparative experiment was carried out using the hydrophone scanning method. The comparison results show that the radiation acoustic field reconstruction results and the absolute acoustic pressure reconstruction results obtained by the laser reflection tomography method are in good agreement with the measurement results of the hydrophone scanning method, which verifies the feasibility and accuracy of the laser reflection tomography method to measure the acoustic field distribution of the transducer. It provides a reliable and accurate measurement method for the acoustic field reconstruction and acoustic pressure measurement of the transducer.

6184-Modeling and Analysis for the Target Detection via Multiple Autonomous Underwater Vehicles

Weihua Gao, Jing Yan, Xiaoyuan Luo
Yanshan University

Abstract—With more and more attention paid to the study of ocean exploration, the long-term monitoring and detection of underwater environment have become a demand. In some researches, the dense sensor deployment is used to monitor the underwater environment. Because of the strong maneuverability of target, the detection performance of the intensive sensor deployment is not high. Therefore, the autonomous underwater vehicle (AUV) is used to monitor the underwater environment. In this paper, we use a group of AUVs which consist of two AUVs with a certain distance to monitor and detect the underwater environment. Firstly, we point out the optimal detection mode of the group of AUVs is along a straight line. Then, based on the linear detection mode, the coverage degree of underwater environment is quantitatively analyzed. Besides that, we give the theoretical formula of target detection probability for stationary and moving targets. Finally, we give some simulation results to further verify the correctness of the theoretical results.

6007-Communication-Aware Swarm Control for AUVs: A Reinforcement Learning-Based Solution

Xuanji Zhou, Jing Yan, Xiaoyuan Luo
Yanshan University

Abstract—The Communication-Aware in the Autonomous Underwater Vehicle (AUV) Swarm Control is an advanced technology, which should apply to the realistic environment. In order to ensure stable communication environment from the leader-follower swarm of AUV, the propagation attenuation of underwater acoustic signal is characterized by mathematical model. Then a prediction model of channel quality is constructed. The unknown parameters in the model can be calculated through few samples. The channel quality at any location within the sample coverage can be predicted. In the meanwhile, this paper adopts the improved artificial potential field to achieve collision avoidance between AUVs. Then, the propagation attenuation of underwater acoustic signal and the improved artificial potential field were incorporated into cost function. The optimal solution of swarm motion was obtained based on Reinforcement Learning (RL) solution, which significantly reduced the code error rate. Finally, the feasibility of the scheme is verified by simulation.

6238- An Arc PVDF Hydrophone with Adjustable Beam Width

Yan Guo, Xin-Ran XU, Zhen-Yu ZHENG, Xue-Rong LIAO, Kang-Yi PENG, Xiao-Long MEI
Science and Technology On Sonar Laboratory；Hangzhou Applied Acoustics Research Institute

Abstract—Generally, the beam width of planar hydrophone is limited by its wavelength size, that is, when the receiving aperture is fixed, the beam width at a certain frequency is also fixed. When the working frequency is increased, in order to meet the beam width index, the receiving area of the hydrophone must be reduced accordingly, which reduces the capacitance value of the hydrophone and the ability of anti-interference and anti current noise of the hydrophone. Large area receiving is one of the biggest advantages of PVDF hydrophone, so how to improve the beam width without reducing the receiving area is an important problem to be solved. Therefore, a circular arc backed PVDF hydrophone is proposed in this paper, which can improve the directivity of the hydrophone and make the beam width no longer limited by its wavelength size. The beam width can be adjusted by changing the shape and radian of the arc backing, so that it can be applied to different frequencies.

6243-Matching analysis for transfer and radiation law of sound through pipe and sound source

Jize Zhong, Diwang Li, Changlin Qiu, Du Shen, Hao Wang
China Ship Development and Design Center

Abstract—At present, there are few researches on the law of pipeline transmission-radiation and the matching between sound source and pipeline in the seawater cooling system, whitch are not strong in supporting the noise control of the seawater cooling system. In view of this, this paper proposes a calculation model of the flow noise radiation in the seawater cooling system by using the plane wave hypothesis and the physical model of single port pipe orifice radiation. The model adopts the inlet pressure boundary, considers the elastic effect of the pipe wall, and models the internal sound field of the pipe and the local radiation sound field of the pipe orifice through finite element, and combines the infinite baffle and the infinite element to simulate the infinite radiation sound field. The deviation between the critical frequency calculated by the model and the theoretical estimation is 0.73%, and the total transfer loss deviation is less than 3.5%. Based on the calculation and research of the DN175 pipe orifice of a civil ship's seawater cooling system, it is found that there is a mismatch between the total transmission loss characteristics of the pipe and the sound source characteristics of the pump. By adjusting the operation mode, the control effect of the system's leaf frequency line spectrum noise is improved by 30dB.

6357-Numerical Simulation of Vortex-acoustic Coupled Acoustic Signals Based on Ray Acoustics

Min Yu, Xuan Zhang, Yongou Zhang, Zhihong Wang
Wuhan University of Technology

Abstract—The energy dissipation during the navigation of underwater targets will form large-scale vortices in the ocean. The coupling between sound waves and wake vortices can determine the existence and morphological characteristics of wake vortices, and then identify underwater targets. Based on the theory of ray acoustics, this paper derives the expression of ray differential equation in moving medium, and analyzes the influence of underwater eddy current field parameters on sound ray propagation. The results show that in the case of low Mach number, the vortex circulation is an important factor affecting the vortex-acoustic coupling characteristics, which lays the foundation for the underwater target recognition method based on vortex-acoustic coupling.

6133-Effects of sound velocity perturbations in the upper layer on the position of sound convergence zones in deep water

Fujin Yang, Tao Hu, Zhen Wang
Institute of Acoustics, Key Laboratory of Underwater Acoustics Environment, Chinese Academy of Sciences, University of Chinese Academy of Sciences

Abstract—Sound velocity profiles (SVPs) data of deep water is measured by an underwater glider in South China Sea. The measured data show that the SVP in the upper layer has a small perturbation at the experiment site. The maximum fluctuation of Sound velocity occurs at 110 m and the standard deviation of the fluctuation is 2.8 m/s. The standard deviation of fluctuations is 1.5 m/s at 200 m, which is the source depth of acoustic experiment. And the measured data of a temperature chain at a fixed place shows that there are no strong internal waves during the experiment. The numerical simulations show that the fluctuations of upper layer SVPs during the experiment have a great effect on the convergence zone (CZ) span of acoustic field in the deep water. This results in that CZ position of deep-water acoustic field has a certain deviation and this deviation value increases with propagation distance. The propagation paths of the sound ray with a grazing angle of 0° is calculated under different SVPs fluctuation, and we analyze the reasons for the influence of SVP perturbations on CZs position of acoustic field in deep water. The average SVP is used to calculate acoustic propagation loss at experiment site. The simulated acoustic propagation loss and measured results are consistent with each other, which indicate that using average SVP can effectively reduce influence of the upper layer sound velocity perturbations on predicting CZs position of acoustic field in deep water.

6039-Feature Analysis on the Circularity Degree of the Complex Sound Intensity in Shallow Water

Jianbo Ma, Chuanlin He, Yi Zheng, Yang Sun
Institute of Oceanographic Instrumentation，Qilu University of Technology Shandong Academy of Sciences

Abstract—In this paper, the equivalence relation between the two expressions of circularity degree vector for the complex sound intensity is derived in detail, and the correspondence between the angle component of circularity degree vector and the imaginary part of the vertical complex sound intensity is clarified through theoretical analysis. Numerical calculation and sea trial data analysis are carried out, and the results show that the amplitudes of the two parameters have similar structure distribution, almost the same “zero-crossing” position and consistent sign distribution. But only when the amplitudes of the horizontal and vertical velocity components are equal, the two parameters are equal one another.

4835-Estimation of Source Strength of Underwater Acoustic Transducer in Shallow Water by Inverse Frequency Response Function

Yucai LIU, Yi CHEN, Wensheng YI
Hangzhou Applied Acoustics Research Institute

Abstract—A source strength estimation method based on the acoustic inverse frequency response function (IFRF) is proposed to solve the problem of poor accuracy of the assessment of the vibration and noise level of underwater acoustic equipment in shallow waters. This method represents the multi-channel transmission function as the interference superposition of the sound source and its multi order virtual source. The transfer matrix builds the relationship between the complex source strengths, the complex pressures at measurement points and the acoustic channel. The source strengths can be estimated accurately from the radiated acoustic field measurement based on the inversion of transfer matrix. The basic principle of the IFRF method is introduced, and the influencing factors of source strength estimation errors are analyzed, including the underwater acoustic channel estimation errors, sound pressure measurement errors, and the conditions of the transfer matrix. The results of simulation analysis and experiments on the lake are presented, the obtained source strength estimation results are in good agreement with the real values, which indicates that the proposed method is feasible and has good performance in estimating the source strength of underwater acoustic transducer.

6311-Influence of Softening Effect of Bubble Water on Cavity Resonance

Jiawen Yu, Desen Yang, Jie Shi
Acoustic Science and Technology Laboratory, Harbin Engineering University, Harbin 150001, China Key Laboratory of Marine Information Acquisition and SecurityHarbin Engineering University, Ministry of Industry and Information TechnologyHarbin 150001, China College of Underwater Acoustic Engineering, Harbin Engineering University, Harbin 150001,China

Abstract—This paper studies the nonlinear resonance of a cavity in an aqueous medium containing bubbles, and the resonance frequency is produced by mixing of nonlinear frequencies. We use the model to simulate the nonlinear interaction between ultrasound and bubble dynamics, which is derived from the wave equation and the Rayleigh-Plesset equation based on finite volume and finite difference. The simulation results reveal the existence of cavity resonance frequency shift at the difference frequency component. The frequency shift increases with the increase of the pressure amplitude. It can be considered that this is caused by the softening effect of the medium. Finally, this article shows that nonlinear resonance frequency shift can be used to enhance the amplitude of the difference frequency component, which provides a new idea for subsequent target detection and recognition.

6296-Effective Nonlinearity Parameter and Acoustic Propagation Oscillation Behavior in Medium of Water Containing Distributed Bubbles

Yuezhu Cheng, Jie Shi, Anding Deng
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Abstract—In this paper, the sound velocity and attenuation model of the fundamental frequency and second harmonic of the medium with distributed bubbles are obtained by using the perturbation method, and the effective nonlinearity parameter expression of the medium is derived based on the effective medium model. The wave-vector- frequency-domain acoustic propagation model is established based on the Westervelt equation. Considering the effects of frequency dispersion and unequal sound attenuation, the spatial variation of the amplitude of the second harmonic and the sum and difference frequency are analyzed in detail, when a single frequency wave or double frequency waves propagate in this special effective medium.

5920- Simulation Analysis of the Effects of the Flow around Underwater Moving Bodies on the Acoustic Signal

Di Zhang, Shihong Zhou, Yubo Qi, Shuyuan Du, Changpeng Liu
State Key Laboratory of Acoustics, Institute of Acoustics, Chinese Academy of Sciences University of Chinese Academy of Sciences

Abstract—The underwater moving bodies interacting with the water flow form a complex flow field. The changing flow field can cause the time-varying Doppler frequency shift of the acoustic signal propagating in the flow field. In this paper, the finite volume method is used to simulate the flow field behind the underwater cylindrical moving body and the horizontal rudder with different deflection angles. The simulation results show that the flow velocity behind the underwater cylindrical moving body does not change dramatically with time, while the flow field behind the rudder blade with a certain deflection angle changes dramatically with time and space. As the rudder blade deflection angle or the moving speed increases, the frequency changing period decreases and the frequency variation increases.

5941-The Evolution of the Speed of Sound Based on Changes of Entropy and Energy in Statistical Ocean

Jie Duan, Hangfang Zhao
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Abstract—To develop geophysical fluid dynamics (GFD) from classical mechanics to thermodynamics or statistical mechanics, the "arrow of time", which is entropy, must be introduced. Entropy organizes the sound propagation in random ocean. With the help of flow velocity and temperature, this paper deduces the relationship between entropy, energy and the speed of sound under small-scale changes in the ocean. Simulations are performed with the space-time data of the three-dimensional rotating stratified turbulent flow of John Hopkins University, verifying deduced expressions, which is beneficial to the study of acoustic propagation and hence target detection, localization and tracking in the stochastic ocean.

4678-Analysis of the Influence of Underwater Acoustic Array Structural Factors on Multi-static Bearing-only Location

Xin Wang, Longxiang Guo, Xueli Sheng
College of Underwater Acoustic Engineering, Harbin Engineering University

Abstract—Aiming at the influence of underwater acoustic array structural factors on Multi-Static Bearing-Only Location (MSBOL), the paper divides the influencing array structural factors into the direction estimation ability determined by the array aperture and the array orientation characteristics determined by the multi-static deployment form. And then the influence of two factors on MSBOL is analyzed. The analysis result of direction estimation ability shows that under the condition that the direction estimation ability of each station is similar, the performance of MSBOL is significantly better than any bistatic combination. And as the direction estimation ability of some of the stations declines, the performance of MSBOL will be significantly reduced and ultimately lower than the optimal bistatic location result. The analysis results of the array orientation show that since the direction estimation of the linear array is obviously affected by the attitude change, the optimal MSBOL result can be obtained when the normal direction of the array points to the target.

6157-Research on a kind of Longitudinal Transducer Driven by Ni-Mn-Ga Alloys

Houqi Wang, Yu Lan, Wei Lu, Rongzhen Guo, Hao Sun
Harbin Engineering University

Abstract—Ni-Mn-Ga alloys, a kind of magnetic shape memory alloys (MSMAs), can exhibit maximum expansion strains of 6% when an external magnetic field applied, and have a fast response time, high power density, which making MSMAbased actuators kHz capable. For this reason, we presented a kind of low-frequency, small-sized longitudinal transducer driven by Ni-Mn-Ga in this paper and fabricated a prototype. The finite element method was used to design and analyze the magnetic induction intensity distribution in the drive magnetic circuit. Meanwhile, the displacement of the radiating surface in the air and the sound source level in the water of the transducer were measured. According to the results, the radiating surface displacement of the transducer can reach up to 0.12 mm in the air, and the sound source level in the water exceeded 130 dB. The strain test result of the Ni-Mn-Ga transducer is much higher than that of piezoelectric ceramics or Terfenol-D with the same dimensions. Therefore, it can be realized by using Ni-Mn- Ga alloys to design a low-frequency transducer with a small size.

Oral session VI-1 (Thursday, Afternoon)

6239-Improved Dynamic Compressive Sensing Based Channel Estimation for Single-Carrier Underwater Acoustic Communication

yunfeng Hu, Jun Tao, Ming Jiang, Chunhui Dang
Southeast University

Abstract—In this paper, an improved dynamic compressed sensing (DCS) scheme was proposed for time-varying channel estimation and tracking in single-carrier underwater acoustic (UWA) communication systems. It employs the stochastic weak selection gradient matching pursuit (StoWGradMP) algorithm to track the support set of the channel impulse response (CIR), and the reduced-order Kalman filter (KF) to estimate the significant taps. Different from existing schemes, the support set is allowed to expand or shrink during the estimation process. Experimental results show the proposed KF-StoWGradMP channel estimation outperforms existing DCS based channel estimation methods at lower complexity. Index Terms—Dynamic Compressed Sensing, Kalman Filter, Time-Varying Channel Estimation, Underwater Acoustic Communications.

6214-Design of FM-DCSK Waveform for underwater covert Communication system

Yuting Yuan, Gangqiang Zhang
National Key Laboratory of Science and Technology on Underwater Acoustic Antagonizing

Abstract—The bit energy of chaotic signal in underwater covert communication system is not stable, which will cause the estimation interference and the bit rate decline. Therefore, the frequency-modulated differential chaos shift keying (FMDCSK) covert communication system was proposed which was combined the FM modulation with the differential chaos shift keying (DCSK) system. The bit energy of signals remained stable by using FM modulation so that the BER performance can be improved. Meanwhile, the system was also combined with the modified DCSK system which uses a two-channel scheme, therefore it can improve the transmission efficiency. In this paper, the feasibility of FM-DCSK was analyzed first. Meanwhile, the Matlab simulation contrasted the two different systems of FM-DCSK and DCSK. The simulation results show that the relative performance in this proposed system can be worked well.

6213-Wormhole Attack Detecting in Underwater Acoustic Communication Networks

JunQing Zhang, Gangqiang Zhang, Junkai Liu
National Key Laboratory of Science and Technology on Underwater Acoustic Antagonizing, Shanghai

Abstract—Because the underwater acoustic communication network transmits data through the underwater acoustic wireless link, the Underwater Acoustic Communication Network is easy to suffer from the external artificial interference, in this paper, the detection algorithm of wormhole attack in Underwater Acoustic Communication Network based on Azimuth measurement technology is studied. The existence of wormhole attack is judged by Azimuth or distance outliers, and the security performance of underwater acoustic communication network is evaluated. The influence of different azimuth direction error on the detection probability of wormhole attack is analyzed by simulation. The simulation results show that this method has a good detection effect for Underwater Acoustic Communication Network.

6211-Virtual Reference Assisted Self-localization Algorithm for Mobile Underwater Acoustic Networks with Only One Anchor

Jingjie Gao, wei Wang, Jianmin Yang, Peng Chen, Zhichen Zhang, Haodi Mei
Changan University

Abstract—Self-localization is one of the basic issues for Mobile Underwater Acoustic Networks (MUANs). Considering the characteristics of MUANs, less anchor nodes and node's movement make the high precision self-localization be more difficult to be achieved. In this paper, a virtual reference assisted self-localization algorithm for MUANs with only one anchor has been proposed. Firstly, the algorithm constructs the virtual reference to assist the only one real anchor in accomplishing the self-localization procedure by taking advantage of the multi-path communication channels which reduces the amount of anchor nodes that should be used in localization greatly. In addition, a virtual reference assisted self-localization method is proposed which makes use of the observation information from both the real anchor and the virtual reference to predict each mobile node's position dynamically and directly. The simulation results demonstrate that the proposed algorithm could work with only one anchor and has higher localization accuracy and lower communication cost than other approaches which make it more suitable and effectiveness for MUANs.

6169-Key generation technology based on multipath structure of underwater acoustic channel

Junkai LIU, Gangqiang Zhang, Junqing ZHANG
The 726 Research Institute of China Shipbuilding Industry Group

Abstract—The data in the underwater acoustic channel (UAC) can be received through the hydrophone. If there is no encryption protection measures, the enemy can easily obtain sensitive information. According to the requirements of secure transmission of under-water network measurement and control secret information, a key generation method based on UAC response characteristics is proposed. Based on the short-term correlation of UAC, the amplitude and time delay characteristics of underwater acoustic channel multipath structure are extracted, the multi-path number with the strongest energy, the number of qualified sound rays and multipath number with maximum delay difference are quantized to generate the original key. Then, the inconsistent key is corrected by key agreement mechanism. the communication parties can generate encryption key in real time to ensure the confidentiality of information. Experimental results show that the short-term correlation of multi-path structure of UAC is good, which verifies the feasibility of key generation based on multi-path structure of UAC and the key generation scheme proposed in this paper can make the matching probability of underwater acoustic key generation not less than 80%.

6142-The Effect of Shell Shape on Self-Interference Signal Strength of In-Band Full-Duplex Underwater Acoustic Communication Modem

Naihua Zheng, Songzuo Liu, Yi Lou, Yunjiang Zhao, Xinyu Liu, Teng Shi
Harbin Engineering University

Abstract—Compared with the half-duplex (HD) underwater acoustic (UWA) communication system, the in-band full-duplex (IBFD) UWA communication system can theoretically double the frequency band utilization. The main challenge of the IBFD-UWA communication is to eliminate the self-interference (SI) signal generated by the near-end transmitter. In this paper, we focus on the effect of the dimensions of the IBFD-UWA modem shell on the strength of the SI signal. The typical IBFD-UWA modem is long cylindrical, and its height is higher than the radius; the strength of the SI signal is very high due to the shape of the shell. Therefore, the finite element method (FEM) is used in the simulation software to calculate the SI signal strength received by shells of different dimensions. The simulation results show that when the diameter increases gradually, the SI signal strength reaches a maximum value, and then the diameter approaches the height and then decreases gradually. When the diameter is gradually larger than the height, the energy of the SI signal received by one size increases suddenly, which may be caused by the material resonance frequency. Then the energy of the SI signal decreases sharply. The simulation results provide a useful reference for the design of the IBFD-UWA communication modem shell.

6187-Generalized Radon Transform Approach to Motion Parameter Estimation of Single Target Moving in Multiple Straight-line Segments

Mingyang Lu, Jidan Mei, Shuchang Wang, Tianfeng Huang, Yuqing Pei, Rui Wang
Harbin Engineering University

Abstract—To improve the estimation of motion parameters by submerged static acoustic detection equipment, we designed a method to estimate target motion parameters based on the model of a target moving in multiple straight-line segments at a constant speed. The number of segments and the time at which the target changes its course are obtained by applying the generalized Radon transform (GRT) to bearing–time records (BTRs). On this basis, the BTRs can be divided into different segments, and these are then processed in turn by using GRT to obtain the motion parameters of each segment, namely heading angle, the time to the closest point of approach (CPA), and the ratio of velocity to the horizontal range of the target at the CPA to the sensor. Computer simulations based on a fixed single vector measurement system serve to validate the feasibility and performance of the proposed method. The results suggest that the proposed method not only estimates the motion parameters accurately, but can also identify the time at which the target changes its course.

5976-Low-frequency Underwater Acoustic Signal Denoising Method in the Shallow Sea with a Low Signal-to-noise Ratio

Yaowen Wu, Chuanxi Xing, Dongyu Zhang, Lixiang Xie
Yunnan Minzu University

Abstract—Due to the serious and complicated noise in the shallow sea environment, the received signal obtained by the hydrophone is disturbed by the noise to a large extent. It has a low signal-to-noise ratio (SNR), which leads to problems such as difficulty in processing the underwater acoustic signal. To solve this problem, to more effectively remove the ocean noise in the useful signal, a denoising method based on sparse decomposition and dictionary learning is adopted. First, a complete Discrete Cosine Transform (DCT) dictionary is randomly constructed. Then the orthogonal matching pursuit (OMP) is used to represent the noisy underwater acoustic signal sparsely, the method of optimal directions (MOD) and K-singular value decomposition algorithm (K-SVD) are used to update the complete DCT dictionary respectively. According to the updated new dictionary and sparse coefficients, the underwater acoustic signal is reconstructed, and the ocean noise is removed. By denoising the different form of simulated signals with different SNRs, the results show that two methods can remove various noises mixed in the underwater acoustic signal effectively and retain the signal details while denoising. The SNR gain can reach about 20dB.

5972-Underwater Small Moving Target Detection Using Maximum Length Sequences

Kaiyang Hou, Tingting Teng, Yiao Zhang
Harbin Engineering University

Abstract—Protecting harbor and coastal security is a growing concern in the field of underwater acoustics, so preventing terrorist attacks by underwater intruders is an important task for active sonar detection. However, the target strength (TS) of the underwater moving target and the signal-to-noise ratio (SNR) are relatively low, meanwhile, active sonar is subject to strong reverberant interferences, which are confused with the target in the time domain and in severe cases can drown out the small target. This paper analyzes the delay and Doppler resolution performance of linear frequency modulation (LFM) signals and maximum length sequences (m-sequences) using wideband ambiguity function, and a pool experiment of detecting the diver is completed. It is found that the m-sequence can separate reverberation from the target in the Doppler domain and has the ability to suppress reverberation, which is more beneficial to active sonar detection.

5957-High-accuracy Single-beam Sounding Using Small Bandwidth and Rough Sound Speed

Xionghou Liu, Yanhua Li, Shulei Lan
Northwestern Polytechnical University

Abstract—For the single-beam sounding system, the accuracy of the depth estimation result is basically based on the instant system bandwidth and the measurement of the sound speed. Traditionally, to improve the accuracy, a large instant system bandwidth and the high-accuracy sound speed measurement are required. However, the large instant system bandwidth and the high-accuracy sound speed measurement will dramatically increase the cost of the single-beam sounding system. In this paper, a new single-beam sounding method using a comb-spectrum signal with a relatively small bandwidth and a roughly measured sound speed is proposed. In the method, the comb-spectrum signal is composed by a set of frequency diverse continuous wave (CW) pulses. Because of the frequency gap between the CW components, their echoes have different phase shifts. These phase shifts caused by the frequency offset are similar to the array manifold vector of uniform linear array (ULA). Hence, similar to the spatial spectrum estimation of the ULA, we use the MUSIC algorithm to process the echoes of these CW components. By scanning along the depth and the sound velocity dimensions, we show that the MUSIC algorithm can output a peak close to the true depth and the true averaged sound velocity. Due to the high accuracy of the MUSIC algorithm, the proposed method can use a small instant system bandwidth and a rough sound speed measurement to obtain a high accuracy depth estimation result. Finally, give the numerical simulations to show the superiority of the proposed method.

5946-Echo Detection Method Based on Matched Filter Using Fast Orthogonal Search

Zhishan Zhao, Liang Jie, Yuwei Li
Shanghai Marine Electronic Equipment Research Institute

Abstract—As a traditional detector in the field of signal detection, the matched filter (MF) still plays an extremely important role in electronic information systems such as sonar and radar. Aiming at the problem of echo extraction in active sonar target detection, this paper proposes an echo detection method based on matched filter using the fast orthogonal search (FOS-MF) by transforming the spectral output of the matched filter into a line-spectrum detection problem and combining a high frequency-resolution spectral analysis tool which is the fast orthogonal search (FOS) algorithm. The results of simulation and experimental data processing show that compared with the conventional matched filtering echo detection method, FOS-MF can detect target echoes and estimate the delays stably and accurately. The method proposed in this paper can automatically extract target echoes even in a low input signal-to-noise ratio (SNR) situation.

5917-Multi-ping Reverberation Suppression Combined with Spatial Continuity of Target Motion

Ruixin Nie, Xionghou Liu, Chao Sun, Yifan Zhou
Northwestern Polytechnical University

Abstract—Reverberation suppression is necessarily required for detecting the underwater low-speed small targets (e.g., frogmen and UUVs). In recent years, the promising reverberation suppression method is to use the correlation characteristics between multi-ping echoes to implement the low-rank sparse matrix decomposition. However, almost no prior knowledge about the moving continuity characteristic of the target has been considered in existing methods, which leads to performance degradation in complicated underwater scenarios. To solve the problem, we introduce the detecting contiguous outliers in the low-rank representation (DECOLOR) to improve the calculation accuracy of the low-rank and sparse matrix decomposition. In DECOLOR, a priori knowledge that the slow small target is moving contiguously with relatively a small size (i.e., a highlight point moving continuously across a group of sonar images), is adopted. And the locations of target highlight point in the group of sonar images are modeled by the first-order Markov Random Fields (MRFs). By doing so, the low-rank and sparse matrix decomposition using the DECOLOR shows a higher accuracy for matrix decomposition. Thus, the proposed method shows a better reverberation suppression ability than existing methods. The proposed methods are tested and evaluated through a series of simulation experiments.

5912-Frequency Line Extractor Using Hidden Markov Models

Yun Gao, Delong Sun
Shanghai Marine Electronic Equipment Research Institute

Abstract—In passive sonar, the automatic detection and tracking of frequency lines plays an important role in the automatic identification of targets. The proposed algorithm based on hidden Markov model (HMM) realizes the automatic initialization and extraction of frequency lines using the Forward Algorithm and Viterbi algorithm. The proposed algorithm improves the detection and tracking ability of the frequency lines in a low SNR environment, and the sea data confirm this conclusion.

6165-Experimental Study on Depth Discrimination for A Moving Source with A Horizontal Array in Shallow Water

Duo Zhai, Fenghua Li, Bo Zhang
Institute of Acoustics, Chinese Academy of Sciences; University of Chinese Academy of Sciences

Abstract—Acoustic source depth discrimination is a robust way to obtain depth information when source depth cannot be estimated accurately. This paper makes use of the fact that the low-order modes which are excited by surface sources generally have low amplitudes in a downward refracting shallow water environment. The depth discrimination depends on the trapped energy ratio in mode space. The performance of the maximum a posteriori mode filter is compared with other mode filters. For a moving source, it has been verified that the broadband processing and time integral can improve the detection rate when the expected false alarm rate is 0.01. Finally, experimental results show that time integral for a moving source can effectively discriminate the source depth.

6258- Hierarchical Construction of Sound Speed Profile based on Argo and Sea Surface Data

Honglin Li, Qianqian Li, Xian Yan, Shoulian Cao, Zhichuan Ma, Kangying Zhou
Shangdong University of Science and Technology

Abstract — Sound speed profile is an important content of hydroacoustics research, real-time acquisition of large-scale, high-precision sound speed profile is of great significance to ocean surveys. This paper studies the Indian Ocean from 2 degrees to 24 degrees north latitude and 50 degrees to 77 degrees east longitude. The data of the Argo sound speed profile; the sea surface temperature SST (Sea Surface Temperature) data and the sea level anomaly SLA (Sea Level Anomaly) data from September 2013 to 2015 are selected. Through correlation analysis, it is found that the sea surface data is feasible to reconstruct the sound speed profile and has a high degree of correlation with the upper layer (mixed layer and thermocline); therefore, through the establishment of a layered model, the upper layer adopts the sEOF-r method. The first two-order coefficients and sea surface data are used to construct a local temperature profile regression database; the lower layer uses the Empirical Orthogonal Function (EOF) method to obtain the full-sea depth temperature profile. Combined with the stable temperature-salt relationship and the empirical formula of sound speed, the sound speed profile is calculated. The analysis shows that the overall root mean square error of the upper layer of the temperature profile constructed by layers is 1.6234, and the overall root mean square error of the lower layer is 0.5439. The overall reconstruction result is accurate and conforms to the characteristics of the water area.

6160-Simulation of Underwater Sound Propagation of High-Speed Sources

Songwen Li
Shanghai marine electronic equipment research institute

Abstract—A signal segmentation method is proposed to simulate underwater sound propagation of high-speed sources. The effects of range and depth change of the source position on the sound propagation are analyzed. The simulated noise of a high-speed source travelling through the underwater channel are calculated for several typical sound velocity profiles of shallow and deep sea. We only care about the conditions that the distance between the source and receiver is not larger than 10 km. And for deep sea, we only care about when the source and receiver are both within shallow area. The calculations show that the influence of the depth change of a moving source on the power spectrum of the received signal is dependent on the rate of change of the sound velocity to depth. It is also shown that when there are only several eigen rays with different phase angles for the underwater acoustic channel, the summation of these eigen rays may cause interference patterns, and periodicity can be seen in the power spectrum of the received signals.

6081-Simulation of acoustic-energy frequency response caused by internal waves in the Yellow Sea

Zhen WANG, Tao HU, Shengming GUO, Li MA
Institute of Acoustics, Key Laboratory of Underwater Acoustics Environment, Chinese Academy of Sciences, University of Chinese Academy of Sciences

Abstract—In this paper, the internal-wave environment dominated by tidal-period internal waves is constructed by using the temperature-chain measurement in an experiment conducted in the Yellow Sea, and the simulation is carried out by using the parabolic equation model RAM. The results show that when the sound source depth is 20 m and the receiving depth is 30 m, the acoustic energy versus frequency curve at a distance of 28 km presents abnormal variations in the specific frequency-band. When the set-value of the internal-wave propagation velocity changes, the frequency corresponding to the lowest energy, the abnormal attenuation frequency-band and the value of abnormal attenuation all change regularly. Further analysis shows that the abnormal variation of acousticenergy in single receiving depth may be caused by the variation of acoustic energy depth-distribution, rather than obvious acoustic energy loss.

6034-Analysis of the acoustic longitudinal horizontal correlation characteristics with wind-generated waves in shallow water

Meijuan Yao, Licheng Lu, Bingwen Sun, Shengming Guo, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—The wind-generated waves can often introduce rough sea surface and bubbles layer underneath the sea surface, which can redistribute the energy of the acoustic field. Taking the coupling effects of wind-generated rough sea surface and bubbles layer into account, combined with the Parabolic equation acoustic propagation model, analysis of acoustic longitudinal horizontal correlation with different wind speeds are carried on. In the given frequency band, with the wind speeds increasing, the acoustic longitudinal horizontal correlation becomes better. The theory of the Normal mode and the normal mode acoustic model are used to give the reason: with the wind speeds increasing, the normal modes with higher orders decline sharply, which leads to fewer effective normal modes. As a result, the interference between the normal modes is weakened to increase the acoustic longitudinal horizontal correlation.

5963-Boundary Slip Effect on Acoustic Scattering from a Rigid Cylinder via Immersed Boundary-Lattice Boltzmann Method

Xinyi Han, JianHua Lu, Yunan Cai, Nan Chen, Meng Xiang
School of Naval Architecture Ocean Engineering Dalian University of Technology

Abstract—Acoustic scattering problems have been main topics in the acoustic community. Most previous work assumed that no-slip on the surface of the solid. Nowadays, more and more studies have shown the existence of boundary slip and its impact on acoustics properties. In this paper, acoustic scattering from a rigid cylinder with boundary slip on surface is carried out by the force correction-based IB-LBM. The boundary slip on acoustic scattering from the rigid cylinder is investigated under the condition of different wave numbers. Numerical result shows that: Different wave numbers affect the energy distribution of sound pressure, and different slip lengths shift the phase and the amplitude of the waveform.

5962-A Lattice Boltzmann Method for Acoustic Propagation in the Presence of Internal Solitary Waves

Yu Wang, Jianhua Lu
Dalian University of Technology

Abstract—Internal solitary wave is a universal phenomenon in ocean which can bring enormously significant impact to sound propagation. To our knowledge, most previous acousticbased methods on the problems of the effect of internal solitary waves on acoustic propagation were done in the frequency domain. It is hard to make inconsistent spatial variation of sound speed with these methods. Therefore, a time domain model based on the lattice Boltzmann method is presented to simulate the sound propagation with and without internal solitary waves. The mechanisms of how the internal solitary waves influence the acoustic propagation involved is investigated. Through compare with and without solitary wave, the main result is this wave will change the distribution of sound field and interfere with the structure of it.

5961-Numerical Study of the Boundary Slip Effect on the Sound Absorption Performance of the Helmholtz Resonator

Yongkun Xiao, Jianhua Lu
School of Naval Architecture, Dalian University of Technology

Abstract—The Helmholtz resonator is one of the most important acoustic devices in the field of acoustic applications. It is believed that the boundary conditions in the resonator cavity are a vital factor to the sound absorption performance of the Helmholtz resonator. It should be noted that almost all the previous works on the topic assumed the no-slip boundary conditions in cavity. Recently, researchers found that the slip velocity on the surface of the fiber material results in a decrease in the attenuation coefficient and an increase in the sound velocity in predicting the acoustic properties of porous materials. However, the effect of the slip boundary condition on the sound absorption of Helmholtz resonator has not been tested up to now in the available literature. Therefore, numerical study on the sound absorption of Helmholtz resonator with slip boundary condition on its cavity is carried out via the lattice Boltzmann method. The slip length of the slip boundary condition under different inlet wave frequency and different inlet wave velocity profile effect on the sound absorption performance is studied in this work. Pout/Pin is adopted to represent the sound absorption performance. The numerical results show that the Pout/Pin decrease from 0.055 to 0.047 with the slip length increases from -1.00 to 1.00 and the change is more obvious in the range of -1.00 to -0.50 for the case of the constant inlet wave frequency and zero inlet velocity profile. The results also show the Pout/Pin increases from 0.01 to 0.16 as the inlet wave length decreases from 1.00 to 3.00 and the change is more obvious in the range from 2.00 to 3.00 when the slip length of the boundary condition is constant and the wave velocity profile is zero.

5948-One method of acquiring radiated sound based on spatial transformation

Biao Wang, Chaoqun Rui, Xingyang Nie, Chengming Luo, Bi Xuejie
Jiangsu University of Science and Tehcnology

Abstract—It is found that the radiated sound of sources in external space can be obtained from results of the near-field space. A new theory for obtaining the radiated sound by any sources in a specific space is proposed — Near-field Acoustic Transformation theory (NAT). The NAT theory is explained by the reciprocity principle of sound propagation. When the farfield directivities of the sound sources need to be obtained, the sound in the source space V is plane wave, and the obtained sound source direction is exactly opposite to the propagation direction of plane wave in V. The range that can be measured by NAT method is further analyzed in free-field, shallow water and reverberation pool. This theory does not need the shape and geometry information of sound sources, and has nothing to do with the sources' material and directivity. It can obtain the free-field radiating sound and directivity of any sound sources in space V. NAT can be applied to reverb conditions. The measuring environment is not limited to free-field conditions. This method provides a new idea for solving the problem of sound radiation measurement in complex environments.

6089- Geoacoustic parameters inversion by combining particle filtering and genetic algorithm

Weiwen WU, Qunyan REN, Licheng LU, Li MA
Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences

Abstract—The spatial variability of seabed properties often has a strong impact on sound propagation in shallow water. The range-dependent geoacoustic inversion has been a hot topic recently. This article proposes a method that combines genetic algorithm (GA) and particle filtering (PF) to solve range-dependent inversion problem. GA has good global optimality and PF can make use of prior information effectively. The method proposed in this article uses GA to initialize the particles in PF, and then feeds the particles to GA after PF. This method can improve the concentration of particles in PF. The simulation results demonstrate that comparing with PF and other methods, GA+PF gives a better estimation of the geoacoustic parameters and the thickness of the sediment layers when the seabed properties change dramatically.

6135-The Radiating Sound Signals of Golden Pomfret Farming in a Large Cage

Peizhen Zhang, Shouyong Gao, Zhenpeng Wang, Huan Liu, Chen Shen, Mo Qingshu
Guangdong Oean University

Abstract—The radiating sound characteristics of golden pomfret farming in a large cage powered by wave energy and photovoltaic generation are studied. Radiating sound signals in time and spectral domain of fish in the cage are measured during 24 hours. The testing contents include: the fish are in a quiet free-swimming state, the fish are excited by outside interference of a large ship, and are stimulated by feeding. The conclusions are as follows: the external disturbance caused by the power equipment and small fishing boats have no obvious effect on the vocalization of fish; When the golden pomfret are in the state of quiet and free-swimming late at night or early in the morning, they do not eat and send the sounds weakly or even keep silence, and average SPL(sound pressure level) of the ocean background is about 70dB. During the feeding process, the fish produce knocking and chewing sounds with frequency band ranged from 300-1100Hz, and the center frequency is 670Hz. The highest SPL in the spectrum is about 88dB. When the fish are disturbed by an passing large ship and feeding activities occur at the same time, the highest SPL is about 103dB with the central frequency of 630Hz. The radiating sound of the fish is superimposed with the interference signal of 100-2400Hz. The results show that under strong background noise, the sound production of fish can be measured by passive sonar. The studies are helpful for mastering time and frequency characteristics of the radiating sound by fish in the large cage. The main purpose of this study is to provide a reference for analysis and evaluation of the correlation between the biological behavior and acoustic ecology of the ocean.

6040-Passive acoustic localization of a natural CO2 seep - implication for Carbon Capture and Storage

Jianghui Li, Paul White, Jonathan Bull, Ben Roche, John Davis, Timothy Leighton, Michele Deponte, Emiliano Gordini, Diego Cotterle, Tian Zhou, Chao Xu
University of Southampton, UK

Abstract — Localizing greenhouse gas (e.g., CO2) leakage from the sub-seabed is essential for determining whether passive acoustic techniques can be an effective environmental monitoring tool above marine carbon storage sites. Here we develop an approach to verify the passive acoustic technique using hydrophones at different positions to localize a discrete natural CO2 vent site offshore the island of Panarea, Sicily. A cross-correlation method determines the relative arrival time of bubble sounds at these hydrophones from the same gas seep. By comparing the time difference of sound arrivals and computing the direct travel path, we are able to localize the vent site. The results show that our approach is capable of localizing a CO2 gas seep with a gas flux of 2.3 L/min at horizontal distances of up to 6.67 m with small errors.

6041-Underwater Noise Classification based on Support Vector Machine

Guoli Song, Xinyi Guo, Wenbo Wang, Jun Li, Hua Yang, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—In the face of more and more underwater noise monitor data, there is a need to process the noise automatically. In this paper, support vector machine (SVM) classifiers with different kernel functions are adapted to distinguish five kinds of underwater noises. At the same time, five kinds of features are extracted from frequency domain, time-frequency domain and Mel transform domain, including noise spectrum level, time-frequency spectrum, power spectral density, Mel-scale Frequency Cepstral Coefficients and filter-bank. According to 7225 samples with a duration of 0.5s and sampling frequency of 44.1 kHz, the results show that treating the kernel function as a "black box" is suitable for underwater noise classification. It can obtain appropriate parameters adaptively and improve the performance. Among the five input features, the classifier performs better with the input features of NL and PSD. Under the condition of -10dB, the mean classification accuracies of NL and PSD features are 93.63% and 94.53%, respectively.

6231-Helical Wave Spectrum of Bending Waves in an Infinite Composite Cylinder with Periodic Rings

Xuewen Yin, Zhixiong Yang, Zitian Wei, wenwei Wu
China Ship Scientific Research Center

Abstract—Bending waves in an infinite composite cylinder with periodic rings is addressed in terms of helical wave spectra. The presence of periodic rings that results in the wellknown wave conversion effect is clearly identified from the contour plot of helical wave spectra. Accordingly, the periodic rings have significant contributions on sound radiation which can be deduced from the curves of radiating components in wave number domain. This work can provide an in-depth understanding of the mechanism of sound radiation from composite cylinders with doubly periodic rings.

6077-Research on Ship-radiated Noise evaluation and Experiment Based on OTPA Optimized by Operation Clustering

Ruibiao LI, Wenjun Bu, Jianwei Cheng
Institute of Noise and Vibration Naval University of Engineering

Abstract—While evaluating Ship-radiated noise with operational transfer path analysis (OTPA), a question arises that the input of OTPA cannot meet the linear system requirement, which results in a large estimated error in several frequencies. Therefore, to reduce the estimated error, in this paper a method based on OTPA optimized by operation clustering is proposed. First, a complete clustering feature matrix is constructed and weighted principal component analysis (W-PCA) used for feature extraction. Then, several classes of operating mode(OM) are clustered by K-means based on the feature, and the classified OMs are taken as the input of OTPA, which can meet the linear system requirement of OTPA. Experiments with cabin in Thousand Islet Lake show that the statistical probability of the line spectrum with an estimated error less than 3 dB is more than 95%, which is an improvement of 16.7% compared to the error before optimization, and the maximum estimated error of the line spectrum is reduced by 11.3 dB. The estimated error of 1/3 Octave is less than 2 dB in all frequencies, which can be reduced by approximately 7 dB. The results verify the feasibility of OTPA optimized by operation clustering.

5109-The Application of Regularization Method to Acoustic Radiation Prediction in Shallow Water

Zhiwen QIAN, Dejiang SHANG, Jingsheng ZHAI, Yuanan HE
School of Marine Science and Technology Tianjin University

Abstract—A method based on the wave superposition method (WSM) and the adjusted Green function for predicting the structural acoustic radiation in shallow water is proposed, which is adopted to construct the equivalent acoustic radiation of elastic structure. The local acoustic vibration model is established by the finite element method (FEM) in the near field, and the WSM is used to calculate the acoustic field in the far distance. In the wave superposition calculation, the virtual source intensity is obtained by using the Green function associated with the ray method, and the sound field is calculated by the Green function based on normal mode. And acoustic radiation of a pulsating sphere in the shallow water is served as an example to verify the accuracy of the method. Considering the fact that the ill-posed problems in the calculation are caused by the velocity noise, the performance of the Tikhonov regularization method on suppressing noise is investigated. It is concluded that the Tikhonov regularization method can greatly improve the stability and accuracy of structural radiation sound field prediction in shallow water, and lay the foundation for practical applications.

6182-Research on the Performance of Sound Absorption Coating Based on Piezoelectric Shunt Damping

Liang Feng, Xinran Xu, Shushu Si, Xu Yan
Science and technology on sonar laboratory Hangzhou applied acoustics research institute

Abstract—The traditional sound-absorbing structure converts sound energy into heat energy through internal friction of the damping material to be absorbed in order to achieve the purpose of reducing sound energy. This paper proposes a piezoelectric shunt damping sound absorption control scheme based on the positive piezoelectric effect of piezoelectric materials. The external sound is connected to the composite material formed by piezoelectric ceramics and rubber by an external circuit system formed by resistors, inductances, and capacitors. It can be converted into electric energy, and the sound wave energy is consumed by resistance heating. This solution can effectively improve the low-frequency sound absorption performance, thereby realizing wide-band reflected sound control.

6262-Ambient Noise Measurements with an Acoustic Submerged Buoy in Deep Sea

Wei Guo, Fuyin Wang, Qiong Yao, Shuidong Xiong, Yanqun Wu, Chengyan Peng
National University of Defense Technology

Abstract—An acoustic submerged buoy moored at the ocean bottom was applied for an ocean experiment in deep-sea area. This submerged buoy consists of a vertical optical-fiber acoustic sensor array and a cross array of fiber-optical vector sensor, 32 channels in total. In addition, there were four underwater signal recorders suspended at different depths along with the submerged buoy. All these sensors were approximately deployed to the depth scale from 4000 to 5000 m. Spectral analysis results of the recorded ambient noise are mainly concerned and discussed in this paper, which includes the time-varying and statistical characteristics of noise level at the frequencies of 100, 200, 500 and 1000 Hz. Furthermore, an attitude analysis method for the submerged buoy is presented by using amplitude fluctuations of low-frequency ambient noise spectra (< 100 Hz). It is shown in the data processing results of the sea trial that the regular motion of the submerged buoy system caused by ocean currents can be embodied clearly with this method.

Oral session III-2 (Friday, Morning)

4855-Simulation Study on Acoustic Scattering Characteristics of a SCUBA Diver

Tianlin Yang, Yunzhe Tong, Xingang Fan
Shanghai Marine Electronic Equipment Research Institute National Key Laboratory of Science and Technology on Underwater Acoustic Antagonizing

Abstract—Based on Kirchhoff approximation, a prediction method on the echo characteristics of a SCUBA diver was presented. Since a scuba diver needs to swing his large fins to overcome the water resistance caused by their diving equipment. As a result, the swing process of the fins may affect the backscattering characteristic significantly. Therefore, a 3D dynamic model of a SCUBA diver's single swing fins was built. The motion process of the diver's single swinging fins is split into 200 frames. The postures of the diver are different in the 200 frames, especially that of the fins. Six typical frames are selected among the 200 frames, which are frames 0, 40, 80, 120, 160, 200 and can represent the whole swing process. The echo waves and surface highlights of different postures at two incidence angles are compared. The study shows that for the head incidence ($\Theta_0=0^0$)the acoustic contribution is mainly from body and fins, and the acoustic scattering echo amplitude of the fins varies periodically, since the cross section of the fins varies periodically as the diver swing. For left side incidence the acoustic contribution is mainly from the diver's leg and air cylinder. Besides that, there is almost no change in the echo characteristics change little for different postures.

6094-Observation and analysis of low-frequency sound horizontal-diffraction using vector sensor in the Reefs Water

Yaxiao Mo, Chaojin Zhang, Licheng Lu, Yuqing Jia, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—A significant phenomenon of bottom-interaction in reefs water, at low-frequency sound propagation, is the horizontal diffraction of energy caused by the noteworthy changes of the topography. To observe and analyze the horizontal diffraction phenomenon, an experiment was carried out in the North Reef of the South China Sea in 2018. Although simulated results illustrate that no effective acoustic path can reach the station placed behind the reef, the explosive signals were still recorded by Ocean Bottom Seismometer (OBS). Using the vector information received by the velocity sensor of the OBS, the back-azimuths of this signal arrival can be accurately estimated. Meanwhile, the sound field distribution in the experimental area is simulated by a three-dimensional parabolic equation method. The back-azimuth estimation and the simulated sound field distribution show that the received sound signal behind the reefs comes from the horizontal diffraction at the edge of the reef, rather than the source-receiving path given by GPS. The horizontal diffraction phenomenon can make part of low-frequency energy diffract to the back of the reefs and continue to spread, then reduce the acoustic shadow zone behind the reefs.

Oral session XI-1 (Friday, Morning)

6271-Numerical simulation of underwater vehicle wake field

Lin Zhu, Yan Zhou, Xinyi He
Optoelectronics System Laboratory, Institute of Semiconductors, Chinese Academy of Sciences; University of Chinese Academy of Sciences; The No.92578 Army of PLA

Abstract—In this work, combining the Reynolds Averaged Navier-Stokes(RANS) equation with the turbulence model RNG k-ε method is used to calculate the flow field of the model adopted simple geometries as submerged objects. The flow field characteristics of the model surface pressure, velocity distribution, vortex core region distribution features and evolution of vortex in the wake during the straight movement state are calculated. The calculation results are compared with the experimental results well. The vortex-wake continues to propagate in the direction behind the vehicle. Therefore, the vortex wake can transmit in the water for a long distance which represents an invaluable source of information for detection and tracking underwater.

5896-The Gradient-type Least-squares Deconvolution Multipath Underwater Acoustic Channel Estimation

Tianfeng Huang, Qiuying Peng, Jidan Mei
Harbin Engineering University

Abstract—An algorithm for multipath time-delay estimation using the Gradient-type procedure to achieve the least-squares (LS) deconvolution is given to obtain a better resolution and estimation accuracy. It uses circular convolution to calculate the circulant matrix, instead of the program of traditional LS algorithm, making it more suitable to process long data. Compared with the matched filtering (MF) algorithm, it could obtain a time-delay resolution better than 1/B, and also be used in negative channels estimating.

6166-A Method of Multipath Mitigation Based on LS and Complex ResNet in Water Supply Pipes

Ruiping Song, Yu Jiang, Jie Qi, Haixin Sun, Cunxiao Fan, Hamada Esmaiel
School of Informatics, Xiamen University

Abstract—There are many challenges in underwater acoustic communication systems, as the underwater acoustic channel characteristics are highly dependent on the water environment. The multipath effect is one of the most impactful factors to the performance of communication. Water supply pipes are common structures in underwater facilities and widely used on the Internet of Underwater Things (IoUTs). Underwater acoustic (UWA) communication is occasionally needed in IoUTs applications using pipes, like submarine pipeline monitoring, but there is little research about communication in water supply pipes. This paper optimizes the underwater acoustic channel estimation for the water supply pipes channel. A complex residual network (ResNet) based on least square (LS) is introduced to mitigate the multipath effect in water supply pipes. The proposed method shows better performance in channel estimation than the conventional LS method and performs almost as well as the minimum mean square error (MMSE) method. The network is tested in water supply pipes by using an OFDM communication system. The simulation result substantiates the validity of the proposed optimized method in a pipe communication system.

Oral session IV-1 (Friday, Morning)

6078-Research on Bayesian Seabed Acoustic Parameter Inversion Method Based on Parallel Tempering Algorithm

RuiMeng Yu, ChuanXi Xing, ZhiLiang Wan, SiYuan Jiang
School of Electrical and Information Technology Yunnan Minzu University

Abstract—Aiming at the problem of nonlinear inversion of seabed acoustic parameters under the semi-infinite elastic seafloor, the Bayesian inversion method is adopted, and the complex sound pressure at various distance points received by the hydrophone is used as the research object for inversion. Among them, the inversion parameters (including sound velocity, density, and sound velocity attenuation) are regarded as random variables, and the inversion results are given in the form of the posterior probability distribution, which can analyze the uncertainty of the inversion results. In order to speed up the inversion convergence, a parallel tempering algorithm is introduced, Markov chains at different temperatures are run at the same time so that the sampling process can be exchanged between Markov chains at different temperatures. This algorithm can effectively solve the common problems in Bayesian parameter inversion-a slow convergence caused by Markov Chain Monte Carlo (MCMC) algorithm. Numerical simulation experiments are used to compare the inversion effects of the simulated annealing (SA) algorithm and the parallel tempering algorithm. The simulation results show that compared with the simulated annealing algorithm, the parallel tempering algorithm can improve the inversion convergence speed and obtain the parameter inversion result with the smallest mean square error and the highest accuracy.

5934-Sensitivity Analysis of Group Velocity Dispersion for the Sediment-Borne Mode in the Deep Ocean

Jingpu Cao, Yubo Qi, Shihong Zhou, Shuyuan Du, Zhaohui Peng
Institute of Acoustics, Chinese Academy of Sciences. University of Chinese Academy of Sciences

Abstract—This paper presents the effects of environmental parameters on the group velocity dispersion for the sedimentborne mode. A three-layer, fluid, and range-independent model is considered. The synthetic signal corresponding to sediment-borne mode is simulated using modal theory, and its group velocity dispersion behaviors are summarized in the time-frequency (TF) domain. The environmental parameters include near-surface water sound speed profile (SSP), water depth, and some bottom parameters. The first-order modal group velocity dispersion in the frequency range of 10-300 Hz is used for the sensitivity analysis. Results of the sensitivity study show that the sediment sound speed and sediment thickness are the main parameters influencing the group velocity dispersion. The basement sound speed, sediment density, and basement density have comparable and much fewer effects. The near-surface water SSP, which is greatly affected by seasonal and diurnal changes, and the water depth, are almost insensitive parameters to the group velocity dispersion. The above results may become the fundamental basis for geoacoustic inversion.

4901- Determination of chewing sound of Whiteleg shrimp in a farming pond

Mengting Shen, Jinlin Li, Xiuxiu Wang, Rixin Zhang, Zihao Wang, Zhengliang Cao
College of Marine Sciences, Shanghai Ocean University

Abstract—This paper is aimed to analyze Whiteleg shrimp's (Penaeus vannamei's) acoustic behavior collected in a farming pond. According to artificial feeding events, the chewing sound from shrimps are obtained by a passive acoustic recorder. The sound pressure level of the 1-minute segments between the two feedings is lower than that of after feeding, but higher than that of before feeding. There are two changing parts in the spectrum of several segments, in which one type has a low-frequency energy mainly in 2kHz, and the other has a high frequency energy in 4-15kHz. It is related to shrimps chewing behavior with a large number of 'click' signals. By analyzing the chewing sound from individual shrimp, time length of the signal is around 0.01s and the frequency range is about 4-15kHz. The behavior corresponding to the sound pressure level of 2kHz mentioned above has not been determined. In addition, from no-feeding data at night, there are also short-time 'click' signals, which are notable different from daytime's data, and sometimes is concentrated on the low-frequency (about 4kHz) from the energy of the signal. Further research is needed to determine whether there is a relationship between the two low-frequency signals.

6170-Research on Ultrabroadband Acoustic Absorbers Based on Slow-wave Metamaterials

Xin Wang, Jiahao Wang, Yongyao Chen
Harbin Engineering University

Abstract—Traditional acoustic-absorbing materials, such as fiber materials and foam absorbers, do not perform well in the low-frequency regime. They also have disadvantages such as poor durability, limited pressure and temperature resistance, therefore not suitable for applications in harsh industrial and military environments. Acoustic metamaterials could provide new solutions to the above problems: the sound absorption performance of metamaterials may not rely on their intrinsic material properties, but could be freely controlled and engineered with acoustic sub-wavelength structures. In this work, we propose a wedged slow-wave acoustic absorber, which is capable of slowing down the sound speed and achieving strong sound absorption over ultra-broadband frequencies. Through analytical and numerical studies, we show that anisotropic acoustic metamaterials can be designed to have a strong dispersion effect that renders significant slow-sound and thermal-viscous effects. This enables a sound dissipation mechanism that can help break the limits of traditional acousticabsorbing materials.

4817-Backscattering Characteristics over a Wide Band of a Sand Bottom in the South Yellow Sea of China

Shengqi Yu, Baohua Liu, Kaiben Yu, Zhiguo Yang, Guangming Kan
National Deep Sea Center

Abstract—Reverberation disturbance mainly derives from the bottom scattering in shallow water environments. Although the scattering strength is an intrinsic characteristic of the seafloor, different sediment types and areas possess diverse acoustic scattering characteristics. Backscattering strength in the grazing angel range of 20° – 70° over a broad band (6 – 24 kHz) of a sand bottom in the area of the South Yellow Sea of China was measured, using an omnidirectional projector and an omnidirectional hydrophone. The backscattering strength increases with the grazing angle and changes more rapidly at large grazing angles (60° – 70°). For frequency dependence, the backscattering strength overall enhances with the frequency. Comparing Lambert’ s law with the measured backscattering strength shows that Lambert’ s law departs from the measured data at large grazing angles (60° – 70°). Fitting curves of a scattering model based on that of Jackson et al. against the backscattering strength indicate that the seafloor roughness scattering is dominant relative to the sediment volume scattering at low frequency (<10 kHz) and at large grazing angles (60° – 90°) for high frequency.

5909-Doppler Effect Analysis of Bottom Reverberation for a Moving Platform in Shallow Water

Dongpeng Mo, Bo Gao, Wenhua Song, Jie Pang, Yiru Zuo
Ocean University of China

Abstract—Bottom reverberation is hardly avoided for active sonar working in shallow water waveguide. In this paper, a monostatic reverberation model of a moving narrowband source in shallow water is developed. The power spectrum distribution of the bottom reverberation signal received by a small moving platform is also discussed. For the active option of a moving underwater vehicle, the Doppler shift occurs during such two processes: sound wave incident from the platform to the scatter and scattering back to the platform. Considering the scattering field comes from multiple directions of the seafloor, the received reverberation signal has different levels of frequency shift. To consider the influence of different propagation paths on the reverberation Doppler Effect, both ray theory and ray-mode analogies are introduced for the reverberation model, and the simulation results show that when the moving platform moves at a certain speed, the energy of the received reverberation signal is broadened due to Doppler Effects. Meanwhile, the spectrum peak will also expand from the center frequency to both ends.

5905-Three-dimensional Acoustic Effect by Seamounts in Shallow Sea

Qile Wang, Wei Zhang, Hanhao Zhu, Zhiqiang Cui, Yangyang Xue
Institute of Marine Science and Technology; Zhejiang Ocean University

Abstract—The complex shallow sea topography will lead to stronger three-dimensional (3D) acoustic effect. The direct numerical simulation of 3D shallow sea sound field under seamount environment is carried out by using the Finite Element Method (FEM). Taking acoustic transmission loss as the research object, the influence of seamounts on the propagation of low frequency acoustic signals in shallow sea in the range of kilometers is analyzed by controlling the seamounts' cross section and the sound source frequency. The simulation results show that the increase of the seamount radius in the direction of the source axis will decrease the blocking effect and increase the backscattering effect. The increase of the radius of seamount in the direction perpendicular to the source axis will increase the 3D scattering effect at azimuth obviously. At the same time, with the increase of the source frequency, the 3D scattering effect will gradually increase.

4669-Computation of acoustic scattering from underwater targets by ACA-BEM

Jiayuan Gong, Hongyang Chen, Longxiang Guo, Wenjian Chen, Guangping Zhu, Hui Sun
Institute of Automotive Engineers, Hubei University of Auomotive Technology, Shiyan, China Acoustic Science and Technology Laboratory, Harbin Engineering University, Harbin, China Key Laboratory of Marine Information Acquisition and Security(Harbin Engineering University), Ministry of Industry and Information Technology, Harbin, China College of Underwater Acoustic Engineering, Harbin Engineering University, Harbin, China

Abstract—The computation of the acoustic scattering from objects in the ocean is useful to analyze the characteristics of the targets, which can be numerically modelled by acoustic boundary element method (BEM). The BEM has a defect of fictitious frequency problem, Burton-Miller method is studied to overcome the singular problems. In this paper, the Hadamard finite-part integral method based on collocation method is studied to reduce the singularity. It is found that, the near singularity is also quite significant and deteriorates largely the accuracy of BEM. A method based on polar transformation is proposed in this paper to overcome such a defect. Once the problems of singularity and near-singularity are solved, the conventional BEM model is established to serve as a foundation for fast BEM.

It is well known that conventional BEM yields a full matrix, which is of $O(N^2)$ memory complexity. Furthermore, the time complexity could be up to $O(N^3)$, if Gaussian elimination method is adopted to solve the linear equation of BEM. Many fast methods are proposed to solve the problems, such as the GMRES iterative solver, fast multipole method and H-matrix (Hierarchical Matrices) method. H-matrix method is applied to overcome the faults of conventional BEM, by using the low-rank approximations to compress blocks of the matrix, which is a pure algebraic method. The ACA (Adaptive Cross Approximation) method is proposed to compute the outer-product form of low-rank matrices, instead of SVD (Singular Value Decomposition), which consumes high CPU time and is of no usability. ACA-BEM is used to predict the acoustic scattering from objects in the ocean, especially the large-scale problems. The directivities of a rigid sphere and a rigid ellipsoid are computed by ACA BEM, the time consumed is very short. For a problem of more than 20,000 DOFs, it can be solved within 2 minutes. Therefore, ACA BEM can be used to solve large-scale acoustic scattering problems very efficiently.

Oral session VI-2 (Friday, Morning)

6134-Digitally Assisted Analog Self-interference Cancellation for In-band Full-duplex Underwater Acoustic Communication

Yunjiang Zhao, Gang Qiao, Yi Lou, Xinyu Liu, Naihua Zheng, Yi Zhang
Yichang testing technique research institute

Abstract—In-Band Full-Duplex (IBFD) Underwater Acoustic (UWA) communication technology can transmit and receive communication signals in the same frequency band at the same time. Theoretically, its frequency utilization efficiency can reach twice of the traditional half-duplex (HD) UWA communication systems. Therefore, it holds great research significance and application value for UWA communication where available spectrum resources are seriously limited. The main challenge in the implementation of IBFD-UWA communication system is to counteract the local selfinterference (SI) signal. Generally, SI cancellation (SIC) can be divided into three main aspects, namely, SI suppression in space, SIC in analog domain and digital domain. Digitally Assisted Analog SIC (DAA-SIC) is concerned as it can deal with complex SI propagation channel. However, in the implementation process of the DAA-SIC scheme, its performance will be affected by hardware conditions, such as the effective number of bits of analog to digital converter (ADC) of auxiliary acquisition link, non-linear distortion of power amplifier (PA) and so on. To deal with the influence of hardware parameters on the performance of DAA-SIC scheme, this paper proposes a new analog SIC scheme. The core of this scheme is to reconstruct the output signal of PA and reduce the non-linear distortion of power amplifier and the influence of effective number of bits of auxiliary link through Memory Polynomial (MP) model and Digital Pre- Distortion (DPD) process. The performance of the existing scheme and the new DAA-SIC scheme is verified by numerical simulation. The simulation results show the effectiveness of the proposed scheme.

6131-Non-cooperative MPSK modulation identification in SIMO underwater acoustic multipath channel

Tao Fang, Songzuo Liu, XiongBiao Wu, Honglu Yan, Imran Ullah
Harbin Engineering University

Abstract—Due to the influence of underwater acoustic multipath channel and lack of prior information, the likelihood-based MPSK modulation identification method is facing great challenges. Therefore, we proposed an identification method combining the orthogonal matching pursuit (OMP) and expectation maximization (EM) in single input and multiple output (SIMO) underwater acoustic channel. First, the blind channel is estimated and equalized by the OMP. Then, the EM is used to compensate the recovered constellation. Finally, the likelihood-based method is applied to identify the MPSK modulation. Numerical results show the proposed method can achieve more than 95% identification rate while the SNR is higher than 7 dB.

6036-A Study of Time Domain Adaptive Decision Feedback MSK Equalization over Time-varying Underwater Acoustic Channel

Ruigang Han, Ning Jia, Biao Liu, Jianchun Huang, Shengming Guo
1.Key Laboratory of Underwater Acoustic Environment, Chinese Academy of Sciences 2.Institute of Acoustics, Chinese Academy of Sciences 3.University of Chinese Academy of Sciences

Abstract—Minimum shift keying (MSK) shows better bandwidth efficiency than phase-shift keying due to its constant envelope property. The performance of block linear equalization (BLE), commonly used for MSK communication in radio communication systems, is limited in the complex time-varying underwater acoustic (UWA) channel because BLE cannot track channel changes within the data block. A time-domain adaptive decision feedback equalization (TD-ADFE) method based on Laurent's decomposition is proposed to address issues pertaining to MSK communications over UWA communication. The method can effectively track the time-varying UWA channel through that the output of encoder updates the equalizer coefficient iteratively, which comprises matched filter, equalizer, differential decoding, and differential encoding. According to the numerical simulation results, the TD-ADFE performed better than FD-BLE over time-varying UWA channel by approximately 5.5 dB when the bit error rate (BER) was 10-3. The sea trial results over 28 hours demonstrated that the BER of TD-ADFE was 36.8% lower than FD-BLE.

6005-Non-Uniform Doppler Compensation Method for Staggered Multitone Filter Bank Multicarrier in the Underwater Acoustic Channel

Xinyu Liu, Gang Qiao, Lu Ma, Naihua Zheng, Yunjiang Zhao
Harbin Engineering University

Abstract—This paper focuses on the results of our research on Doppler estimation and compensation for Staggered Multi-Tone filter bank multicarrier (SMT-FBMC) communication system in the underwater acoustic channel. We propose a Doppler compensation algorithm for the large-scale Doppler in underwater acoustic (UWA) channel. First, we resample the SMTFBMC signal at the receiving end using the coarse estimation factor calculated by the synchronous signal. Then we analyze the residual Doppler effect resulting from resampling. We study the composition of the baseband signal through the analysis filter bank (AFB) and found that the residual Doppler has the same impact as the carrier frequency offset (CFO). Finally, we estimate the residual Doppler factor by measuring the phase shift of the pilot signal and achieve the residual Doppler compensation in the time domain. The simulation results show that the proposed algorithm can eliminate the error floor caused by resampling, and improve the performance of the bit error rate (BER) of nearly 5dB in both Doppler compression and extension cases.

5994-Frogmen formation voice communication technology based on Fast ICA

Xiao Zhang, Xiaomeng Liu
Jilin University

Abstract—Frogmen formation voice communication has become a mega trend nowadays. Among various methods of modulation, single side band (SSB) multi-user voice communication system holds the advantages of remaining speakers' tones, however with no ability of resisting interference from other users in the same frequency band. Considering the frequency band utilization of the system, there is a need for an underwater voice communication system with many frogmen working in the same frequency band simultaneously. In this work, a multi-user voice communication technology based on fast independent component analysis (Fast ICA) is proposed, which is applied to noise-free cases as well as the environment with noise. For simulation, it is demonstrated that non-noise algorithm can almost recover sources with similarity coefficient approaching 1.0 and the improved algorithm for noisy cases is able to lessen distortion and reduce interference effectively. In the experimental scenario, the average similarity coefficient between sources and separated voices can reach above 0.88 in two-user and three-user systems, which indicates that the proposed voice communication technology is able to realize multi-user transmission in the same frequency band.

5952-Discrete Events and Finite State Machine Based Program Architecture for Underwater Acoustic Communication Network Simulation

Menghua Wen, Lu Ma
Hangzhou Applied Acoustic Research Institude

Abstract—In recent years, ocean exploration is more and more popular in the world and underwater acoustic communication networks are becoming useful. As a result, it is important to have a research tool that is easy to learn for underwater network research. This paper introduces a kind of program architecture used for underwater network simulation. It is based on two key methods, which are discrete events and finite state machines. It can simulate main process of physical-layer communication, MAC and route protocols in network. As for communication in physical layer, signal to noise ratio (SNR) of a received signal at a node can be calculated. Furthermore, the process of two signals colliding together at a node can also be simulated and signal to interference and noise ratio (SINR) can be calculated. Process of MAC and route protocols can also be simulated, such as backoff and timing, handshaking and searching for routes.

Comparing with other network simulation software, such as OPNET and NS2, the program introduced in this paper has an advantage, which is easy and testable. It can be implemented using C programming language and windows operating system. Programmer does not need to spend time to learn LINUX operating system. Programmer can monitor operation status while program running, convenient to debug. It is easy to search for the place where mistake happens.

5931-Research on Real-time Simulated Self-interference Cancellation Technology of Full Duplex Underwater Acoustic Communication

Gang Qiao, Yinheng Lu, Yi Lou, Yunjiang Zhao, Chenlu Yang, Songwen Wu
Harbin Engineering University

Abstract—In-band full-duplex Underwater acoustic communication (IBFD-UWAC) can significantly improve the utilization of the communication frequency band. Because the local high power interference signal will affect the reception of the expected signal, the self-interference cancellation (SIC) becomes the core of IBFD-UWAC. This paper proposes a real-time SIC testing method based on Simulink Desktop Real-Time®. This paper uses least mean squares and recursive least squares adaptive algorithms to achieve self-interference cancellation. Hardware-in-loop simulation results show that both algorithms can achieve 55dB real-time SIC under time-varying UWA channels. Compared with the traditional method, the algorithm proposed in this paper is performed in real-time, which dramatically increases the efficiency of communication between the two sides. This method is suitable for IBFD-UWAC.

5923-Deep Learning-Based Code Index Modulation Spread Spectrum Underwater Acoustic Communication

Gang Qiao, Yufei Liu, Feng Zhou, Suleman Mazhar, Yunjiang Zhao, Guang Yang
Harbin Engineering University

Abstract—This paper proposes a deep learning-based code index modulation-spread spectrum (CIM-SS) underwater acoustic (UWA) communication system. The system is characterized by the variant model of the recurrent neural network at the receiver of the communication system, which can directly demodulate the received signal after the synchronization without de-carrier and de-spreading operation. To verify the performance of the deep learning-based CIM-SS UWA communication system, the channel impulse response will be used to simulate the UWA channel. The signals passing through the UWA channel will be used for offline training and online testing of the neural network model. The bit error rate performance of the system with different model structures under different signal-to-noise ratio (SNR) conditions is compared. The simulation results show that the deep learning-based system can achieve better performance than the conventional system under the conditions of low SNR and severe UWA channels.

Oral session VII-2 (Friday, Morning)

5954-Direction of Arrival Estimation of Underwater Acoustic Target Based on Off-Grid Sparse Bayesian Inference

ZhiLiang Wan, ChuanXi Xing, SiYuan Jiang
Yunnan Minzu University

Abstract—The complex and changeable underwater signal transmission environment will lead to low accuracy of underwater acoustic target azimuth estimation. The searched peak is not apparent, and the traditional DOA estimation method will produce off-grid errors. In response to this situation, this paper adopts the off-grid sparse Bayesian inference algorithm to study the DOA estimation of the underwater acoustic array receiving signal. The performance of the off-grid sparse Bayesian derivation algorithm and the MUSIC algorithm was simulated and compared with the underwater acoustic array signal. The deviation between the estimated value of the two algorithms and the theoretical value was verified through multiple Monte Carlo experiments, and the root mean square error was obtained. It shows that the method in this paper can be applied to the DOA estimation of underwater acoustic targets. Compared with the MUSIC algorithm, the method in this paper has higher estimation accuracy, sharper search peak, and smaller root mean square error.

5925-Application of Striation-based Beamforming for Enhanced Passive Azimuth Estimation with Horizontal Line Array in Shallow Water

Changpeng Liu, Shihong Zhou, Yubo Qi
State Key Laboratory of Acoustics, Institute of Acoustics, Chinese Academy of Sciences University of Chinese Academy of Sciences

Abstract—The dispersion of normal modes in shallow water leads to interference striations with certain slopes on intensity spectrogram of the range-frequency domain, which also causes the performance of conventional beamforming (CBF) to degrade in both array gain and output fidelity. The striationbased beamforming (SBF) has been proved to be one effective technique to improve these problems for pulse signals but the phase shift related to the waveguide invariant can deflect its main-lobe to a position that is not corresponding to the source azimuth. In this paper, the phase delay introduced by waveform truncation is analyzed. It is shown that the phase shift related to the waveguide invariant can be compensated when the header truncation point (HTP) is exactly set at the arrival point of the dominating modes (APDM) from the source to the reference array element. Simulation and experimental results show that the arrival point of signal peak (APSP) could be one effective estimation of the APDM. SBF is applied successfully on such specially truncated signals for enhanced passive azimuth estimation without the knowledge of waveguide invariant or the source range.

5911-Difference Coarray Design based on Genetic Algorithm and Convex Optimization

Lening Wang, hangfang Zhao
College of Information Science & Electronic Engineering, Zhejiang University

Abstract—Large hydrophone array is an effective device for receiving acoustic signals in the ocean. In order to reduce engineering costs while meeting the needs of performance, a sparse array design method is proposed in this paper. This method combines genetic algorithm and convex optimization weighting to design a special sparse array named Difference Coarray (DC). In the design process, peak side-lobe level (PSLL) and degrees of freedom (DOF) is used as the objective function of genetic algorithm to design DC. Then convex optimization weighting is performed to reduce the sidelobes of the array obtained in the first step. By analyzing the beam patterns of the DC with element position uncertainty, it can be seen that the design array with convex optimization weighting maintains low side-lobe level while narrow main lobe, which demonstrates that DC has strong anti-interference ability. In addition, the beam pattern performance of the DC, coprime array and nested array is compared to prove the advantages in PSLL. The results prove that DC has lower PSLL under the same main lobe, which is beneficial to weak target detection.

5906-Source power spectrum estimation using *r-ω* interference structure in shallow water

Bohan Yuan, Haozhong Wang, Chunhui Hu
Ocean University of China

Abstract—The power spectrum of the radiated signal is an important feature of passive target recognition. A method to estimate the power spectrum features of the source by using the range-frequency(*r-ω*) interference fringe structure is proposed, which uses a horizontal array to receive the broadband signal radiated by an unknown source and obtains the sound intensity interference structure of the r-ω plane. And it combines the waveguide invariant to correct the influence of the dispersion and absolute distance on the r-ω sound intensity interference characteristics. Then, with no completely environmental information but the waveguide invariant, by tracking a certain corrected interference bright fringe, the method can extract the normalized source power spectrum. The feasibility of this method is verified by numerical simulation.

6181-A Discrimination Method between Surface and Submerged Targets based on Frequency Diversity Wavenumber Domain Features

Li Peng
Science and Technology on Underwater Test and Control Laboratory

Abstract—The discrimination between surface and submerged targets is one of the research focuses of passive sonar target recognition. In this paper, a discrimination method based on frequency diversity in wavenumber domain is proposed. The energy distribution in frequency-wavenumber domain is extracted by horizontal array modal beamforming method, and the wavenumber domain information of each frequency point is coherently superimposed to obtain the frequency diversity wavenumber domain eigenvalue. According to the prior knowledge of environment and the normal mode acoustic field simulation method, the decision threshold of discrimination can be generated. Based on the comparison between the eigenvalues of frequency diversity wavenumber domain and the decision threshold, the surface and submerged targets resolution of passive horizontal array is obtained. Simulation results show that the proposed method can effectively extract the frequency diversity wavenumber characteristics of target radiated noise in 96m and 192m horizontal array aperture, which can be used for engineering discrimination of surface and submerged targets.

6121-Research on Magnetic Anomaly Signal Separation Method of Crossover or Overlapping Buried Submarine Cables

Chunkai Zhou
China Ship Development and Design Center

Abstract—Due to the rapid development of submarine cable engineering, there is not only crossover between submarine cables, but also overlapping of different types of buried submarine cables, which causes serious interference to the detection of submarine cables and makes it very difficult to detect and locate them. Effective detection and accurate positioning of overlapping buried submarine cables are of great economic value and practical significance for laying, timely maintenance and replacement of submarine cables. The conditions of the seafloor in the coastal area are complex, and to avoid mooring damage or shark bites, submarine cables are usually buried under the seafloor and coated with armored steel wire layers, which provide a prerequisite for magnetic detection. For the magnetic detection of crossover and overlapping buried submarine cables, the methods such as upward continuation or matched filtering are usually used to separate and identify magnetic anomalies in deep and shallow parts, but the separation effect is not ideal and the accuracy is low. In this paper, the wavelet multiscale decomposition method and empirical mode decomposition method are used to separate the magnetic anomaly signals in the deep and shallow parts of the overlapping buried submarine cables. The simulation results show that the signal separation effect of the two methods is ideal and can be effectively applied to the magnetic detection of overlapping buried submarine cables.

6046-Ultra-long distance explosive source localization based on characteristics of IMS acoustic signal

Chaojin Zhang, Bingwen Sun, Yaxiao Mo, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—The hydroacoustic network of the International Monitoring System (IMS) is designed to monitor the world's oceans to detect signals that might originate from any underwater nuclear test. To analyze the abilities of detection and parameters estimation of IMS hydrophone stations, an ultra-long distance explosive experiment was deployed in the Western Pacific. These underwater explosions deployed by the Institute of Acoustics with energy yields equivalent to 1 kilogram of TNT were detected at hydrophones HA11, which consists of two triplets at the north and south of Wake Island. Explosive signals are used to characterize and locate the explosions. The Effect of the bathymetry on azimuth estimation in the deep sound channel at distances up to thousands of kilometers is discussed. A joint localization method that combines the propagation times and back-azimuths is applied to get the latitude and longitude of the explosions. The experimental results suggest that the azimuth estimation error is less than 0.5° and the joint localization method can improve the accuracy of locating the explosions.

6042-Eigenvalue Decline Index of Correlation Matrix for Shallow Water Source Depth Discrimination

Guangying ZHENG, Wenbo ZHU, Fangwei ZHU, You SHAO, Qiaoli ZHANG
Hangzhou applied acoustics research institute

Abstract—Source depth discrimination is important for anti-submarine warfare and marine biology. Given the difference in the vertical correlation of acoustic fields excited by sources at varying depths, a physics-based quantity characterizing the vertical correlation of acoustic field is proposed for passive surface/submerged source classification in a shallow water range-independent waveguide. The eigenvalue decline index of correlation matrix is the ratio of the maximum eigenvalue to the second largest eigenvalue of the receiving signal correlation matrix, which is calculated to characterize the oscillation properties of the correlation coefficient matrix. The eigenvalue decline index is then analyzed and discussed under the simulation condition of the typical isovelocity sound speed profile in shallow water. This decline index presents obvious separability so long as the receiving vertical line array is designed properly. The condition for the vertical correlation characteristics of the acoustic field is that the spacing of the array elements should be no more than one-third of the wavelength. Using the eigenvalue decline index may provide a robust alternative method for binary source depth classification.

OBOR session (Friday, Morning)

6288-On High Angular Resolution Processing for Multiple Targets Detection in Passive Underwater Sensor Array Systems

Umar Hamid, Shurjeel Wyne, Shahid Ali
COMSATS University Islamabad CUI

Abstract—This paper presents a high angular resolution processing approach for improved detection of multiple targets in passive underwater sensor array systems. These array processing systems are used for surveillance and detection of both surface and subsurface targets. Two beamforming techniques namely FFT based beamformer and MVDR beamformer along with two types of energy detection techniques namely CED and PED have been discussed. MATLAB simulations of these techniques have been developed and applied to data acquired through a passive uniform circular array. The simulation results showed that MVDR beamformer with PED for energy detection is the most suitable processing approach for high angular resolution in terms of detecting close space targets in the 3600 angular spectrum.

6171-Acoustic Wave Analysis in Deep Sea and Shallow Water Using Bellhop Tool

Durr E Shehwar, Sana Gul, Muhammad Usama Zafar, Urooj Shaukat, Ali Hassan Syed, Syed Sajjad Haider Zaidi
Xi'an Jiaotong University

Abstract—Underwater wireless communication technologies are gaining immense popularity due to their wide applications ranging from sea surveillance to climate recording, oil production control, and autonomous vehicles. Acoustic communication is the most commonly adopted technique for this purpose as it offers the least attenuation, high speed, and longer range compared to other communication techniques. But the composition of the sea is not uniform, and the behavior of acoustic wave varies as we move from shallow water to deep sea. This paper gives a comparison of acoustic wave propagation in two different channels of the Arabian Sea and the propagation characteristics of high frequency and low-frequency acoustic signal for each channel. The paper also discusses a comparative analysis of transmission losses incurred in both channels for given frequencies and thus becoming a useful tool for choosing the appropriate frequency for reliable underwater wireless communication.

6112-Seasonal evolution of Sea Surface Salinity in the Northwestern Indian Ocean: Argo Data Study

Sartaj Khan, Shengchun Piao, Yang Song, Shazia Khan, Bingchen Xu, Zeeshan Babar
Harbin Engineering University

Abstract — This research explores the seasonal evolution of sea surface salinity (SSS) in the Northwestern Indian Ocean (NWIO) over the Sea of Oman (SOO) and the Arabian Sea. For this study we used the datasets provided by the Argo floats within the timeframe from 2004 to 2019. For SSS, values of salinity are used nearest to the sea surface (depth $\leqslant$ 10 m), as it would be comparable to satellite SSS measurements. From the seasonal evolution of SSS, we investigated the co-existence of two water masses in the Arabian Sea region: 1) the Arabian Sea High Saline Water (ASHSW) that is in excess of salinity (> 36.9) and occupying the north and central basins of the Arabian Sea and 2) the Bay of Bengal Water (BBW) that is inferior in salinity (< 35) and occupying the south basin of the Arabian Sea.

5965-Research on Observability Conditions for Single and Multiple Observing Stations in Underwater Bearing Only Tracking

Asra Nusrat, Yaan Li
School of Marine Science and Technology

Abstract—The underwater bearing only target tracking is a typical nonlinear filtering problem where a moving or stationary observer monitors the sonar bearings received from an acoustic target as measurements to estimate its position and velocity. However, the target state might not be fully observable because the observing station does not have exact information about the target range. The unavailability of range parameter makes the observability a crucial problem for the bearing only target tracking system. Therefore, the requirement to identify the observability conditions plays a dynamic role in defining the observer trajectories and to attain unique tracking solutions. We can adopt different approaches such as using two or more stationary observing stations or single maneuvering observer to resolve the range observability problem. In this paper, the target is assumed to be moving with constant speed and heading whereas the observing station is non-maneuvering which is the most suitable condition in typical scenarios. Also, the observability conditions are briefly discussed in the case of single and multiple observing stations to achieve unique tracking solutions for target states. The popular estimators such as Extended kalman filter (EKF) and Unscented kalman filter (UKF) are used to estimate the target states in this research. Simulations are performed to see the results of underwater bearing only tracking for two observing stations. The simulation results show substantial effect on the observability and overall tracking performance by changing the distance and initial conditions for two observing stations. The effect of changing both the position and distance has also been analyzed between the two observers. Simulation results have shown better convergence and stability for two observers than single observing station in different scenarios.

5762-Low-Complexity Iterative Hybrid Equalization for OSDM Systems

Sheraz Anwar, Wenwei Ying, Jiangqiao Li, Haixin Sun, Bisma Gul
Xiamen University

Abstract—In this paper, we propose an iterative hybrid equalization algorithm, where our main aim is to provide a better solution towards the problem of high computational complexity during the transmission of Orthogonal Signal Division Multiplexing (OSDM) over underwater acoustics (UWA) channel. Our projected hybrid algorithm is a combination of block and least square QR (LSQR) equalization algorithms. Existing block equalization algorithm followed the iterative matrix inversion in doubly-selective channels, without the consideration of severe impairments in UWA channel. Thus, we added LSQR equalization along with this algorithm and offered a hybrid algorithm. LSQR exhibits compensation of UWA channel matrix inversions, by halting the process of iterations and thus, results in low computational complexity. Hence, by the addition of LSQR, our proposed algorithm also exhibits above mentioned advantages. Simulation results of our recommended hybrid method validate its significance over existing block and LSQR equalization techniques.

5083-Full-duplex Underwater Optical Communication Systems: A Review

Imran Ullah Khan, Basit Iqbal, Songzuo Liu
College of Underwater Acoustics Engineering, HEU, China

Abstract-Underwater Optical Communication (UWOC) systems are very attractive to researchers due to their ability of low power consumption, less complexity, high data rates, and covert communication. Various half-duplex (HD) UWOC systems has been proposed in this regard, but due to half-duplex characteristics, these systems have failed to improve the high throughput gain, high power efficiency and high data rates etc. Hence, we provided a review of different Full-Duplex UWOC systems using different light sources, with respect to transmission range, operational power, data rate, wavelength, and different underwater communication mediums. We observed that these FD systems have improved the communication range as well as data transfer rates, while implementing different light sources (i.e. lasers, avalanche photo diodes (APD), green and blue LEDs and lasers) in their transceivers. However, we pointed out that power inefficiency is a major issue faced by FD-UWOC systems. We also presented BER comparison of different FD-UWOC systems, implementing different modulations schemes, and pointed out FD UWOC systems implementing un-coded 8PPM and BPSK outperformed.

Finally, we concluded the paper and also highlighted some future directions for various issues the FD-UWOC systems are currently facing, and hope that our review can provide a platform for future research directions.

6375-Multiple RTS and DATA Receptions in a Loop-Based Underwater Propagation Delay Aware MAC Protocol

Basit Iqbal, Liu Songzuo, Imran Ullah Khan
Harbin Engineering University

Abstract-Due to the long underwater propagation delays, the underwater sink node may not receive all of the requests to send RTS and DATA frames from the various underwater sensor nodes, resulting in massive collisions. We proposed an underwater Medium Access Control (MAC) protocol that takes into account the long propagation delay to evaluate the performance of the carrier sense multiple access collision avoidance (CSMA/CA) protocol utilizing a loop-based single hope underwater sensor network. The proposed protocol is designed to restore multiple RTS control packets from n underwater sensor nodes to the underwater sink node in a single slot time. The sink node received multiple RTS frames without overlapping because the n underwater sensor nodes transmitted the RTS frames at the same time, but they were received at different times at the receiver end due to differences in propagation delays that depend on the distances between the n sensor nodes and the sink node. In this paper, by altering the number of underwater sensor nodes and the size of the contention window, the proposed MAC protocol throughput is evaluated by using the underwater propagation delay.

5977- Design and Analysis of Li-fi Underwater Wireless Communication System

Aman Muhammad, Gang Qiao, Muzzammil Muhammad
Harbin Engineering University

Abstract- Abstract-Efficient exploration of techniques for underwater communication is still needed to reduce energy consumption, transmission losses and should also provide high speed communication. This paper presents a simple yet high speed communication system based on visible light communication, also recognized as light fidelity (Li-fi), for underwater applications. The concept of Li-fi for use in underwater wireless communication is borrowed from a novel approach presented by Dr Harald Haas of Germany to improve data transfer and information security for in air applications. This paper presents basic design of a Li-Fi underwater communication system and novel concepts that can help to reduce the overall power consumption. Simulation and comparative study is also given in the paper to provide useful insight of this new technology.

Oral session V-2 (Friday, Morning)

6127-Spectrum Analysis of Deep Water Ambient Noise in the Philippine Sea

Jiahua Zhu, Wei Guo, Bingbing Zhang, Yanxin Ma, Yangyang Chen, Lu Lu
National University of Defense Technology

Abstract—This work put forward an analysis of the spectrum characteristics of deep water ambient noise in the West Pacific, in terms of depth dependence and the relationship to temperature, based on the experimental data obtained in the autumn of 2020. The results illustrate that the ambient noise is higher in the morning than the afternoon and evening; the minimum noise level is about 10dB and 40dB lower than the mean and maximum noise level; the mean standard deviation of noise level higher than 1kHz is about 6.3dB during the measurement.

5930-The Analysis of Reverberation Affected by Tide Changes in Shallow Water

Wenrong Yue, Juan Yang, Feng Xu, Zhong Li, Ran Miao
Institute of Acoustics, CAS

Abstract—Cognitive sonar automatically perceives dynamic marine environment, thus optimizes the working parameters and performance. So it is necessary to monitor the tidal level by sonar itself in shallow water. In this paper, based on the three-dimensional acoustic field calculation theory, the equation reflecting the relation among reverberation intensity and sea depth is deduced, and the reverberation variation caused by periodical tidal changes is discussed by experiments and simulation. The experiment shows that the change law of the reverberation intensity has the positive correlation with sea depth in the trial sea. This conclusion provides a reference for the study of cognitive sonar dynamic marine environment perception.

5959-Research on Multiplicative Speckle Noise Denoising Method of Side-Scan Sonar Image based on Analysis Sparse Decomposition

SiYuan Jiang, ChuanXi Xing, ZhiLiang Wan, LiLi Du, RuiMeng Yu
Yunnan Minzu University

Abstract—Because of the use of echo imaging, Side-scan sonar will inevitably introduce multiplicative speckle noise to cause image distortion and affect the follow-up research. Aiming at the Side-scan sonar multiplicative speckle noise, this paper improves the original Side-scan sonar image sparse decomposition denoising algorithm. Firstly carries on the logarithmic transformation to the noisy image, then uses the analysis model to carry on the sparse decomposition to reduce the noise, and finally transforms back to the spatial domain to get the denoised image. This method has a good denoising effect on the multiplicative speckle noise of the Side-scan sonar image. compared with the existing denoising algorithms, the simulation results show that the mean square error (MSE) is reduced by 23.27, the peak signal-to-noise ratio ((PSNR)) is improved by 4.97dB, the structure similar-ity (SSIM) is increased by 0.06, and the edge retention index (EPI) is increased by 0.09.

6062-Waveform Prediction of Underwater Acoustic Propagation Using Finite-difference Time-domain Method

Jiahui ZHU, Jinrong WU, Qiannan HOU, Li MA
Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences, University of Chinese Academy of Sciences

Abstract—There have appeared many methods to model underwater acoustic propagation, such as normal mode, wavenumber integral, parabolic equation, ray and so on. Most of these methods can only obtain the frequency-domain characteristics of acoustic propagation. When the source is a pulse signal, it will be very complex to predict waveform in time-domain using these methods. Finite-difference time-domain can obtain time-domain waveform directly. In this study, the waveform prediction of a 30 Hz pulse signal propagating underwater is obtained by finite-difference time-domain method. The waveforms calculated from normal mode have been compared with waveforms calculated by finite-difference time-domain method. The results show that waveforms from the finite-difference time-domain method have time delay error due to the numerical dispersion. The error can be reduced by decreasing the discrete spatial and time steps. Normal mode solutions have errors in near-field, while finite difference time domain method can solve in both the near-field and far-field. Simulation cases show that the finite-difference time-domain method can be applied to predict waveform of underwater acoustic propagation signal with reasonable accuracy.

6162-Acquisition and analysis of long-range sound field based on underwater glider

Jian Li, Xinyi Guo, Li Ma
The Institute of Acoustics of the Chinese Academy of Sciences

Abstract—In this paper, a long-range ocean experiment was carried out by underwater glider, and the sound velocity profile of the sea area was obtained by Kriging method. Using the sound speed profile, the propagation characteristics of long-range sound field were simulated and compared with experiments. On this basis, the characteristics of horizontal and vertical direction of sound field and its application direction are analyzed.

6086-Moving Acoustic Source Transmission Trial in the Marginal Ice Zone of the Arctic

Xueli Sheng, Chaoping Dong, Longxiang Guo
Harbin Engineering University

Abstract—A moving acoustic source transmission trial was conducted on the edge of the Canadian Basin during the Arctic Research Expedition. The sound source towed by the ship emits CW-LFM signals of 600-800Hz, and the signals are collected by an autonomous hydrophone. The matched filter result shows a clear multiple reflection structure, and as the distance increases, the time delay between multi-path gradually decreases. By comparing with the simulated channel impulse response, the source of the reflected signal is confirmed. The direct wave and reflections produce strong interference in the receiving end. In addition, there is an obvious convergence zone at a distance of 6 kilometers. Finally, this paper compares the transmission loss (TL) in the trial and the theoretical cylinder TL results. It turns out that the propagation loss in the trial roughly follows the cylinder expansion loss.

5964-An Ice Thickness Measurement Method based on Up-looking Sonar

Tongxin Liang, Danzhu Yu, janhua Lu
School of Naval Architecture Ocean Engineering Dalian University of Technology Dalian, China

Abstract—Underwater acoustic methods to measure sea ice thickness has incomparable advantages. The works on sea ice thickness measurement mostly ignore the geometry of the sea ice surface and regard sea ice as horizontal sea ice. However, there are few works on the measurement of the thickness of non-flat sea ice. A method is proposed to measure the thickness of the sea ice with inclined lower surface, as the first step to measuring the thickness of non-flat sea ice. The feasibility of the method is verified by the simulation test.

6111-Feature Fusion of Rotating Machinery Based on EEMD and LLE Algorithm

Sibo Gao, Zhiyuan Dong, Wei Yang, Qiang Zhang, Xiaohan Gao, Shujie Liu
Dalian University of Technology

Abstract—The signals of rotating machinery usually contain complex information components, and it is difficult to fully describe the degradation characteristics and trends of its performance only depending on a single time domain or frequency domain characteristics. Therefore, this paper proposes a feature fusion method based on local linear embedding (LLE), which extracts the multi domain features of the signal to obtain the original feature set, uses LLE algorithm for feature dimension reduction and fusion, and uses Chebyshev inequality to identify and divide the operation state of the equipment. Finally, the method is verified by the rolling bearing life cycle signal.

6100-Semi-Supervised Noise Classification Based on Auto-Encoder

Haiyan Ni, Wenbo Wang, Meng Zhao, Qunyan Ren, Li Ma
Key Laboratory of Underwater Acoustics Environment, Institute of Acoustics, Chinese Academy of Sciences, University of Chinese Academy of Sciences

Abstract—Supervised classification algorithms are often used for marine noise classification. However, limited by insufficient labeled samples, the performance of the supervised classification method is typically influenced. To alleviate the limitations of insufficient labeled samples, in this paper, a semi-supervised noise classification method based on an auto-encoder (AE) has been proposed using radiated noise of four kinds of ships. This method takes a two-step training process, including unsupervised pre-training and supervised fine-tuning, making full use of unlabeled data and limited labeled data, respectively, which reduces reliance on label information for noise classification. The performance of this method is compared with traditional backpropagation neural networks (BPNN) and support vector machines (SVM). Experimental data analysis demonstrates that the semi-supervised noise classification method has improved the accuracy with the different amounts of labeled samples, especially when labeled samples are relatively rare.

5937-Source Depth Discrimination in Shallow Water Using Modal Correlation Scintillation Index

Xiaobin LI, Chao SUN, Xionghou LIU
School of Marine Science and Technology, Northwestern Polytechnical University

Abstract—Traditional methods for the source depth discrimination encounter the problem of performance degradation when the surface or internal wave motions cause variations of the source depth. While the modal scintillation index (SI) can classify surface/submerged source by using the fluctuations in the received pressure field. However, calculating the SI requires normal mode functions in advance, which is difficult to obtain accurately in practice (sound speed profile or long enough aperture desired). To address this problem, we propose a method to utilize modal correlation scintillation index to separate surface and submerged sources on a single receiver requiring only knowledge of the water depth. Specifically, we extract the autocorrelations and the cross-correlations of normal modes from the received signal autocorrelation function via warping transform. The variance in the estimated magnitude of the modal autocorrelations and the crosscorrelations normalized by the squares of their expected value over some observation intervals are defined as modal autocorrelation scintillation index (MACSI) and modal crosscorrelation scintillation index (MCCSI), respectively. The derivation and the simulation results provide that a source near the surface (all products of mode functions sharing a common zero-crossing) will exhibit scintillation indices with large values, while with small values for a submerged source near at least one product extremum. The method can be used to determine the depth of the source with unknown sound speed profile details or sound source range, and no need for the source movement.

5921-Optimal location method of spontaneous data fusion based on TDOA/AOA

Yifan Zhou, Yingmin Wang, Ruixin Nie, Qian Cheng, Guolei Zhu
Northwestern Polytechnical University

Abstract—Aiming at the problem of positioning underwater targets in a wide range of sea areas, the modern optimization technology simulated annealing algorithm is introduced into the non-linear programming of the multistatic sonar azimuth estimation. According to the development trend of long-distance wireless positioning technology[1], the data fusion positioning model based on Time Difference Of Arrival(TDOA) and Angle of Arrival(AOA) is analyzed, and a TDOA/AOA data fusion positioning method based on the simulated annealing(SA) algorithm is proposed. Simulation experiments are conducted to analyze the positioning accuracy of this method in a wide range of sea areas under different working conditions, which verifies the effectiveness and feasibility of the method.

6274-High-resolution DOA Estimation Algorithm of Vector Hydrophone Based on Preselected Filter

Wu Zhou, Zhenduo Wang, Zhe Xie
Hangzhou Applied Acoustics Research

Abstract—Outputting the acoustic field pressure and particle velocity at the same time and at the same point, a single hydrophone can be used to estimate the direction of arrival (DOA) of the target. It has received extensive attention internationally. The DOA estimation methods of single vector hydrophone can be divided into two categories. One is the maximum likelihood estimation method based on acoustic energy flow, representative algorithms including acoustic intensity averager and histogram method; the other is based on the characteristics of the vector hydrophone array flow, and apply high-resolution algorithms commonly used in array signal processing to single vector hydrophones. These high-resolution algorithms include Minimum Variance Distortionless Response (MVDR), Multiple Signal Classfication (MUSIC), and Estimating Signal Parameter via Rotational Invariance Techniques (ESPRIT). The resolution of the MVDR is not as good as the MUSIC and the ESPRIT, but the quantity of computation is much smaller than the latter. Aiming at the problem of wide output spatial energy spectrum peak and poor spatial resolution of the MVDR, this paper proposes a high-resolution DOA estimation method for single-vector hydrophones based on the theory of the optimal preselected filter--ECKART filter. This method can significantly improve the spatial resolution and output signal-to-noise ratio (SNR) of the MVDR algorithm based on single-vector hydrophone.

6177-Research on Passive Positioning Technology of Time Reversal Mirror Based on Submerged Single Vector Sensor

Xiang Xiao, Shiqi Mo
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Abstract—The vector sensor is a new type of sonar in recent years, and the vector signal processing technology has also been developed. The vector sensor can simultaneously pick up the acoustic pressure and particle velocity information in the acoustic field at a common point. The vector sensor can suppress the isotropic noise field. Only a single vector sensor can complete the target azimuth estimation. However, single vector sensor cannot complete target positioning based on acoustic pressure and particle velocity information alone, and other environmental information needs to be combined. The time reversal mirror (TRM) technology in underwater acoustics comes from the phase conjugation method in optics, which is a positioning technology. The TRM is used in the field of active sonar firstly. With the gradual maturity of the modeling of multi-path acoustic propagation in the underwater waveguide environment, passive positioning technology based on virtual TRM can be realized. With the development of vector signal processing technology, the performance of TRM can be effectively improved. In recent years, research in the field of passive TRM has mainly focused on the underwater communication. Research on the passive positioning technology of TRM is lacking. Under the above background, this paper studies the passive positioning technology of TRM based on single vector sensor.

6079-Aliasing line spectrum recognition method based on sound pressure and acceleration

Tianxing LI, Jinrong WU, Li MA
Institute of Acoustics, Chinese Academy of Sciences

Abstract—Aiming at the problem of aliasing of sound source line spectrum at low sampling rate, a spectrum estimation method based on joint processing of sound pressure and acceleration channel is proposed. According to the inherent characteristic of 90 ° phase difference between sound pressure and acceleration channel, the aliasing line spectrum in the sampling rate range is suppressed. Theoretical analysis and simulation results show that this method can effectively improve the recognition ability of aliased line spectrum, and retain the real frequency line spectrum in the range of sampling rate. The experimental results verify the effectiveness of the method.

6217-A compressive sensing SAS imaging method based on resampling of observation space for seabed small target

Shi Yi
Hangzhou Applied Acoustics Research Institute

Abstract—High resolution synthetic aperture sonar (SAS) imaging of small targets is easy to be confused and difficult to identify in the background, due to the strong influence of the seabed reverberation. In this paper, an anti-submarine reverberation technology which consists of azimuth compressive sensing is used to image small targets in the seabed under the condition of sparse space. In synthetic aperture sonar, the coupling problem of two-dimensional space caused by carrier movement cannot be ignored. To overcome this problem, nonlinear interpolation is adopted to achieve azimuth-range decoupling in range-Doppler domain. At the same time, the image pixels at different distances are not consistent with their azimuth, which is caused by two-dimensional decoupling. However, this paper proposes a spatial resampling technology based on compressive sensing in observation space to reconstruct the spatial spectrum of observation at different distances, so as to complete the construction of the compressive sensing observation matrix. The scattering coefficient is reconstructed by the optimist matching pursuit method to finally obtain the precise positioning imaging of SAS small target. In actual data processing, the new method in this paper can clearly image small target on the seabed, effectively reduce the inference of reverberation on the target imaging, and improve the recognition rate of SAS small target.

5945-Range estimation on a single hydrophone deepening vertically in the Pekeris waveguide

Xiao Yuan
Ocean university of China

Abstract— A method for range estimation is proposed in this paper on a single hydrophone deepening vertically in the Pekeris waveguide. Many short-aperture vertical arrays can be synthesized by a single hydrophone deepening vertically. Then, we can estimate elevation angles of every short array located at different depths by conventional beamforming or other methods of DOA estimation, namely, synthetic aperture beamforming. According to the linear relationship between depths and elevation angles, source range estimation can be achieved.

Oral session VI-3 (Friday, Morning)

5904-Doppler tracking and symbol synchronization method for mobile M-ary spread spectrum underwater acoustic communications

Guang Yang, Gang Qiao, Feng Zhou, Yuanan He, Yunjiang Zhao, Yufei Liu
Harbin Engineering University

Abstract—Doppler effect leads to the distortion of the wide-band underwater acoustic (UWA) communication signal. It brings frequency offset to the signal carrier. Simultaneously, the UWA signal length is compressed or broadened. For the UWA communication with a large relative velocity, the influence of Doppler effect is more prominent. This paper presents a method of Doppler tracking and symbol synchronization for movable M-ary spread spectrum (MSS) communication system, which provides a solution for mobile spread spectrum underwater acoustic communication with variable Doppler and large environmental noise. Using a large time bandwidth product of the spread spectrum code carrying information, the Doppler estimation is realized by searching the frequency of M spread spectrum codes within a certain range, and the next symbol is synchronously corrected in the time domain according to the estimation results. This method does not need the re-sampling operation for Doppler compensation. Simulation results show that the proposed method can accurately estimate and track the rapidly changing Doppler, and is suitable for mobile spread spectrum underwater acoustic communication. Compared with the conventional M-ary spread spectrum method, it is more robust.

5763-Underwater Acoustic Channel Estimation Based on Sparsity-Aware Deep Neural Networks

Longjie Gao, Sicong Liu
Xiamen University

Abstract—The estimation of the underwater acoustic channel (UAC) is a difficult problem in underwater acoustic orthogonal frequency division multiplexing (UA-OFDM) systems due to the detrimental characteristics of the UAC, including severe multipath fading, Doppler spread, and large transmission delay, etc. To overcome the problems and improve the performance of UAC estimation, a deep-learning-based approach utilizing a sparsity-aware deep neural network (DNN) emulating the sparse recovery algorithm of approximate message passing (AMP) is proposed for UAC estimation in this paper. The proposed method called Sparsity-Aware-DNN-based UAC Estimation (SAD-UACE) decomposes the conventional iterative sparse recovery algorithm of AMP into several differently parameterized layers of a DNN to learn the inherent sparse structure of the UAC, so that the accuracy of estimation can be improved, especially in severe conditions of underwater acoustic communications. Simulation results show that the proposed SAD-UACE method can significantly improve the accuracy and spectral efficiency of UAC estimation, compared with other state-of-the-art methods, especially in severe conditions of low SNR or insufficient pilots.

5793-Passive Estimation Method for Motion Parameters Of Underwater Near-Field Moving Target

Nan Zou, Junyi He, Tongsheng Shen, Wanrong Zou
Harbin Engineering University

Abstract—The Doppler effect will affect the accuracy of passive positioning, but it can provide more target motion information. Passive positioning for moving target in the near field is always difficult. In order to make better use of the Doppler information of the moving target in the near field, this paper proposes a passive estimation method based on the Doppler coefficient difference. The mapping relation between motion parameters and Doppler coefficient difference is derived. By using the differential evolution algorithm, according to the least squares criterion, the target motion parameters are obtained. The simulation analysis shows that the differential evolution algorithm can estimate the motion parameters of the near-field target under the condition of reasonably setting the upper and lower bounds and the algorithm parameters. And the tolerance of this estimation method to the estimation error of the Doppler coefficient difference can also meet the general application requirements. When this algorithm is applied to a linear array, the estimation accuracy is higher for targets that are closer to the center of the array and have a smaller angle with the normal direction of the array, while the estimation accuracy of targets in the long distance and with a large angle in the normal direction of the array is lower.

6070-Source Ranging Using Attention-based Convolutional Neural Network

Xu Xiao, Wenbo Wang, Qunyan Ren, Meng Zhao, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—Source ranging based on ship-radiated noise is a crucial task in many practical applications. Deep neural networks (DNNs) have shown outstanding performance but poor interpretability on source ranging, leading to the heavily hidden risks of blind trust in the AI black box. In this study, an attention-based convolutional neural network (ABCNN) is proposed for the ship ranging in an attempt to visualize the features of concern in neural networks. Acoustic data of four ships were collected during a sea trial conducted in January 2021 to validate the ship ranging performance of ABCNN. Results showed high accuracy in ship ranging using synthetic data and part of the experimental data as a training set for the proposed method. The attention mechanism visualized a concentration on the inherent features of ships and the waveguide effect of underwater acoustic channels.

6136-Covert Underwater Acoustic Communication Based on Ocean Ambient Noise

Biao Liu, Jianchun Huang, Ning Jia, Shengming Guo
1.Institute of Acoustics, Chinese Academy of Sciences 2.Key Laboratory of Underwater Acoustic Environment, Chinese Academy of Sciences 3. University of Chinese Academy of Sciences

Abstract—To achieve covert underwater acoustic communication (UAC) at energies with a low probability of detection (LPD), a system should work at a low signal-to-noise ratio (SNR) with no repeating patterns in the transmitted signal. Not all covert UAC schemes can satisfy both requirements. The present paper studies a truly covert UAC scheme. The transmitted signal consists of both the initial signal (the previously recorded ambient noise of the ocean) and an information-bearing signal generated by multi-step operations on the initial signal (time-domain symmetrical division, phase rotation, time reversal, and counterpart exchange). As the two signals are transmitted together, the receiver does not require pre-knowledge of the initial signal for demodulation. Hence, each symbol can be assigned a different initial signal, thereby avoiding repeating patterns in the signal and improving the covertness of the system. After optimizing the rotation phase condition, the performance of the UAC system was analyzed in numerical simulations. The scheme achieved covert UAC and exhibited good performance at low SNR.

Oral session VII-3 (Friday, Morning)

6067-High-Resolution Quaternion-Based Algorithm for Coherent Underwater Sources with Linear Vector-Hydrophone Array

Yi Lou, Xinghao Qu, Ruofan Sun, Gang Qiao
College of Underwater Acoustic Engineering, Harbin Engineering University

Abstract—For scenarios of coherent underwater signals at a low signal-to-noise ratio (SNR), a novel high-resolution DOA algorithm based on quaternion algebra has been proposed to improve the poor performance of the subspace-based method without eigendecomposition (SUMWE). We construct four quaternion-based models by judiciously arranging the received data and then obtain the signals' statistical characteristics by performing cross-correlations between the models. In the quaternion algebra framework, we statistically eliminate the autocorrelation noise by using the properties of circular signals. The noise elimination provides a high-resolution performance for the algorithm at a low SNR. Moreover, both the crosscorrelations and autocorrelations are utilized to enhance DOA estimation accuracy. Compared with the SUMWE-like methods, the proposed algorithm shows superiority in terms of estimation accuracy and angular resolution.

6063-Two-dimensional Direction Estimation of Generative Adversarial Beamforming

Jingben Liu, Jinxin Dong, Jiantao Liu, Lianghao Guo, Chao Yan
State key laboratory of acoustics, Institude of acoustic, Chinese Aacdemy of Sciences University of Chinese Academy of Sciences

Abstract—To solve the problem of large main lobe width of conventional beamforming methods, a two-dimensional deconvolution beamforming method based on machine learning is proposed. The algorithm uses the conditional generative adversarial network to learn the mapping relationship between beam power spectrum and point source distribution. In the process of algorithm training, the two-dimensional scanning results of conventional beamforming are input. The main lobe of the network output is narrower. Since this method inherits the advantages of the conventional beamforming, it is more robust than the adaptive beamforming method in the case of steering vector errors.

5924-An Identification Method of Underwater Targets Based on Sparse Representation

Jiawei WANG, Feng XU, Juan YANG
Institute of Acoustics, Chinese Academy of Sciences, University of Chinese Academy of Sciences

Abstract—An identification method of underwater targets based on sparse representation model with mixed-norm regularization is proposed in this paper. The proposed model employs three different features of acoustic signals, which are with complementarity and correlation: the central moments feature, the wavelet packet component energy (WPCE) feature and the Mel Frequency Cepstral Coefficients (MFCC) feature. From those features of training data, a sparse representation matrix can be optimally estimated. Then, the class labels for test samples are determined via the minimum reconstruction error criteria. To evaluate our model, a pool experiment of three different targets has been conducted, and the results show that the proposed method has high recognition accuracy.

6206-Real-time Detection and Classification for Targeted Marine Mammals

Yankun Chen, Weiping Wang, Yinian Liang, Defu Zhou, Chao Dong, Jie Li
South China Sea Marine Survey and Technology Center of State Oceanic AdministrationSMST

Abstract—With the continuous development of offshore engineering, major offshore projects develop rapidly. During the development of offshore engineering, different degrees of noise will be generated, and the man-made noise can have harmful effects on marine mammals. Currently, the researchers usually use Passive Acoustic Monitoring(PAM) method to monitor the marine mammals. However, it is impossible to acquire, monitor and analyze the sound of marine mammals in real time and lack of comprehensive information of marine mammals monitoring, and the data analysis and study of vocalization rules can only be carried out after data collection is completed and equipment is recovered. Therefore, this paper proposes a real-time automatic detection and classification technology to monitor targeted marine mammals efficiently and continuously timely in offshore engineering areas.

5951-Tree Dimensional Reconstruction of Forward- Looking Sonar Images Based on Oren and Nayar Model

Kun Cheng, Feng Xu, Juan Yang
Institute of Acoustics, Chinese Academy of Sciences

Abstract—Shape from shading(SFS) algorithm, based on Lambert diffuse reflection model, is often utilized for three-dimensional(3D) reconstruction from two-dimensional(2D) forward-looking sonar image. However, the Lambert model has been demonstrated to be an inaccurate approximation to the diffuse component, so traditional SFS is not reliable to reconstruct the 3D model. This paper applies a modified SFS algorithm in optics, based more accuracy Oren and Nayar diffuse reflection model, to the 3D reconstruction from 2D sonar images. After verification of the simulation data and sea trial data, the 3D model, reconstructed by the algorithm in this paper, is closer to the actual size of objects and recovers the details of objects better. Thus the modified SFS algorithm, in this paper, is more accurate than the traditional SFS in 3D reconstruction from 2D forward-looking sonar images.

4872-Image Formation Theory and Experiment Based on ML Criterion and EM Algorithm

Rongjie Huang, Song Wang, Hangfang Zhao
Ocean College, Zhejiang University

Abstract—We obtain data and communicate with others every day. Under so much data, a large number of images are formed and grasped by us. As we all know, information theory builds a foundation of communication. However, whether image formation theory could be guided by information theory needs further study. In this paper, we introduce information-theoretic image formation (ITIF) model and point out the goal of image formation and its relationship with information theory. Since data is not equal to information which is measured by entropy, inference should be used to extract information from data. Human beings communicate by making use of sound waves and electromagnetic waves which carry information. The wave is described by equation while the image is characterized by dispersion equation. The latter is related to the former by the Fourier transform. The image formation method depends on the metric of information. It is easy to derive the maximum entropy (ME) and Maximum Likelihood (ML) under the metric of Shannon entropy and Fisher likelihood information. The paper focuses on ML and its numerical computation method (i.e., Expectation-Maximization algorithm). In order to further reduce the complexity of EM and avoid complex mathematical expectation calculation in E-step of EM algorithm, we introduce Monte Carlo Expectation Maximization (MCEM) algorithm where sample mean replaces population mean in E-step. After introducing the sampling theorem and channel capacity theorem as array design principles, a double-helix array in pool experiment serves to prove the effectiveness of ML criterion, EM and MCEM algorithm we propose. Finally, in the end of the paper, we discuss about extensibility of the introduced algorithm and conclude our work.


COA 2021

6265- A method for impedance characteristics of underwater transducer planar array based on Near-field acoustic holography technology

Yan Xiao, Yuechan Liu, Jinfeng Han, Xiya Luo, Zihong Ping, Jingzhao Ji, Jinfeng Li
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Abstract—In order to get a deeper research on the underwater acoustic transducer array and obtain the radiation impedance quickly and accurately, a measurement method based on near-field acoustic holography (NAH) for impedance characteristics of underwater acoustic planer array has been proposed. Using this method, the self-/inter-radiation impedance characteristics of the source plane can be obtained by the sound source surface information which has been reconstructed by NAH. For illustration, based on the NAH principle measurement model for planar array impedance characteristic, a five-element linear array and a nine-element planar array were used to numerically analyze this measurement method. And the pool test of the very low frequency transmitting transducer is carried out. Both of the numerical simulation results and the experiment results show that the NAH measurement method proposed by this paper has certain feasibility in measuring the impedance characteristics of the transducer.

6234-A Hydrostatic Pressure Resistant Class III Flextensional Transducer

Binying Yang, Sisi Dai, Chang Fu
Shanghai Marine Electronic Equipment Research Institute

Abstract—Since the hydrostatic pressure resistance ability of class III flextensional transducer is usually poorer, we did some researches on the common hydrostatic pressure resistance ability of deep water transducer to improve it. The hydrostatic pressure resistance ability of class III flextensional transducer can be improved through the way of overflow fills the acoustic compliance tube. With the simulating calculation of class III flextensional transducer using finite element software, a transducer prototype was made and a fitness to the transducer of small size acoustic compliance tube was designed. The conclusion is that the hydrostatic pressure resistance ability of acoustic compliance tube is over 3MPa. The transducer has two resonance peak at 760Hz and 2000Hz, with TVR 115dB and 125.1dB. TVR should be over 113dB between 680Hz and 3000Hz. The transducer still can work normally with hydrostatic pressure of 3MPa. The results showed that the hydrostatic pressure resistance ability of overflow class III flextensional transducer which fills the acoustic compliance tube was improved, and with the high-power transmitting ability in board band of frequencies.

6220-Study of the Radiation Characteristics of Saucer-Shape Transducer

Binying Yang, Yan Wang, Chang Fu
Shanghai Marine Electronic Equipment Research Institute

Abstract—In order to study the radiation characteristics of the Saucer-Shape transducer, the vibration mode and electro-acoustic performance of the transducer were simulated and analyzed by using finite element software, and a transducer prototype was designed and manufactured. The measured results show that within the frequency band of 1.5~3kHz, the transmission voltage response fluctuation is less than 3dB, the source level is more than 196dB, the source level at the resonance point is more than 200dB, and the hydrostatic pressure resistance is more than 5MPa. The results show that the Saucer-Shape transducer not only has wide working band but also enables large transmitting power.

6154-Research on Detection Range Prediction for Oversea Wide-aperture Towed Sonar

Jingyi Wang, Xiaopeng Kong, Guangli Cheng, yanan Chen
Naval University of Engineering

Abstract—Sonar detection range is one of the most important indexes to investigate the performance of sonar equipment. The prediction of sonar action range plays a vital role for mastering sonar detection performance and improving the probability of target detection. Therefore, the study of sonar range prediction methodology for sonar detection is of great value in practical terms. Low-frequency and wide-aperture towed sonar is one of the main developing directions of domestic and foreign equipment in recent years. As the main passive sonar, its detection ability directly restricts the underwater information control. The sonar detection range mainly depends on transmission loss, target property and sonar qualification. Due to the difficulty in obtaining operation parameter of foreign sonar equipment, combined with the absence of detailed description of sonar qualification (e.g. the array structure, array length, array element number, placement method, detection index, the signal processing method, etc.), it's impracticable to directly extract indicators such as sonar detection operating range, direction finding and ranging accuracy from equipment performance description, not to mention evaluate the detection performance. In this paper, a method is proposed to predict the detection range of line array sonar abroad，which includes collecting clues, estimating parameters, theoretical analysis, assessment testing and adjustment(Fig.1). In the first stage, based on the collected information of sonar equipment, the semi-quantitative analysis is carried out by using the method of hypotheses and deductions (assuming some parameters as quantitative values), to estimate the sonar parameters, spatial gain, time gain, detection index, bandwidth, integrating factor. Then, the Marine environment model is established to calculate the transmission loss in the sea area. The detection range can thus be predicted through the sonar equation. A domestic towed sonar assessment test is conducted based on previous theoretical analysis in the second stage. The objective of the test is to verify the rationality of the sonar parameters deduced from the analysis, adjust the semi-quantitative calculation results, and obtain the actual detection performance of foreign sonar.For concealable submarine in underwater navigational status, since it has not reached the critical speed of cavitation, narrow-band line spectrum is the main feature of its low-frequency noise. The narrow-band detection ability of passive alarm sonar is crucial as the United states, Japan and South Korea identify the target according to the characteristic line spectrum of Chinese submarine. In addition, broadband detection of short-range targets (<10km) provides support for target tracking, recognition and type determination by listening. Therefore, the significance of broadband detection ability could also not be neglected. In this paper, based on passive detection modes of broadband parabolic detection and narrowband detection, the detection distances of passive sonar equipment such as SURTASS (USA), SQR-19 (USA, Japan)

and TB-16 (USA) are calculated respectively. The method presented in this paper is a feasible attempt for the detection range prediction of the wide-aperture towed array sonar, which provides a theory foundation for the further study of the foreign sonar detection performance. Above all, it offers certain reference for commanding submarine operations.

6110-Study on the Performance of Concave Flextensional Transducer Based on Finite Element Method

Yuchen Sun, Weiyi Chen, Zongji Li, Pingbo Wang, Qian Xie, Shizhe Wang, Yaojun Jia
Naval University of Engineering

Abstract—Cymbal transducer, as the fifth-generation flextensional transducer designed with a "sandwich" structure, is widely applied in underwater acoustics transducers, accelerometers and ultrasonic medical devices because of its advantages including high sensitivity, simple structure, easy fabrication, low cost, and convenient batch production. With such characteristics as small size and light weight, it can also better achieve lower frequencies, which is difficult to realize with traditional transducers. However, the Cymbal transducers of such a traditional design can no longer meet actual needs since they feature low-pressure resistance and narrow bandwidth when the underwater target acquisition evolves toward large water depth, wide frequency band, and low frequency. Based on the traditional Cymbal structure, this paper introduces a design of concave Cymbal transducer structure, which adopts a hollow piezoelectric ceramic ring and an inverted metal end cap. The proposed design can enhance the pressure resistance of the Cymbal transducer, expand its frequency bandwidth and improve its electromechanical characteristics. It is demonstrated that the finite element method can be used with a two-dimensional 1/2 axisymmetric model to analyze and identify the changes in the structural dimensions of the piezoelectric ceramic ring and the metal end cap. On this basis, this paper generalizes how such changes affect the electromechanical characteristics of the concave Cymbal transducer such as resonance frequency, bandwidth and quality factor, in a bid to provide a reference for industry personnel.

6104- Research on Segmented Circular Transducer with Adjustable Transmitting Directivity

Qiang Shi, Pengkun Zhao, Hong Xu, Zhengyao He
School of Marine Science and Technology, Northwestern Polytechnical University

Abstract—This paper studies the method of transmitting beam design and directivity adjustment of segmented circular transducer. The modal synthesis method is used to design the transmitting beam pattern of segmented circular transducer, and a method of adjusting the beam directivity by using the superposition of multiple orthogonal acoustic radiation poles is proposed. A three-dimensional finite element model of segmented circular transducer is established by using finite element method, and the transmitting beam directivity of the transducer is controlled by applying the optimized weight to each channel of the transducer. Finally, the segmented circular transducer is designed and manufactured, and the experiment is carried out in the anechoic water tank to verify the method of beam design and directivity adjustment of the segmented circular transducer proposed in this paper.

6074-Analysis of Directivity Index Under Large Azimuth Angle of Linear Array

Jieqi Zhu, Fuhu Chen, Di Huang
Hangzhou Applied Acoustic Research Institute

Abstract—This article has carried out a detailed analysis aiming at the problem of the change of directivity index under large azimuth angle of linear array, and explains the change of the directivity index at large azimuth angles under different conditions, carries out the corresponding simulation and verification. The analysis in this article shows that it is suitable for the design and index demonstration of towed linear array sonar, flank array sonar, etc., and it has huge engineering application value.

5913-Analysis of the Influence of Watertight Materials on the Acoustic Performance of Two Types of Transducers

Sheng-wei ZHAO, Tian-ji ZHAO
Hangzhou Applied Acoustics Research Institute

Abstract—Watertight material is an important part of the acoustic transducer, but most scholars have not considered its influence on the performance of the acoustic transducer in the design process. This paper uses finite element simulation software to model and analyze the two common acoustic transducers, and compares the effects of the external watertight materials of the two transducers on the acoustic performance, and proves that for some special types of acoustic transducers, watertight materials cannot be ignored.

6228-Cavity Resonance Sound Absorptive Material Parameter Optimization Based Image Recognition and Deep Learning

hao song, zixian cui, lin su, zhengkai li
System Engineering Research Institute

Abstract—Traditional modelling and optimization methods for sound absorptive materials require manual testing and huge computation effort. Artificial intelligence is an ideal method for the prediction and identification of complex systems in these cases. This study presents an optimization approach based on image recognition combined with deep learning for cavity resonance sound absorptive material. The sound absorptive material model is conducted using the acoustic-structure coupling model in COMSOL Multiphysics for the sound pressure distribution and behaviour during different frequency excitation. The cavity material plane wave image recognition model was obtained using the CNN method of multiscale layered features. The image arrangement was then processed and sent to the convolutional layer for feature extraction. Subsequently, the feature record was entered into the loop. The association between the kinematic parameters of the cavity material and the sound pressure distribution is obtained through the prediction layer. Using the prediction of CRNN, the results indicate that the range of the cover thickness should be between 50~70 mm and the angle should be between 45~60°. It also showed that this optimization method could be successfully applied for similar materials and components, with certain universality.

6175-Effect of MODAS Data on Convergence Zone Distance Prediction

Yinquan Zhang, Shuang Zhang, Feng Zhu, Zhishun Hu, Siyu Gao, Qian Chen
National Marine Data and Information Service

Abstract—Underwater acoustic environment (UAE) prediction is essential for accurately estimating sonar performance and making credible tactical decisions. Modular Ocean Data Assimilation System (MODAS) provides an efficient way to reconstruct real-time three-dimensional ocean sound speed field and has potential use in UAE prediction. However, the effect of MODAS on UAE prediction is not clear, which prevents MODAS from being used in practice. Taking account that convergence zone (CZ) is a typical feature of deep-sea UAE, this paper studies the effect of MODAS on CZ distance prediction. A method is proposed to quantitatively describe the accuracy of CZ distance prediction. The method takes the CZ distance as a random variable and uses Monte Carlo sampling method to obtain the probability density function (PDF) of CZ distance. The performance of MODAS on CZ distance prediction is numerically simulated in a range-independent and a mesoscale eddy waveguides. It is shown that: (1) In the range-independent waveguide, if the sound speed disturbance of internal waves with respect to the background sound speed profile is less than the RMSE of MODAS, the prediction of CZ distance for local measured sound velocity profile is more accurate. (2) In the mesoscale eddy waveguide, the performance of MODAS is better and the performance improves as the RMSE of MODAS decreases.

6069-Radius Estimation of Thin Spherical Shells proud on the Sediment based on Resonance Peak Intervals

Jianer Huang, Xiukun Li
Harbin Engineering University

Abstract—Resonance peak feature has important application value for target detection and recognition. For the underwater elastic thin spherical shell, there are approximately equal resonance peak intervals in midfrequency enhancement range of backscattering form functions, which can characterize its inherent characteristics. This paper theoretically analyzes the causes of this phenomenon. And based on this feature, a simple expression is given to estimate the radius of elastic thin spherical shells by the resonance peak intervals. Numerical simulation results show that the proposed method has certain feasibility for the target in the free field and proud on the sediment.

6189-Construction of Acoustic Dipole and Its Performance Verification Test in Shallow Water

Chunxia Meng, Xiaoyuan Li, Zhongcheng Ma, Feng Cao, Hang Su
Science and Technology on Underwater Test and Control Laboratory DaLian, China

Abstract—The complex underwater noise field is formed in the process of the ship's constant volume sound source sailing. Due to the large number of machinery and equipment on the ship, and the navigation state of the ship on the sea is easy to change, these factors make it difficult to obtain the low-frequency radiated noise characteristics of the ship in a stable state. Therefore, it is an effective way to understand and master the characteristics of low-frequency underwater radiated noise field by using directional sound source in controllable state. Dipole transducer is a typical directional sound source with horizontal or vertical octagonal directivity, which is widely used in seismic and logging research. However, few dipole transducers are used in underwater acoustic research. The reason is: the directional emission of underwater acoustic low-frequency transducer is a big problem in the current transducer design. The directional emission technology of low-frequency dipole transducer is related to the distance / wavelength of the radiation surface. Because the position relationship of the radiation surface is fixed, it can only form the ideal directivity at a specific frequency. This brings great inconvenience to the application of underwater acoustic low- frequency dipole transducer. Firstly, the mathematical model of sound field radiated by acoustic dipole is established; then, the common non-directional low-frequency sound source is used to construct an acoustic dipole source. By adjusting the distance between two low-frequency sound sources, low-frequency dipole signals with different frequencies can be emitted. The lake test results show that the maximum difference of horizontal directivity of dipole source is less than 0.5dB and the depth of concave point is more than 21dB; finally, the test scheme in shallow water is designed, and the low-frequency narrow-band signals of 63Hz and 80Hz are emitted by the acoustic dipole source in uniform towing state, and the received signals of the bottom mounted hydrophone are analyzed and processed. The results of marine test show that the horizontal directivity of the dipole sound source constructed by two low-frequency sound sources can meet the requirements of acoustic test at multiple frequencies. The dipole transducer constructed in this paper has the advantages of simple structure, convenient equipment connection and wide signal frequency band, which can be applied in the study of underwater acoustic field characteristics of ships. Using the dipole sound source constructed in this paper, the sound propagation characteristics of underwater directional sound sources such as ships in the far field can be studied.

6179-Data Assimilation for Ocean-Acoustic Coupled Model

Wuhong Guo, Mei Han, Peiqin Fan
Navy Submarine Academy

Abstract—Through embedding acoustic calculations into the dynamic ocean and achieving an ocean-acoustic coupled numerical model, a dynamic forecast and assessment of the acoustic environment is established in this study. Incorporating data assimilation from meteorologic and oceanic forecast into the acoustic environment study to providing initial value for the Ocean-Acoustic coupled model, the calculation efficiency and forecasting precision are improved significantly. Meanwhile, We illustrated the prediction errors of the sound velocity section as well as the 90% probability interval of the transmission losses, the uncertainty histograms of the sound velocity, and the transmission losses. The experimental results reflected the influence of marine temporal and spatial variations on the uncertainties of the underwater acoustic environment and quantified uncertainties of the underwater acoustic environment. What's more, the results also indicate that the method used in this study could delineate and quantify the uncertainties of the underwater acoustic environment caused by marine dynamic changes.

6027-Ocean Front Model Based on Sound Speed Profile and its Influence on Sound Propagation

Yuyao Liu, Wen Chen, Wei Chen, Yu Chen, Lina Ma, Zhou Meng
National University of Defense Technology

Abstract—In the ocean front environment, the existence of ocean front has an important impact on sound propagation due to the obvious change of sound speed profile. According to the two-dimensional parameterized model of ocean temperature front constructed by Olivier et al, we build a two-dimensional parameterized feature model of ocean front based on sound speed profile, calculate and compare the influence of ocean front on convergence area by setting different ocean front environment. The results show that when the sound wave propagates from the warm water mass to the cold water mass, the convergence area moves forward, and the degree of the forward movement changes with the intensity of the ocean front; when the sound wave propagates from the cold water mass to the warm water mass, the convergence area moves backward, and the degree of the backward movement changes with the intensity of the ocean front. We also analyze the reasons for the formation of the acoustic shadow area at a specific location under the condition of strong ocean front when the sound wave propagates from the warm water mass to the cold water mass, which may provide a reference for the acoustic concealment of the target under the environment of ocean front.

5991-Analysis of Sound Speed Profile in the South China Sea based on Empirical Orthogonal Function Algorithm

Jin Huang, Yu Luo, Yanyi Li, Jian Shi, Xu Zheng, Jingjing Wang
College of Geodesy and Geomatics, Shandong University of Science and Technology

Abstract—In marine mapping, the sound speed profile (SSP) is an essential parameter. The SSP reflects the characteristics of the ocean sound field's vertical structure. Furthermore, analyzing the SSP has an important significance on the propagation of underwater sound signals. The empirical orthogonal function (EOF) can extract the SSP data's main features. It is widely used in SSP fitting and other applications. In this paper, the studying area is 116° ~117° E,18° ~19° N in the South China Sea. Using the Argo data from 2010 to 2020, this paper first visually analyzes SSP, carries out the EOF's analysis, and then elaborates the basic EOF principle. It confirms that the EOF has a good application value for the South China Sea, and the first sixth order function can accurately describe the sound speed profile. Then this paper analyzed the EOF's temporal function. The study found that the third mode of temporal function strongly connects with the ocean's climate condition. And the two severe fluctuations in 2010 and 2014 have a strong relationship with the typhoon passage. In other words, the degree of extreme fluctuations is positively correlated with typhoon intensity. In brief, understanding the SSP's temporal pattern is beneficial for applying various engineering scenarios. It can improve the accuracy of sound speed correction of marine acoustic instruments, while the study of marine climate environment has an important role.

5018-Research on Phase Characteristics of Parametric Sound Field in Water Medium

Zhongcheng Ma, Lianghao Lv, Tiansi An
Dalian Scientific Test Control Technology Institute

Abstract—The phase control of parametric array is a new application direction.The phase characteristic mechanism of parametric sound field is analyzed. The phase characteristics of parametric acoustic source in the interaction region of primary wave in surface seawater are researched by means of contrast measurement. The unique law of phase change in parametric field is obtained. The phase of the difference frequency wave of the parametric array is stable under good sea conditions, which is fluctuated randomly under wind and wave conditions. Due to the sound velocity dispersion of the medium, the phase difference between the parametric sound field and the conventional sound field increases with the propagation distance, which can reach tens of degrees under worse sea conditions.

6018-A Method for Determining Normal Mode Number in Shallow Water Waveguide Based on Dispersion Curves

Xiaoman Li, Biao Wang, Lin Ma, Xuejie Bi
School of Electronic and Information, Jiangsu University of Science and Technology

Abstract—In order to determine the normal mode numbers from the received signal of broadband pulse sound source in shallow water waveguide, a method for determining normal mode numbers in shallow water waveguide based on Bayesian estimation theory is proposed in this paper. The dispersion curves extracted from the measured data is used as the input signal of Bayesian inversion theory, and the replica is calculated by dispersion formula, which is composed of bottom reflection phase shift parameter, depth, propagation range and average sound velocity in water. The bottom reflection phase shift parameter is used to describe the bottom geoacoustic parameters, which can reduce the number of inversion parameters and prevent interference between parameters. Then a double cost function for normal mode number and marine environmental inversion parameters is established, the determination of normal mode number takes precedence over parameters inversion. Finally, the normal mode number is determined accurately by comparing the dispersion curves calculated from the inversion results with the measured results. The method is not only simple and easy to operate, but also Significantly improve the calculation speed and inversion efficiency. The experimental data processing results prove the effectiveness and accuracy of the method.

5062-An Inversion Method for Shallow Water Geoacoustic Parameters Based on BIC Criterion

Yangyang Xue, Wenliang Wang, Hanhao Zhu, Guangxue Zheng, Zhiqiang Cui
Zhejiang Ocean University

Abstract—In this paper, a geoacoustic parameters inversion method for shallow water based on Bayesian Information Criterion (BIC) is developed. In this study, the seabed is *n*-layer horizontal elastic medium, and the inversion parameters in each layer medium include the seabed density ρ_n, compression wave (P-wave) velocity c_{pn}, shear wave (S-wave) velocity c_{sn}, attenuation for the two wave α_{pn} and α_{sn} and each layer depth h_n. Taking the acoustic pressure p as the research object, the error function between the measured acoustic pressure and the predicted acoustic pressure is established according to the Bayesian theory and likelihood function. The inversion result is obtained with the simulated annealing algorithm (SA) under Metropolis rule. The BIC is introduced as the judgment basis to realize the optimal selection of the seabed model structure. Through the analysis of the inversion result: marginal posterior probability distributions (PPD) concentrated constrained with near the true values and the matching degree of the transmission loss (TL) matches the preset true value very well, show the effectiveness of the method in this article.

6053-Experimental investigation on seabed seismic wave induced by a pulse acoustic source

luwen meng, dexin zhao, tao wang, guangming li
Academy of Military Sciences

Abstract—To observe the separation phenomenon of the various components of the seabed seismic wave and obtain the propagation characteristics of each component in the time domain. a pulse acoustic source experiment was designed and carried out on the lake. The experimental results show that: different types of seabed seismic wave can be induced by air gun pulse sound sources in shallow water, and they can be received by vertical vibration sensors placed on the bottom of the water; the seabed seismic wave is dominated by Scholte wave, whose propagation speed is related to the parameters of the lake bottom medium and lower than the underwater acoustic velocity; the dominant frequency of the Scholte wave is below 25 Hz, which is not easily interfered by strong acoustic signals in the water.

6064-Study on Acoustic Scattering Characteristics of Fish

Lanyue Zhang, Yutong Sun, Yi Yang, Desen Yang, Guilin Zhai
Harbin Engineering University

Abstract—Using acoustic method to study the fish monitoring technology in aquaculture vessels has many advantages, such as reducing the pressure of the marine environment and improving the quality of fish. The target strength of fish is the main parameter of monitoring and estimation, and it is usually researched by the model approach. In this paper, acoustic scattering theory and KRM model were used to calculate and evaluate the acoustic scattering characteristics and the target strength of fish, and relevant experiments were designed to measure the target strength of fish in the field. The experimental results verified the rationality of KRM method, which provided a theoretical basis for fish breeding on the industrial ship.

5800-Simulation of Backscatter Signal of Submarine Target Based on Spatial Distribution Characteristics of Target Intensity

Song Zhao, Lanrui Li, Xinhua Zhang, Dawei Zhang, Mingyuan Li
Dalian Naval Academy

Abstract—Array signal simulation of active sonar echo is an important basis for the verification of new target detection technologies and equipment training. Backscatter signal simulation is the main part of echo signal simulation of mono-static sonar target. Based on the improvement of the traditional highlight model of submarine target, this paper presents a method to simulate the backscatter signal of a submarine target based on the spatial distribution characteristics of target intensity at a different angle of the ship's side. Compared with the traditional method, the backscatter signals obtained by the proposed method can better reflect the broadening and amplitude fluctuation characteristics of the backscatter signals of the submarine target in the time domain. As for the spatial distribution of the target intensity, it can change with the spatial variation of the incident Angle of the signal, and get the spatial distribution diagram which is consistent with the variation law of the "butterfly figure" of the simulation target, so that the simulated backscatter signal of the target is more consistent with the spatial distribution characteristics of the target intensity of the given target, which can provide technical support for the simulation of the active sonar echo signal.

5008-Modelling convergence zone propagation under the influence of Arctic front

Ruichao Xue, Yanming Yang, Jinbao Weng, Hongtao Wen, Lina Lin, Hongxia Chen
The Third Institute of Oceanography, MNR

Abstract—The ocean front will cause the sound velocity profile to change considerably within a short distance, and this has a significant impact on the underwater sound field. In this study, we investigate the influence of the Arctic front on underwater acoustic propagation. Hydrological data from seven stations, as measured in the course of China’ s 8th Arctic scientific investigation, over a distance of 300 km in the Nordic Sea are used to carry out simulations using the Bellhop model. The results show that the Arctic front changes the characteristics of the convergence zone, including distance, width and the number of convergence zones, within a fixed distance. With the absence of ice in this area, these changes are closely related to the depth of the sound source, but not to the frequency.

6146-Phase-shifted sensitivity calibration of fiber optic vector hydrophone based on heterodyne method

Wenjing Li, Yi Chen, Jun Zhang
Hangzhou Applied Acoustics Research Institute

Abstract—In order to realize the calibration of fiber optic vector hydrophone with wide frequency band and large dynamic range, the research on the phase-shifted sensitivity calibration technology of fiber vector hydrophone based on heterodyne method has been carried out. The heterodyne-arctangent demodulation simulations were performed on signals with a large amplitude of 120 rad or a high frequency of 50 kHz respectively, which verified that the demodulation algorithm has the ability to demodulate signals with a wide frequency band or a large dynamic range. A phase-shifted sensitivity calibration system based on the heterodyne method was developed, and the standing wave tube comparison method was used to calibrate the phase-shifted sensitivity of fiber optic vector hydrophones in the frequency band of 20 Hz to 1.25 kHz. Below the resonant frequency of the fiber optic vector hydrophone, the maximum difference between the calibration result and the theoretical calculation result is 1.2 dB, and the measurement uncertainty of the calibration system is 1.5 dB (k = 2).

6164-Development of Underwater Multi-channel Real-time Ranging and Positioning System

Wang Hao, Li Li, Huang Yu, LIU Wen-shuai
Dalian Scientific Test and Control Technology Institute

Abstract—In order to solve the problem of underwater system multiple hydrophone units to obtain the target real-time distance and position in ocean engineering, this paper proposes a multiple redundant position algorithm based on time-delay estimation. First the article introduces the mathematical model of real-time underwater acoustic signal processing and positioning, then the overall design of the system is carried out, followed by the subsystem design, and developed the prototype system. Finally the system is validated by sea test. The results show that the system has the advantages of fewer wild spots, high positioning accuracy. And the system is easy, reliable and highly integrated."

6115-Research on AUV Integrated Navigation Method Based on Improved Particle Filter Algorithm

Fengyang Chi, Yan Xiao
Heilongjiang Institute of Technology

Abstract—In view of the problem that GPS navigation equipment cannot be used underwater, the integrated navigation method which is based on the strap-down inertial navigation system (SINS) and long-base line (LBL) positioning system with buoys network are researched in this paper. The mathematical model of SINS/LBL integrated navigation system is established， and the integrated navigation method which is based on Rao—Blackwellised adaptive particle is researched, which dynamically reduces the particle number through the Euclidean distance and the cost function between particles. The simulation analysis of SINS/LBL integrated navigation shows that， compared with the standard particle filter algorithm, the Rao—Blackwellised adaptive particle filter algorithm is higher accuracy in position error estimation, and the number of particles is less, so it can be solved the state estimation problem of high-dimensional integrated navigation system.

6066-Comparative Analysis of Pressure Depth Conversion Methods for Marine Acoustic Datum Depth Constrained Positioning

Chaoyi Wu, Mingzhen Xin, Fanlin Yang, Jinjin Wei, Xiaofei Zhang
College of Geodesy and Geomatics, Shandong University of Science and Technology

Abstract—The underwater positioning of marine acoustic datum is mainly based on the principle of spatial distance intersection positioning. As the limitation of the observation structure, the observation error is easy to accumulate in the vertical direction. If the accurate depth of marine acoustic datum can be obtained and used for depth constrained positioning, it will help to further improve the positioning accuracy of marine acoustic datum. The depth gauge based on the principle of pressure measurement has been widely concerned due to the advantage of autonomous depth measurement. However, the effect of pressure-depth conversion on the positioning error of marine acoustic datum under depth constraint has not drawn enough scholarly attention. This paper focuses on the evaluation of the pressuredepth conversion accuracy of different seawater physical models and conducts an experimental analysis based on Argo buoy data. The results of the experiment show that the TEOS- 10 model has the highest conversion accuracy, and using accurate profile information of temperature, salinity, and pressure parameters to correct the depth data is helpful to improve the accuracy of marine acoustic datum positioning.

4838-Research on the Influence of Non Identical Position of Acoustic Ranging in AUV Underwater Guidance

Jun Cao, Zaiming He, Weizhe Xu, Shenshen Yang, Wei Zhang, Hao Liu
China Ship Scientific Research Center

Abstract—In the upsurge of unmanned and intelligent, AUV technology and equipment have been widely concerned, which plays an increasingly important role in the sustainable utilization of marine resources. Although AUV technology is maturing, but the problem of short endurance has not been solved effectively. In order to obtain the multiple increase of AUV sailing distance and time, the world's maritime powers have carried out research on AUV autonomous underwater guidance and docking technology. Long distance acoustic positioning is the first action of AUV underwater guidance. When the acoustic ranging and positioning system is used for AUV underwater guidance, the acoustic ranging system is usually installed on AUV, the acoustic beacon is installed on the guidance docking platform. When AUV is guided underwater, the acoustic ranging system sends an interrogation signal at the beginning of each ranging cycle. When the acoustic beacon on the guidance platform receives the interrogation signal, a reply signal is transmitted after the preset turnaround time of beacon. AUV underwater guidance has the phenomenon that acoustic signal transmission and reception are not in the same position. The conventional acoustic ranging and positioning method is based on the static target model, the AUV motion in acoustic ranging is ignored. Simply use half of the two-way travel time as the observation value of the one-way travel time. This observation value is not equal to the one-way travel time between the beacon and the position of the AUV transmitting signal, nor the one-way travel time between the beacon and the location of the AUV receiving signal. For the approximate error of acoustic ranging observation model, theoretical derivation and simulation analysis are carried out. The influence degree and law of AUV motion on non identical position of acoustic ranging are obtained. Theoretical derivation and simulation analysis show that: The approximate error of distance measurement corresponding to the position of transmitting signal and receiving signal is equal in size and opposite in positive and negative. When the AUV speed is 1m / s, the maximum ranging error is -0.667m, and the ranging error decreases with the distance. In addition, the ranging error is proportional to the AUV velocity. When the relative horizontal position of AUV's straight track and beacon is different, the variation rule and numerical value of acoustic ranging error will not be affected. When the relative vertical position of AUV's straight track and beacon is different, the variation rule and numerical value of acoustic ranging error will not be affected. When AUV is guided from different directions, the AUV heading does not affect the variation rule and numerical value of ranging error. On the whole, the ranging error is not only proportional to the AUV speed, but also to the distance between the signal transmitting position and the beacon’s vertical line. But with the AUV approaching the underwater guidance platform, the influence is getting smaller, and the guidance accuracy is getting higher.

6099-Research on the Application Technology of Manned Submersible Bathymetric Sidescan Sonar System in the Abyss Zone

Lei Yang, Xiangxin Wang, Tongwei Zhang, Shengya Zhao
Deep Sea Technology Department Nation Deep Sea Center

Abstract—The exploration of the Micro-topography and landforms in the abyss area is one of the main application directions of manned submersible. It is of great significance to use the Bathymetric Sidescan Sonar System of manned submersible to obtain high resolution topography and geomorphology map of abyss area. This paper introduces the composition and working principle of Bathymetric Sidescan Sonar System and key technology of Jiaolong manned submersible after the upgrade of Jiaolong manned submersible. Combined with the data obtained from sea trial and scientific application voyage of Jiaolong manned submersible, the advantages of underwater vehicle automatic navigation technology in the exploration of topography and geomorphology in the abyss area are analyzed, which combined with the subjective initiative of human, the Bathymetric Sidescan Sonar System could still working in the best condition. This paper also discusses the interference of digital underwater acoustic communication system on the mapping of Bathymetric Sidescan Sonar System. Finally, the detection results of the line stations are given. It provides a reference for the application of Bathymetric Sidescan Sonar System for manned submersible in the exploration of micro topography and geomorphology in the abyss area.

6012-Dominant Rays Analysis in Shadow Zones of Deep Ocean and Its Application on Fast Bearing Estimation of Active Sonar

Zhibin Han, Jun Song, Xiuting Yang, Chunmei Zhao, Hao Zeng, Ning Li
92578

Abstract—In shadow zones of deep ocean, the horizontal line array of active sonar is unable to distinguish the elevation angle and the bearing angle because of its axial symmetry, which leads to bearing estimation error when the elevation angle is large. The traditional improved method estimates elevation angles of all positions with acoustic field model and then gets the actual elevation angles according to the actual time delay for beamforming weight vector compensation, whose computing efficiency and real-time performance are low. In this paper, an improved fast bearing estimation method in shadow zones is proposed. We show that the sound field fluctuation in shadow zones is due to the energy fluctuation of the rays having different emanating angles. And a quantitative relationship between the detectable areas and the rays with high energies is calculated based on the ray interference theory. The elevation angles at the boundary location of the detectable areas can be calculated according to this relationship. And hence, elevation angles of all positions can be obtained by linear fitting. Simulation results show that this method can decrease bearing estimation errors effectively, meanwhile it has a much low computation burden which is useful for the real-time calculation.

5986-Self Noise Measurement and Analysis of ""Sea wing 300"" Underwater Glider

Chunping Zhai, Zhongcheng MA, Kewen WANG, Lin WU
Science and Technology on Underwater Test and Control Laboratory

Abstract—In order to carry out ocean sound field observation in deep sea, wide frequency band and long-term space-time based on the underwater glider platform, this paper uses the opportunity of "Sea wing 300" underwater glider sea test, carries the underwater acoustic sensor of rigid binding and elastic suspension installation mode, analyzes the basic characteristics of the underwater glider's self noise. The results show that the underwater acoustic sensor adopts the elastic suspension mode, which can significantly reduce the low-frequency vibration interference of the moving platform. On this basis, the time-frequency characteristics of the acoustic field signals of different equipment such as the buoyancy driving mechanism, the pitching mechanism, the steering mechanism, the CTD pump and the flow noise are obtained, and the application suggestions are given according to the distribution of the acoustic field characteristics.

6058-Analysis of Wave Components and Propagation Rules of Seabed Seismic Waves in Shallow Sea

Xue Xia, Xiayun Luo, Changwang Huang
The 41st Unit Unit Designation 91388

Abstract—In order to analyze the wave components and propagation rules of seabed seismic waves in shallow sea, the seismic wave field of shallow sea is simulated by the high-order staggered grid finite difference method based on shallow sea sound field model. The calculated results show that, the wavefront of direct, reflected and transmitted waves are pherical surface, and amplitude is proportional to one of r points; the wavefront of Scholte wave is cylindrical surface, and amplitude is proportional to one of the square root of r points; the wavefront of lateral wave is conical surface, and amplitude is proportional to one of squared r.

6139-Study on the Acoustic Scattering Characteristics of the Parametric Array in the Wake Field of Underwater Cylindrical Structures

Jikang Li, Desen Yang, Guangzhi Chen
Harbin Engineering University

Abstract—The wake generated by the underwater structure can evolve into a wake vortex with a special flow structure, resulting in a change in the speed of sound distribution, which has an important impact on the propagation of parametric array in the ocean and causes fluctuations in the sound field. The difference-frequency sound wave generated by the parametric array is the core of the parametric array technology. The study of the difference-frequency sound field distribution characteristics is the basis for the development of the parametric array technology and the theory of the interaction of sound waves. The frequency domain algorithm is used to calculate and analyze the nonlinear acoustic scattering characteristics of the underwater vortex field and explore the nonlinear acoustic scattering characteristics of the wake field of a cylindrical structure under the conditions of different moments and Mach number. The results show that the spatial directivity of the nonlinear acoustic scattering field of the wake vortex will cause the directivity of the parametric acoustic field to shift. The difference-frequency wave becomes concave and convex on the opposite sides of the parabolic axis and the wave energy is focused and scattered. The focus will cause the amplitude of the wave to increase and decrease accordingly. The main lobe offset will increase as the flow velocity increases.

6031-Intensity fluctuation and depth dependence in acoustic experiment of Yellow Sea front and internal waves

Chunhui Hu, Bohan Yuan, Haozhong Wang
Ocean University of China

Abstract—Nonlinear internal waves (NIWs) passing through the vertical line array and induced acoustic fluctuation were observed in AEYFI2005 (Acoustic Experiment of Yellow Sea Oceanic Front and Internal Wave in 2005). In this paper, we present analysis of the peak fluctuation of the wideband signal recorded by the vertical line array which is deployed at 37 km away from the source, and the antinode fluctuation of the depth function of the 1st normal mode induced by NIWs. Although there exists no significant mode coupling, the peak-to-peak variation of signal amplitude larger than 6dB is observed. Simultaneously, it is found that the antinode fluctuation of the depth function of the 1st normal mode extracted using the data-derived method is good in agreement with the fluctuation of thermocline measured by the thermistor chain. We explain these experimental results by using numerical simulations and theoretical analysis. It turns out that these can be interpreted as acoustic fluctuation due to the variation of local depth function of normal modes induced by NIWs.

6216-Analysis of Irregular Characteristics of Reverberation Spectrum in Shallow Sea

Jianglin WU, Yunfei CHEN, Bing JIA, Yang ZHANG, Zhizhuan WANG, Jingying WANG
Science and Technology on Underwater Test and Control Laboratory

Abstract—Shallow sea reverberation is one of the main interferences in the active detection of underwater targets, and the working frequency of active sonar continues to expand to low frequencies, and the problem of reverberation interference is also receiving increasing attention. Focusing on the need to dig deeper into the frequency domain characteristics of shallow sea reverberation, this paper starts from the fluctuation characteristics of the low frequency reverberation spectrum in shallow seas, and uses spectral irregularity (SI) to characterize the spectrum fluctuations of the reverberation in shallow sea. First, based on the shallow sea reverberation point scattering model, the shallow sea reverberation is simulated. Combining with the definition of the spectrum irregularity value, the statistical results of the shallow sea reverberation spectrum irregularity value are studied, and the different pulse widths and different time periods of the multi-sample data are analyzed and compared. The results show that at the same transmitting frequency, when the pulse width of the transmitted signal increases, the SI value of the reverberation basically gradually decreases, and the SI value of the reverberation basically obeys the increase with the attenuation of the reverberation level.

6204-Seabed Sediment Classification based on Multifeatures Fusion and Feature Selection Framework

Yan Pang, Feng Xu, Jia Liu, Yue Zhao
Institute of Acoustics, Chinese Academy of Sciences University of Chinese Academy of Sciences

Abstract—An improved framework used to classify sediment using the signal reflected by the seafloor is put forward in this paper. The proposed framework is verified by the data collected by 400-kHz Reson 7125 multibeam echo sounder(MBES) in the experiment carried out by California Seabed Mapping Project. After fusing the 21 features extracted firstly from the seabed sediments signals acquired from MBES image, the four most important features which still retain clear physical meanings are selected by the random forest feature algorithm to calculate features importance. Finally, the classification results are obtained by support vector machine(SVM), k-nearest neighbor(KNN) and decision tree(DT), respectively. The results show that the presented method could achieve excellent classification accuracy on different classifiers by combining feature fusion and feature selection.

6256-Analysis of underwater noise characteristics of Yangjiang offshore wind farm during construction

Yi Liang, Zhenyi Ou, Weiqi Zhong, Ke Qu, Mingxia Hu, Guowei Song
College of Electronics and Information Engineering, Guangdong Ocean University

Abstract—Renewable wind energy has become an advantageous alternative. By the end of 2020, the total global offshore wind energy capacity has exceeded 35GW, growing more than 106% in the 5 past years, and the capacity has exceeded 6GW. It is estimated that by 2025, the global installed capacity of offshore wind energy will reach 100GW. In 2020, China's new offshore wind energy installed capacity exceeded 3GW, accounting for 50.45% of the world's new installed capacity and became the second-largest offshore wind energy market in the world. Offshore wind energy projects will produce noise pollution with different characteristics during the construction and operation stages, which will cause temporary or permanent damage to marine life to some extent. In this paper, the on-site survey of the underwater noise during the construction period of the second section of the Shapa offshore wind farm in Yangjiang, Guangdong. The survey was conducted on two days, and the measurements were carried out at different distances outside the wind farm. Time-domain waveform analysis and frequency spectrum analysis were performed on the data. The research in this paper can provide technical reference for environmental impact assessment of offshore wind energy projects, and has great application value. Through the analysis of the underwater noise characteristics of the offshore wind farm at different distances, the following results are obtained: Firstly, as the distance increases, the measured sound pressure values far away from the wind farm site are slightly smaller than those at the edge of the wind farm. Due to the multi-path effect, the duration of the acoustic pulse signal measured at the edge of the wind farm is shorter than that outside the wind farm. The noise power of piling at the edge of the wind farm tends to be stable, which has little impact on the apogee. Secondly, the sound pulse of piling causes the underwater noise sound pressure level at the edge of the wind farm to be generally higher than that at the site far away from the wind farm. With the distance increasing, the frequency of the sound pressure peak will be shifted. The noise intensity has the largest change in the frequency range of 0~1000Hz, and it has little impact when the frequency range is over 1000Hz. The underwater noise at the edge of the wind farm is greater than the underwater noise far away from the wind farm by a relatively constant value. Thirdly, as the distance from the wind farm increases, the frequency spectrum within the frequency range of 150Hz to 250Hz changes significantly. Fourthly, the wind farm has little impact on the nearby underwater acoustic environment during the construction

period, and the impact range is small, which is not enough to damage the hearing of creatures near the wind farm. However, whether the noise has a long-term impact on the physiology and behavior of nearby marine organisms remains to be verified by further experimental studies.

6194-Experimental and Simulation Research on Flow Noise of Underwater High Speed Vehicles

Youzhi Wang, Lianhui Jia, Xinyu Guo
Science and Technology on Underwater Test and Control Laboratory

Abstract—In this paper, the mechanism and characteristics of underwater high-speed vehicle flow noise are studied by experimental and simulation methods. The experiment was carried out in a gravity-type low-noise water tunnel of Harbin Engineering University. The radiation noise of the model under multiple incoming flow velocities was measured. At the same time, combined with the PIV particle tracing technology, the sound position and mechanism of underwater targets were further explored. Then establish the same model through CATIA and use ANSYS software to establish the flow field and sound field calculation models respectively, and simulate the flow noise of the model at different flow speeds. Finally, the experimental data and the simulation data are compared and analyzed. The results show the flow noise of the target increases with the increase of the flow velocity, and the turbulent velocity and pulsating pressure at the head of the model are higher, followed by the tail, and the convective noise in the middle section contributes less.

5007-Acoustic Signature Analysis and Numerical Simulation on Radiated Noise of Underwater Contra-rotating Propellers

fuqiang Ma, yansen Liu, lixun Xie, wenshuai Hu
Science and Technology on Underwater Test and Control Laboratory Dalian

The noise of contra-rotating propellers contributes a major part to the underwater vehicle. The special noise properties often become an important basis for detecting and identifying targets. This paper establishes the numerical simulation and calculation approach on the radiated noise properties of contra-rotating propellers, which was set up based on the theory of acoustic analogy and the large eddy simulation approach, and then the numerical simulation results are verified. Taking the DTMB contra-rotating propellers which consists of DTMB3689 and DTMB3849 as an example, the numerical calculation of the hydrodynamic performance of the contra-rotating propellers is carried out based on the solving method of Reynolds stress turbulence model and the results agree well with the experimental results. The disk velocity distribution, blade pressure distribution and hydrodynamic wake distribution of the contra-rotating propellers are analyzed. Analyzing the acoustic signature of contra-rotating propellers shows that the low frequency line spectrum not only reflects the multiplicative frequency feature, but also the additive frequency feature, and the relationship between the radiated noise of the contra-rotating propellers and its inherent structure and its motion state is correlated.

6291-The study on noise characteristics of underwater electric propulsion

Yingbo XU, Wenfeng ZHAO
China Ship Scientific Research Center

Abstract—In order to study the noise characteristics of underwater electric propulsion, the vibration and noise of the electric propulsion were measured in a cavitation tunnel. The performance of the noise is studied and the relationship between vibration and noise was analyzed. The results show that there are significant peaks in the noise spectrum whose frequency is consistent with the switching frequency and its multiplication of motor controller, and the peaks have a great contribution to the overall sound pressure level(OASPL). The noise level and narrow-band peak width of electric propulsion increase with the rotate speed increasing. Only part of the peaks in the vibration acceleration spectrum of electric thruster can radiate noise.

6260-Research on Engineering Estimation Method of Mechanical Noise for SWATH

Shuai Wu, Guang Li, Zhe Liu, Wenwei Wu
China Ship Scientific Research Center

Abstract—The engineering estimation method of mechanical noise for SWATH is studied in this paper. Based on the analysis of the vibration transmission path and the common engineering estimation methods of underwater acoustic radiation for conventional surface ship machinery, the vibration transmission path for SWATH's machinery is studied, and the common method's adaptability for predicting this ship's mechanical noise is explored. The research shows that the vibration transmission path for SWATH is more complicated. Compared with the characterization method of the contribution radiation characteristic of the single rib plate, the length of the hull joint frame can better predict the underwater acoustic radiation of SWATH. The error is less than 5 dB, and this method is of great significance for the vibration and noise control of SWATH.

6254-Simulation and Analysis of External Radiated Sound Field of Underwater Structure

Zhe Liu, Shuai Wu, Guang Li, Weibo Wang
China Ship Scientific Research Center

Abstract—The simulation of external sound field is one of the key problems in the radiated noise calculation of underwater structure. The influence of external acoustic environmental factors, such as limited water depth and free surface, is also lack of enough research at present. Firstly, the calculation method of underwater radiated noise is verified by a stiffened cylindrical shell, and then the area size, shape and element size of the external sound field is discussed. Finally, the effect of finite water depth and free surface on the radiated sound field is analyzed. The results can provide a reference for the calculation of radiated noise of underwater structure.

6250-Water Hammer Control of Ship's Trim Balance System

Lingbo ZHOU, Zhikuan HU, Yudong SUN, Yong DUAN
China ship scientific research center

Abstract—In order to solve the transient noise and vibration problems caused by the water hammer when closing the valve in one ship's trim balance system, the way of developing the structure, operation method and closing strategy of the valve was studied. Then the new valve's control effect was verified on the full-scale trim balance system pipeline test bench. The test results showed that, the multi-channel method had a good effect both on the positive and negative pressure water hammer's control that realized up to 24.9dB of vibration reduction and 95.4% of pressure reduction. Further applying the two-stage control strategy on the basis of the multi-channel method showed better control effect, which raised the pressure and vibration control effect up to 64.3% and 7.3dB respectively.

6193-Acoustic Radiation from Fluid-loaded Stiffened Composite Laminated Plates according to Layerwise Plate Theories

Zhixiong Yang, Xuewen Yin
China Ship Scientific Research Center

Abstract—Acoustic radiation from a fluid-loaded laminated composite plate with two sets of periodic stiffeners is investigated, in which the expressions for the stress tensors due to the transverse shear deformation are included on the basis of Reddy's layerwise plate theories. By employing the Fourier transform method and the stationary phase approximation, far field pressure expressions are presented to address the acoustic characteristics of the stiffened laminated plate. Sound pressure obtained from the layerwise theory are compared with existing results from the classic thin plate theory, and increasingly remarkable differences among them are found from medium to high frequency range. Numerical calculations are subsequently carried out to explore the influences of the spacing of the stiffeners, the thickness of the plate, and the lamination schemes on the sound pressure. Practical concerns are addressed which would be beneficial to the optimization design of stiffened plates.

6137-Study on Vibro-acoustic Characteristics of Laminated Composite Cylindrical Shell

Jiang-hai WU, Xi-chen HOU, Hong-ci GUO, Yong DUAN, Hong-zhen ZHU
China Ship Scientific Research Center

Abstract—Composite cylindrical shells are widely used in various transportation vehicles. Its vibration and radiated sound characteristics have attracted the attention of many researchers. In this paper, the vibro-acoustic characteristics of laminated composite shell are investigated using wave approach method. The dynamic response of composite shell is carried out based on the Love`s thin shell theory and compared with results solved by FEM under unit driving force. It is found that the two results are in good agreement on isotropic steel and composite shell, respectively. Additional, the vibro-acoustics characteristic of composite shell are discussed when they are filled with water. When applied to the pipe system, the vibration acceleration level of composite cylindrical shell is the same level as isotopic steel pipe. This work could provide some guidance for the vibration control of composite cylindrical shell.

6120-Analysis of Vibration Noise and Transmission Characteristics of Flow-induced Rudder

Yunong Yang, Qing Wang
National Key Laboratory on Ship Vibration Noise, China Ship Development and Design Center

Abstract—In order to study the flow-induced vibration and transmission characters and the influence of rudder on the flow field, a small-scale Suboff model which consists of the rudder and the connected part of the hull is established in this paper. Based on the structural FEM, the vibration transfer function of the rudder-hull is analyzed. And the flow field is calculated by CFD method, which the one-way fluid-structure coupling calculation is carried out by STRACCM+ and ABAQUS, and the unsteady flow field part is solved by the DES turbulence model. The trace distribution of the fluid micro-clusters near the rudder and the hull is given by adding streamlines. The vibration transfer function results show that the vibration of the rudder blade has attenuated when it is transmitted to the rudder root and the hull structure. The fluid traces indicate the presence of eddy currents near the root and seam of the rudder. As speed changes, fluid elements are accompanied by bending and rotation, which causes interference. Therefore, when the rudder is not operating, the main factor that affects the concealment related to the rudder is the flow field and the structural characteristics of the rudder. Under the speed condition of 8kn, the simulation results also show that the structural sound radiation component of the rudder is mainly near the natural frequency of the rudder. This article does not consider the rudder working conditions and the vibration and noise of the rudder power unit, steering mechanism and other equipment.

6075-Three-Dimensional Numerical Simulation on Flow-Induced Vibration of Condenser Tube Bundles

Yuelin Li, Chao Sun, Yuechan Liu, Shiqin Ai
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Abstract—Taking the heat exchange tube in the condenser as the research object, the three-dimensional finite element model of the heat exchange tube and the Internal and external fluid of pipe is established, and the bidirectional fluid-solid coupling calculation of the heat exchange tube is carried out. The time-domain and frequency-domain curves of lift, drag and displacement of the heat exchange tube and the time-domain and frequency-domain curves of the pressure pulsation in the tube are obtained. At the same time, the acoustic simulation calculation is carried out for the vibration noise of the heat exchange tube. The time domain and frequency domain curves of sound pressure near the heat exchange tube are obtained. The simulation results show that the frequency of pressure pulsation corresponds to the frequency of lift and drag. The flow velocity in the tube studied in this paper will affect the amplitude and waveform of the pressure pulsation but will not affect its frequency. The sound pressure frequency of the upper and lower sides of the heat exchange tube only corresponds to the lift frequency, and the sound pressure frequency on the left and right side corresponds to the lift and drag frequencies.

6065-The Hydrodynamic Noise Suppression of a Scaled Submarine Model by Trailing-Edge Serrations

Yalin Li, Tao Zhang, Junxiang Ye, Juyi Wu, Zenghui Zhang, Yongwei Liu
Beijing Mechanical Electrical Engineering Overall Design Department

Abstract—Hydrodynamic noise seriously reduces the survival of underwater vehicles. The optimization of line type has been used to reduce hydrodynamic noise for a long history. However, the investigation on reducing hydrodynamic noise by flow control needs intensive study and further development. To reduce the hydrodynamic noise from the model of SUBOFF, the hush characteristic of owls feather was applied to design the trailing-edge serrations of the sail hull. Numerical simulation is performed to investigate the effects of different serrations amplitude and serrations wavelength on the hydrodynamic noise from the model of SUBOFF. The result shows that the hydrodynamic noise from the sail hull shell by the separation of the surface boundary layer and the vortices at the trailing edge is reduced. The trailing edge serrations with amplitudes of 0.1c and wavelengths of 0.1h can reduce hydrodynamic noise by more than 10dB in the frequency range of 10 to 2000Hz, where c is the chord length and h is the height of the sail hull. The research results provide a new method for reducing hydrodynamic noise in the flow control.

6028-A Hybrid Numerical Analytical Method for Calculating Hydrodynamic Self-Noise of Ribbed Acoustic Window

Jin Liu, Ying Zhou, Dongsen Hu, Qi Shen, Mengsa Yu
China Ship Scientific Research Center

Abstract—For the acoustic optimization design of the sonar acoustic window which is the ribbed shell structure, the sonar part is simplified into a regular model composed of an elastic rectangular plate and a rectangular cavity. The structural modal vibration is solved by finite element numerical method, Rayleigh integral equation of external infinite sound field is solved by approximate structural modal functions, and internal finite sound field is solved by theoretical analytic method. Establishing an equation of vibro-acoustic and considering the character of temporal-spatial random surface excitation, a fast calculation method for the hydrodynamic self-noise of the sonar part is formed based on the hybrid numerical analytical method. Taking an elastic plate as an example, the hydrodynamic self-noise of the sonar part is calculated and the result is compared with that calculated by the theoretical analysis method and numerical transfer function method, verifying the accuracy and computational efficiency of the hybrid method.

5955-A Denoising Method for Ship Radiated Noise Based on Adaptive Neuro-Fuzzy Interference System

Xin Yue, YaoHui Lv, Hengping Yan, WeiQi Liu
Ocean University of China

Abstract—Ship radiated noise denoising is an important step before underwater target detection. To obtain better denoising effect, adaptive fuzzy inference system (ANFIS) is used to denoise ship radiated noise. Experimental results show that there is a nonlinear component in ship radiated noise signal, and ANFIS can deal with this nonlinear relationship. Firstly, the received signal is composed of the random noise with a certain signal to noise ratio (SNR) and the expected signal with a certain SNR, and then the random noise with a certain SNR is added to the mechanical noise to form the reference noise. Finally, the received signal and reference noise are used as the input of ANFIS to get the denoised signal. The experiment is carried out by Monte Carlo method, and the results are evaluated by SNR. The results show that the method has good denoising effect on ship radiated noise.

5903-A novel design of rotated piezoelectric actuators based on impact driving principle

Jianhui ZHANG, Sucheng GAO
Guangzhou University

Abstract—The design of rotating piezoelectric actuators is mainly based on the guide shaft structure, it requires a high accuracy of the output shaft and shaft hole. The working performance and application range of the rotating inertial piezoelectric motor are limited, thus a rotating inertial piezoelectric motor without a guide shaft structure was designed. The actuator can achieve unidirectional rotation movement by the whirling of the inertial mass to produce asymmetrical inertial impact force when the piezoelectric bimorph pasted on the substrate was applied to the asymmetric electrical signal. The dynamic model of the rotated actuator is constructed, the working principle of the newly designed rotating inertial piezoelectric motor is analyzed and verified by simulation. A piezoelectric experimental system was conducted and frequency characteristic, step length characteristic was tested. The results show that the step size resolution of the rotating inertial piezoelectric motor is 0.64μrad at 100V and 250Hz.

5789-Research on Characteristics of Shallow Ocean Ambient Noise Based on Mooring and Floating Platform

Yongjiao Wang, Zhigang Shang, Bo Zhang, DongHai Wang, Lipeng Chu, Yanyan An
China Academy of Electronics and Information Technology

Abstract—This paper is provided for study the characteristics of shallow ocean ambient noise in a certain area of the South China Sea. Firstly, collecting process of original data is described, which is based on ocean ambient noise monitoring system. Here, the system is a long-term and real-time system and works in a mooring platform. Moreover, to further analyze ambient noise characteristics, we introduce a new method. According to the noise level relationship between external noise, i.e. noise generated by monitoring system equipment and wind noise, etc., and ambient noise at shallow sea, we can find the correlation of them. In addition, we study noise level changes in shallow sea with time in the fixed depth, to obtain variation rule of noise level characteristic. The influence of external physical fields on the noise of the marine environment is shown in this paper. It provides data basis for the correct evaluation of the performance of underwater acoustic equipment in specific sea area, the detection interference reduction of background noise in underwater acoustic channel for underwater equipment, and the correct placement and use of underwater acoustic equipment. This paper provides theoretical support for mastering the spatial and temporal statistical characteristics of ocean ambient noise field.

6158-Low-frequency Vibration Energy Harvesting Using Magnetic Shape Memory Aolly

Haoyuan Du, Linxiang Wang
Zhejiang University

Abstract—In this paper, a low-frequency vibration energy harvester based on magnetic shape memory alloys (MSMAs) is proposed to harvest the vibration energy. The principle of energy harvesting using the magnetic shape memory alloy is clarified, and the related experimental schematic diagram is designed. When the harvester is vibrated, the cantilever beam will exert force on the sample, which will make the martensite reorientation causing the axial magnetic polarization to change and leads to the change of magnetic flux. Therefore, when a pick-up coil is surrounded by the specimen, voltage will be induced according to Faraday's law. The magnetic field generated by the NdFeB magnet in the experimental device is simulated and verified, and the modal analysis of the cantilever beam is implemented to ensure that it can meet the requirements. Then the energy harvesting experiment is carried out and the induced voltage generated at low frequency (no more than 50 Hz) is depicted. The RMS values of the induced voltage at different frequencies are calculated. At low frequencies, the experimental results show that the proposed energy harvester has advantages in generating voltage compared with other devices, which further demonstrates the effectiveness of using magnetic shape memory alloy to capture low-frequency vibration energy and can provide references for the acoustic energy harvesting to some extent.

6144-The Suppression Effect of the Hydrodynamic Noise from Airfoil Structure by Suction Technique

Liu Wenshuai, Liu Jianmei, Wang Tianxiao
Dalian Scientific Test and Control Technology Institute

Abstract—In this paper, we have proposed a new method to control the hydrodynamic noise from airfoil structure by the suction technique. A set of suction holes are placed on the front edge of the airfoil structure. Then, the fluid is transported into the tail or the transition zone because of the pressure difference. Flow field around the airfoil structure has been controlled, thereby the hydrodynamic noise has been attenuated. We have used the large eddy simulation to calculate the flow field. The hydrodynamic noise has been calculated by the Lighthill's acoustic analogy and the combination of the finite element and infinite element method. We have investigated the noise reduction effect of the position, diameter and period with the hole. The results indicate that the suction hole can reduce the turbulent fluctuation pressure which is the main source of the hydrodynamic noise. The noise reduction effect can reach more than 6dB in the frequency range from 10Hz to 1500Hz. The suction technique in our work can provide a new idea for the hydrodynamic noise control of underwater vehicles.

6143-The Hydrodynamic Noise Reduction Effect of the Dimples on Airfoil Structure

Liu Jianmei, Wang Tianxiao
Dalian Scientific Test and Control Technology Institute

Abstract—The hydrodynamic noise is the main noise source of underwater vehicles at high velocity. In this paper, we have studied the noise reduction effect of dimples. The dimples are placed on the transition area of airfoil structure and the turbulent flow can be changed. The flow field has been calculated by the large eddy simulation. Then, the turbulent fluctuation pressure has been extracted for the sound field calculation as the source. The hydrodynamic noise has been calculated by the Lighthill's acoustic analogy and the combination of finite element and infinite element method. We have investigated the noise reduction effect of different aspect-ratio and diameter of the dimple. The results show that the dimples can prevent the boundary layer separation and control the hydrodynamic noise of airfoil structure. The reduction effect of hydrodynamic noise can reach 7dB under the optimized parameter. The study in this paper can help broaden the visual for the control of the hydrodynamic noise for underwater vehicles.

6205-Feature Vector Generation of Underwater Acoustic Signal based on Multi-Domain Feature Extraction

Haiquan Shi, Jinghe Chen, Litao Yang
Kunming Shipborne Equipment Research and Test Center

Abstract—Based on time domain, frequency-domain and time-frequency domain feature extraction algorithm proposes a composite feature vector generation method, combined with support vector machine (SVM) to classify three kinds of typical underwater target radiated noise identification, the results show that, based on the characteristics of composite target recognition probability is 94.29%, were higher than the recognition probability of independent features, to verify the effectiveness of this method in classification of underwater acoustic target recognition.

6180-Experimental Analysis of Statistical Property of Low Frequency Reverberation Envelope in Shallow Water

Feng Cao, Xue Gang Zhang, Jing Han, Shuai Lv
Science and Technology on Underwater Test and Control Laboratory

Abstract—Reverberation is the main background interference of active detection and identification, which is produced with active signal emission. It is traditionally assumed as a combination signal of a large amount of random scatters at the receiving hydrophone which leads to a Gaussian-distributed time-domain signal and a Rayleigh-distributed envelope following the central limit theorem. However, with the advent of high-resolution active sonar systems, the target-like scatter signals namely clutter arising from fluctuation or variety in seafloor or hydrographic would produce the non-Rayleigh reverberation with longer tail and it is a main factor restricting the active sonar long-range detection. Aiming at this phenomenon, the Rayleigh distribution model and two typical non-Rayleigh statistical models-the Weibull distribution and the K distribution model are studied using the low-frequency reverberation test data (signal center frequency at 420Hz) obtained from a typical shallow-water environment in the northern South China Sea. Based on the measured multi-sample reverberation data, the probability density distributions of different signal forms reverberation are calculated respectively. The parameters of different models are estimated by the method of moments (MOM) to perform the theory simulation and curve fitting, and then the correlation between data processing and model simulation results are calculated. Comparative analysis based on the experiments shows that the pulse length of transmitting signal has an important effect on the statistical characteristics of the reverberation in shallow water, which is reflected in the fact that the envelope distribution of short pulse-width reverberation presents stronger non-Rayleigh properties compared with long pulse-width reverberation. In addition, the long-range reverberation present stronger non-Rayleigh properties fitting with the non-Rayleigh models well relative to the short-range reverberation. The effect of frequency form on the reverberation envelope statistical characteristic is relatively insignificant.

5802-A Coupled Mode Reverberation Theory for Clutter Induced by Inhomogeneous Water Columns in Shallow Sea

Jie Pang, Bo Gao, Wenhua Song, Yiru Zuo, Dongpeng Mo
Ocean University of China.

Abstract—The detecting performance of active sonar in shallow sea is restricted by seabed reverberation and clutter. In this paper, the seabed reverberation and target-like clutter caused by inhomogeneous water columns are modelled by coupled mode reverberation theory. Taking nonlinear internal waves (NIWs) as examples of the common inhomogeneous water columns, mode coupling matrices are derived by coupled mode to describe the process of energy exchange and mechanism of reverberation clutter. It is found that the oscillation phenomena of the reverberation intensity which is after the clutter arrival are well explained by the coupled mode theory and the oscillation periods are connected with the speeds of nonlinear internal waves. A theoretical basis is proposed in this research for identifying strong interferences of clutter caused by NIWs. Meanwhile, the oscillation mechanism is expected to realize the monitoring of internal waves.

6355-A deafness free MAC protocol for underwater acoustic communication networks with Directional Antennas

Yang Jianmin, Hu Qing, Xu Lingji, Xiao Peng, Gao Jingjie, Jiarong Zhang
Sun Yat-sen University

Abstract—Most of the existing underwater acoustic communication network use omni-directional transmission technology, which has problems such as poor communication concealment and low throughput, which severely limits network performance. The application of directional transmission technology to the underwater acoustic communication network can effectively solve the various problems existing in the omnidirectional underwater acoustic communication network, but there will also be new problems, such as the deafness problem. Aiming at the problems of low throughput, poor communication concealment and deafness, this paper proposes a deafness free medium access control (DF-MAC) protocol for underwater acoustic communication network with directional antennas. In the protocol, each node uses directional and omnidirectional modes to transmit data, and divides the underwater acoustic channel into two sub-channels. By sending a busy tone signal on one of the sub-channels, the neighboring node can distinguish whether the collision encountered is a normal data packet collision or a neighboring node collision, and then take different measures. This protocol can effectively solve the problem of deafness in the underwater acoustic communication network, increase network coverage, and improve communication concealment. The simulation results show that the proposed MAC protocol can significantly improve the throughput performance of the underwater acoustic communication network.

6153-Research on Multi-Base Sonar Localization Based on Improved TLS Algorithm

Xuanzi Yin, Erzheng Fang, Ziling Zhou, Chenyang Gui
Harbin Engineering University

Abstract—This paper proposes an improved multi-base sonar positioning algorithm with Constrained Total Least Squares (CTLS) method, based on the Total Least Squares (TLS) algorithm applying to multi-base sonar system location, which aims to solve the problem that the positioning accuracy is seriously affected by the measurement error. This method is achieved by adding constraints to the TLS. To ensure that the form of system matrix and data vector of the localization equation remain unchanged after the constraints are added, and the CTLS algorithm is implemented by the method of continuous projection. The simulation results show that, based on the working mode of multi-base sonar with one transmitter and multiple receivers, compared with the TLS algorithm, the CTLS algorithm used in this paper can reduce the localization variance by about 12% in the case of errors in both the base station location and the measured values. The CTLS estimation method has superior estimation performance and robustness, and it has important application value for the efficiency and accuracy of target localization.

6126-Detection Performance Analysis of Multistatic Sonar System Based on Cumulative Detection

Ziling Zhou, Erzheng Fang, Xuanzi Yin, Chenyang Gui
Harbin Engineering University

Abstract — With the development of acoustic stealth technology and underwater acoustic countermeasure technology, the detection performance of monostatic sonar system for low-noise targets is difficult to meet the operational requirements, while the comprehensive detection of multistatic system may greatly improve the detection performance, which provides a new way to solve the detection problem of a quiet target. Therefore, a fusion detection algorithm based on vector hydrophone for multistatic sonar system is proposed in this paper. The detection performance of four kinds of sonar systems is compared, which are monostatic distributed, monostatic centralized, multistatic distributed and multistatic centralized. Detection performance is quantitatively analyzed by the detection range of detection probability above the detection threshold. The research has a certain reference value for large-scale target detection.

6085-Research on Mobile Underwater Acoustic Spread Spectrum Communication Technology Based on Double-Differential Coded

Feng Zhou, Wenbo Zhang, Huiming Chen, Guang Yang
Harbin Engineering University

Abstract—In a digital communication system, if the channel has a random carrier frequency shift or two nodes that are in motion with each other, the communication channel must have a frequency shift. Therefore, the received signal can only be non-coherent demodulation at the receiver. Double-Differential coding is a commonly used non-coherent demodulation method. The unknown frequency and phase changes can be eliminated through three consecutive signal samples. Since the Double-Differential coding take advantage of three consecutive signal samples, it is only suitable for slow fading transmission channels. During the observation time of the three signal samples, the channel characteristics change slowly and linearly. The combination of the Double-Differential coding and the Direct Sequence Spread Spectrum technology can effectively improve the ability of the Direct Sequence Spread Spectrum to resist Doppler frequency offset. However, due to the limitation of the DSSS system, the ability of the Double-Differential coding to cancel the Doppler frequency offset in the DSSS system is limited. Its ability to resist Doppler is related to the duration of spread spectrum chips.

5926-Experimental Demonstration of Cyclic Shift Spread Spectrum Underwater Acoustic Communication

Pengyu Du, Chao Wang, zhe Xie
Hangzhou Applied Acoustic Research Institute

Abstract—Aiming at the cyclic shift spread spectrum (CSSS) underwater acoustic communication technology, this paper proposes a CSSS underwater acoustic communication technology based on dual-k coding. The reliability of the communication system can be significantly improved by taking the output of the cyclic shift energy detector at the receiver as soft information for symbol by symbol statistical inference decoding. The results of data simulation and deep-sea underwater acoustic communication experiment show that the decoding gain of CSSS underwater acoustic communication system based on dual-k code is about 3 ~ 4dB higher than that of traditional methods.

6113-Design of underwater acoustic passive location system for impact point at sea based on the Beidou difference and dual cross-array

Shizhe Wang, Zongji Li, Pingbo Wang, Yuchen Sun, Li Dong, Huadong Chen
Academy of Weapony Engineering Naval University of Engineering

Abstract—The research on the location of the impact point at sea is of great significance for improving the combat performance and designing the cannonball weapons system. It is not only the prerequisite and important step to evaluate shooting accuracy and density of cannonballs correctly, but also the beneficial information and necessary guarantees for the production and development of cannonball weapons.

Starting from the actual situation of the navy, this scheme chooses a relatively reliable and low-cost acoustic location method, and combines the carrier phase difference technology (RTK technology) which has higher accuracy in Beidou satellite navigation to improve the original three-sensor array location method. Based on this, an economic impact point location system at sea is designed, which combines Beidou differential location, direction finding and dual cross-array passive cross-location. Its main idea is to integrate the signals received by Beidou location module and dual cross-array in order to calculate the absolute spatial position of the impact point.

In this paper, the dual cross-array location principle is derived in detail, and the system location error is simulated and analyzed. The simulation results show that the location method is accurate and reliable. and the location principle is simple, efficient and convenient, which satisfies the needs of the nearshore shooting ranges at sea, it has certain application value and development prospects.

6084-A Hydroacoustic Positioning Method Based on Analysis of the Error Region of Three-circle Intersection

Pei Cui, Kaina Jiang, Junjun Lv, Zhe Zhao, Jin Yue, Dawen Jiao
Dalian institute of measurement and control technology

Abstract—A hydroacoustic positioning method based on three-circle intersection presented in this paper is used to locate the underwater measuring units equipped with sensors to measure magnetic and electric field. Due to the existence of controllable and non-controllable error sources such as measurement distance of underwater acoustic and entry depth of the surface positioning device in the positioning process, there is a triangle error area that makes the positioning results not satisfactory. In order to improve the positioning accuracy, the convergence and diffusion law of the triangle error area are studied with data analysis software by setting error ranges of the positioning circle radius and the step size in response to the measured results in sea test. The analysis results show that the optimized positioning method based on the three-circle intersection can well reduce the size of the triangle error area and effectively improve the positioning accuracy.

6047-Modeling and Estimation of the Space-time Varying Channels

Yijia Zhu, Lanyue Zhang, Jiaxin Ma
Harbin Engineering University

Abstract—On the basis of BELLHOP model, the influence of transmitter's active travel on underwater acoustic channel is emphasized, and a BELLHOP-based space-time channel model is established. According to the characteristics of CW pulse signal, LFM pulse signal and HFM pulse signal, and inspired by the conventional Doppler estimation method in communication, this paper improves them and estimates the Doppler factor in combination with the established model. Simulation results show that the performance of Doppler factor estimation of HFM signal is better. For the estimation of delay and attenuation coefficient, LFM signal has the best energy aggregation characteristic in fractional domain, and the position and amplitude of correlation peak are obtained to estimate the delay and attenuation factor.

6045-Automatic Detection Method of Underwater Acoustic Pulse Signal Based on Power Spectrum Entropy

Xiao NIU, ZhiXiang YAO
College of Electronic Engineering Naval University of Engineering

Abstract—In the actual work of reconnaissance sonar, without any prior information, an adaptive threshold selection method based on power spectrum entropy is proposed in this paper in order to solve this problem that is poor adaptability of pulse signal detection method. By using the difference between the power spectrum entropy of pulse signal and background noise, the background noise change is to find out. And the detection threshold value is dynamically adjusted, so as to realize that the detection threshold automatically changes with the background change. In this paper, the detection threshold, detection probability and false alarm probability of this method are deduced theoretically under the background of Gaussian white noise. The steps of automatic threshold selection under non-Gaussian background are presented. Through simulation analysis and sea trial data verification, the adaptability and practicability of this method are proved.

6037-Research on Frequency-domain Adaptive Line Enhancement Based on Pre-whitening Matched Filter

Xi-hai JIANG, Xiao-lin WANG, Qi YAN, Tao WEI
Hangzhou Applied Acoustics Research Institute

Abstract—A frequency-domain adaptive line enhancement based on matched filter (FDAMF) is a nonlinear filtering algorithm, which greatly improves the detection performance of matched filter in an additive white Gaussian noise. Due to strong reverberation interference, the detection performance of FDAMF drops sharply in the complex and variable ocean environment, so it is difficult to detect long-range target. In order to improve the detection performance in the complex marine environment, a frequency-domain adaptive line enhancement based on pre-whitening matched filter is proposed to whiten the colored reverberation. By theoretical and simulation analysis, it can obtain better detection probability under lower input signal to noise ratio. Testing sea trials show that the processing gain of this method is about higher than 6.4dB that of the conventional method, thus an adaptive pre-whitener based on autoregressive model used in FDAMF can suppress the reverberation effectively.

6026-A Method of Extracting Underwater Acoustic Beaconing Signal

Leilei Deng, Xie Zhao, Bingjie Yin
Kunming Shipborne Equipment Research and Test Center

Abstract—Most of the methods for extracting underwater acoustic beaconing signal are currently suitable for a good hydrological environment. Aiming at the problem of long-range detection of acoustic beaconing signal in harsh environments such as platform movement and serious transient noise interference, a method combined "matched filtering with Doppler filter bank, adaptive line enhancement based on variable step frequency-domain least mean square (LMS) algorithm and Zoom-FFT" is proposed. Verification test of the proposed method is carried out on the lake. The results of data processing show that this method could reduce the Doppler sensitivity and suppress the transient interference. Meanwhile, the output signal-to-noise ratio (SNR) and frequency resolution are improved, which provides an excellent signal environment for the back-end acoustic beacon positioning.

5942-Research of modified hyper-beam performance based on passive sonar

Huaibin Yan, Xiefan Pan, An Fu
Shanghai Marine Electronic Equipment Research Institute

Abstract—The key to array signal processing is to enhance the processing gain in the background of strong reverberation and high noise while the processing gain plays an important role in improving system detection performance and reducing target detection false alarms. Traditional weighted processing method mainly reduces the side lobe and sharp the beam-width, however, it is difficult to reconcile the two aspects. The output of the hyper-beam loses phase information, and thus post-processing such as spectrum analysis cannot be performed. This paper introduces an idea of modified hyper beam, and then apply it to space-time processing of passive signals. The modified hyper- beam technique uses the output of hyper-beam as weight coefficient to the conventional beam output, which can retain the beam output phase information while reducing the main lobe width and side lobes. The experiment data analysis based on passive sonar verify that the processing gain brought by the method in this paper can further improve the detection performance and improve the tracking effect.

5927-Line spectrum detection for sonar based on time reversal convolution and interference suppression

Xiangling Meng, Zhishan Zhao, Xiaoyong Jiang
Shanghai Marine Electronic Equipment Research Institute

Abstract—This paper proposes a time reversal convolution and interference suppression (TRCIS) method, and deduce the principle of TRCIS for detecting CW signal in broadband noise. From the simulation and experiments, conclusions can be drawn such as the signal-to-noise ratio (SNR) gain of TRCIS increases linearly with the input SNR; the detection threshold is about 2 dB lower than that of the conventional line detection methods. Then, by using TRCIS as a preprocessing technique of adaptive line enhancer (ALE), the time reversal convolution and interference suppression based adaptive line enhancer (TRCIS-ALE) is proposed. Through the simulation comparison with conventional line detector, ALE and coherent accumulation based on adaptive line enhancer, the conclusion can be obtained that the SNR gain, detection threshold and ROC curve of TRCIS-ALE are all significantly better than the other three methods.

5919-Design of Multi-Channel Signal Acquisition and Transmission Unit Based on Multi-core DSP

Xin Liu, Jinyang Wang
Harbin Engineering University

Abstract—Based on the increasing requirements for the number of hydrophone channels, sampling rate and real-time data processing in underwater acoustic signal processing, a multi-channel signal acquisition platform is designed and implemented in this paper. As an important part of the underwater positioning and navigation system, the multi-channel signal acquisition platform is responsible for implementing the control of the entire system. The platform aims to realize the collection and transmission of high-speed real-time multi-channel hydrophone signals and various external serial port signals. According to the system design requirements, this paper selects the quad-core DSP TMS320C6674 and Cyclone IV GX series FPGA as the core processing device of the platform, can realize the real-time sampling of 32-channel 200kHz sampling rate and the reception of 4 channels of serial information. It uses PCIE and Gigabit Ethernet interfaces as data transmission interfaces, and the system has a high transmission rate. After the system joint tuning, the correctness of the design of each module was tested, and the transmission rate and packet loss rate of the system were tested through a long-term copy machine to prove that the system can work stably for a long time and meet the system design expectations.

5918-Design and Implementation of Preprocessing Unit of FPGA-based Ultra-short Baseline Positioning System

Xin Liu, Hao Zhang
Harbin Engineering University

Abstract—The underwater acoustic positioning system is the mainstream of current underwater navigation positioning. Ultra-short baseline underwater acoustic positioning is one of its main methods. It has the characteristics of high accuracy, small baseline size, and convenient use. This paper designs a preprocessing system for ultra-short baseline positioning, which realizes the acquisition and A/D conversion of real-time analog signals, and performs digital filtering and sliding related processing on the FPGA platform. This article takes the SOPC system as the core, buffers the real-time signals of multiple channels, and uses the overlap preservation method to perform sliding-related segmentation processing on the buffered signals, including FFT transform, signal mixing, and IFFT transform. The results are proofread and sent into the DSP. This system implements the algorithm part through FPGA, which greatly reduces the burden on the DSP and allows the DSP more time to process other parts.

4890-An Adaptive Compact Kernel TFD Analysis Based on Parameters Pre-estimation for the Multi-component Non-stationary LFM Signals

Yuhan Liu, Shuai Yao, Yuxuan Jiang
Key Laboratory of Underwater Acoustic Signal Processing of Ministry of Education Southeast University

Abstract—To design a high-resolution time-frequency distribution (TFD) for the analysis of non-stationary multi-component linear frequency modulation (LFM) signals, a novel signal-dependent adaptive compact kernel-based TFD (ACKD) is presented in this paper. The proposed ACKD firstly represents the signal in the ambiguity domain and then applies an optimal signal-dependent adaptive compact kernel. The signal-dependent adaptive compact kernel is designed based on parameters pre-estimation that accounts for the directions and lengths of the auto-terms energy, which represents the signals in the ambiguity domain. Instead of depending exclusively on visual inspection of TFD figures in the time-frequency domain, comparisons are made using the Boashash-Sucic normalized instantaneous resolution performance measure. Simulations are presented to justify the feasibility and validity of the proposed method. In all presented cases, compared with the Wigner-Ville distribution (WVD) and the classical CKD, the proposed ACKD shows a more stable and excellent performance in the ability of cross-interferences rejection and component energy of signals concentration around their respective instantaneous frequency.

4862-Detection of Underwater Moving Target in Low Signal-To-Noise Ratio Conditions UsingSpectrogram Analysis

Xu Yanfeng, Pan Xiefan
Shanghai Marine Electronic Equipment Research Institute

Abstract—For underwater port security, the echo signals of underwater low-speed moving targets usually suffer from the low signal-to-noise ratio (SNR) which are induced by random noise or reverberation. Beamforming is conventional and very effective method to improve the SNR, but time-consuming and high computational cost with the number of receiving elements increasing. This paper presents a signal processing method based on frequency-wavenumber (or called FK) spectrogram analysis to improve the detection ability in low SNR environment. The method can simultaneously evaluate the velocity of moving targets, which is very useful when the doppler frequency is difficult to be measured because of slow moving speed of target or using such a doppler insensitive signal as source signal (e.g., linear frequency modulation signal). The spatial and temporal data are transformed into frequency and wavenumber domain through two-dimensional Fourier transform. The energy of moving targets in signals will concentrate on an inclined line distributed in the FK spectrum. The slope of the line represents the velocity of moving target. The procedure of beamforming is not necessary for the method, because the target signals can be easily separated from the echo signals by the FK spectrogram. The inclined line representing targets in the spectrogram is further extracted by Radon transform. Then the relationship between velocity and slope of the inclined line is built. We also give proof that the velocity calculated by the method actually is radial velocity of moving target through the first-order Taylor expansion. Furthermore, after the slope of line of moving target is calculated, a filtering operation is designed to separate the signals of target from the original and overlapped signals. Echo signals from the diver recorded in the environment of shallow sea are used to verify the method. The results show that the method can obtain an accurate estimation of velocity. The error of velocity is about 0.14%, compared with the velocity directly reading from the signals after beamforming.

Additionally, strong noise is successfully suppressed after filtering. It is found that about 3dB gain is obtained after filtering.

6368-Direct Wave Interference Suppression Method with Sparse-Sidelobe Constraint in Bistatic Sonar

Donghu Nie, Xin Su, Dongqi Li, Yongce Wang, Jia Liang
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Abstract—In order to suppress the strong direct wave interference in the bistatic sonar system, this paper proposes a method that combines the weighted sparsity-constrained capon beamformer with the zero constraint. The algorithm uses the sparse distribution of beam response and adds sparse constraints (l1-norm constraints) in the side lobe. By using the orthogonal characteristics of the signal subspace and the noise subspace, a weighted matrix is constructed to weight the sparsity constraint. Subsequently, the optimal weight can be derived by minimizing the output power. In the bistatic sonar system, according to the prior knowledge of the system configuration, the direction of direct wave is often known. Based on the fact, the zero constraint is used to set the beam output response of the array This work was supported by: the National Natural Science Foundation of China(11974090, 11774074, 61771152), National Key Research and Development Program of China under Grant No. 2017YFC0305702, 2018YFC0308500 form to be a null in a fixed direction. Under the constraint of null, a least-square method is exploited to approximate a constraint pattern to an ideal pattern in order to solve the optimal weight. Consequently, a deeper and wider null is generated, which improves the anti-steering vector angle mismatch of the array ability. In the case of small deviations in the direction of the interference wave, the receiver can also effectively suppress the interference.

6235-Passive Broadband Acoustic Source Localization Based on Orthogonal Propagator Method

Tao Wang, Dexin Zhao, Luwen Meng, Feng Liu, Liang Chen
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Abstract—In the field of underwater acoustic signal processing, broadband array signal processing is an important research issue, which is more complex than that of narrowband. Broadband passive localization of underwater acoustic sources is investigated in this study. In order to improve the ability to locate multiple radiation sources which are emitted from ships, the orthogonal propagator method (OPM) is proposed to estimate direction of arrival (DOA) for the target. Based on the theory of spatial spectrum estimation, the linear decomposition of the covariance matrix is adopted to form the orthogonal propagator, and the spatial spectrum is constructed according to orthogonality of subspaces. Then, the directions of ship radiation noises are determined by searching the extreme points of the spatial spectrum. For broadband underwater acoustic signals, the non-coherent subspace method is used to average the effective frequency points in bandwidth to reduce noise interference, and OPM algorithm operating in broadband underwater acoustic signal, on arbitrary sonar array, is derived. In order to verify this method, numerical simulations are conducted to test its performance in localization accuracy, beam width and spatial resolution. During the simulations, a uniform linear array consisting

of 96 elements is designed. Additionally, comparisons between the proposed method and conventional beamforming technique are conducted. Comparison results show that the OPM method performs better in spatial directivity and spatial resolution.

6233-Application of time domain broadband spatial matrix filter in ship noises separating area

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Abstract—In order to solve warship noises separation problem. Separation technique for ship noises by designing of time domain broadband spatial matrix filter （TDBSF） is provided. Main technical points of the technique include supposing ship as several point noise sources, using space filtering function of sonar array design broadband frequency hydrophone array, designing time domain broadband spatial matrix filter according to ship noises testing requirement. On the basis of the necessaries separating the noise source is living the matrix wave filter passband room when staying length , shall fathom to such an extent that ship noise data time share passages is handled , and achieves separating to the main noise source data of ship . Simulation results show that the proposed separate technique can get out different noise signals in a condition of SNR ⩾ -6dB& SNR ⩾ -6. Totalized error of noise signal separated by this method is no more than 2dB.

6176-A Method to Improve Cross-azimuth Detection of Weak Targets under Strong Interference

Kaiyue Zhang, Wei Wang, Xiaolin Wang
Hangzhou Institute of Applied Acoustics

Abstract—Sub-band Peak Energy Detection (SPED) is a passive sonar detection method that can effectively distinguish two azimuths when the targets' bearings are close. It can improve the bearing resolution of the bearing time recorder (BTR). However, its performance is affected by the beam width and side lobe level of beams. The performance of SPED will be greatly decreased so that it is difficult to detect weak target, especially when the energy of two targets is obvious. In order to solve the problem of detection and estimation of weak targets under the strong interference, an extended band with sub-band peak accumulate detection (E-SPAD) method is proposed based on SPED. Through signal processing of acoustic data from real lake trial, verified that the method can improve the detection ability and the accuracy of the azimuth estimation of weak targets, and further improve the display effect of BTR.

6141-Influences and Modification of Random Errors in Amplitude and Phase on The Fidelity of Vessel Radiated Noise Power Spectrum with Array

Yang Wang, Yan-sen Liu, Gui-juan Li
Science and Technology on Underwater Test and Control Laboratory

Abstract—In the acquisition of vessel radiated noise characteristics based on acoustic array, element failure or acoustic propagation or other reasons will cause the random errors in amplitude and phase of each channel signal, and lead to vessel radiated noise power spectrum acquired by beam-forming. In order to modify this error, based on mathematical model, the difference between mean power spectrum of all channel signals and power spectrum of beam-forming with random errors in amplitude and phase was analyzed, and a correction method for power spectrum amplitude was established. The simulation results show that the effect of errors in phase is much greater than the errors in amplitude, and the correction method in this paper can effectively reduce the beamforming power spectrum amplitude error. And the analysis results of measured data show that, taking the mean power spectrum of all channel signals as the reference, the error before correction was 3dB~5dB, and the corrected error was 1dB~3dB, meeting the error range requirements.

6118-Directional-of-Arrival Estimation for A Novel Non-uniform Linear Array

Wei Qiu, Shuqing Ma, Bing Yan, Le Li, Changchun Bao, Lilun Zhang
College of Meteorology and Oceanology, National University of Defense Technology

Abstract— Non-uniform linear arrays (NLAs) usually have the ability to form a larger array aperture than conventional uniform linear arrays (ULAs) with the same number of sensors. In this paper, we proposed a directional-of-arrival (DOA) estimation scheme for a novel kind of NLA, in which sensors are placed in a quadratic rule instead of the equal interval in ULAs. In this way, the received signal of the NLA of a single snapshot can be viewed as an LFM signal, and consequently the DOA estimation problem can be cast as the LFM parameters estimation problem. Next, the fractional Fourier transform (FrFT) is employed and together with the CLEAN technique to estimate the DOAs of the sources. Finally, various simulations are carried out and results are shown to verify the performance of the proposed DOA estimation method for this novel NLAs.

6098-Application of Frequency-Wavenumber Filtering Method in Underwater Multi-Target Signal Separation

Dexin Zhao, Luwen Meng, Guangming Li, Tao Wang
Academy of Military Sciences

Abstract—In order to effectively separate multiple target signals and reduce noise interference to underwater target signals, the frequency-wavenumber(f-k) filtering method commonly used in the seismic data processing was applied to the separation of underwater multi-target signals and the denoising processing of underwater acoustic data. By analyzing the f-k spectrum of multi-target underwater acoustic data, the parameters of the sector-filter were designed, then f-k filtering of multi-target underwater acoustic data were carried out. The filtering processing results show that the f-k filtering method can separate the multi-target signals that are aliased in the time domain and the frequency domain. And the f-k filtering method also has a certain inhibitory effect on noise, which can effectively improve the signal-to-noise ratio.

6083-A Novel Reverberation Mitigation Method Based On MIMO Sonar Space-Time Adaptive Processing

Shijin Chen, Yuxuan Zhang, Sheng Yan, Chengpeng Hao
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Abstract—Multiple-input multiple-output (MIMO) sonar can provide higher spatial resolution, better reverberation mitigation ability, improved processing gain compared to phased-array sonar by waveform diversity. High degree of freedom makes fully space-time adaptive processing impractical in MIMO sonar for reasons of the high demand of secondary data for filter designing. To overcome the problem, a novel space-time adaptive processing method via iterative generalized sidelobe canceller (IGSC) is proposed. IGSC can achieve a fast and accurate estimation of space-time covariance matrix (STCM) using a few snapshots and realize near-optimal reverberation mitigation performance. Numerical experiments validate the effectiveness of IGSC.

6073-A Novel Adaptive Reverberation Suppression Methods for Moving Active Sonar

Yuxuan Zhang, Shijin Chen, Chengpeng Hao
Institute of Acoustics, Chinese Academy of Sciences

Abstract—Reverberation is one of the main interferences for the active sonar in a shallow sea and seriously affects the detection performance. For the moving sonar system, the motion of the active sonar platform will cause the reverberation in different azimuths to have different Doppler shifts. Space-time adaptive processing (STAP) can utilize this feature to improve the performance of reverberation suppression. However, the limitation of insufficient secondary data leads to the degradation of STAP performance in practical applications. To overcome this problem, we propose a novel STAP scheme to suppress the reverberation adaptively in this paper. This approach exploits the sparsity of reverberation space-time spectrum to reduce the requirement of secondary data and improve the estimation accuracy of reverberation covariance. Simulation results show that, compared with the conventional STAP method, our proposed algorithms obtain a better reverberation suppression ability and detection performance.

6057-DOA Estimation of Wideband LFM Sources based on Narrowband Methods Integration Using Random Forest Regression

Wu Yun, Li Xiukun, Cao Zhimin
Harbin Engineering University

Abstract—For underwater target detection, DOA estimation of wideband LFM sources is one of the most important and challenging issues, which should be solved efficiently and reliably. However, in practice, especially under low Signal-to-Noise-Ratio (SNR) condition, DOA estimation performance of the mainstream methods, such as Incoherent Signal Subspace Method (ISSM), Coherent Signal Subspace Method (CSSM), and Fractional Fourier Transform (FrFT) based Method, is always unsatisfactory in both accuracy and false alarm rate. In this paper, at first, a group of spatial spectrums were obtained by employing several complementary narrowband DOA estimation methods like the one for each sub-band of frequency snapshots in the ISSM method respectively. And then, using random forest regression (RFR) technique, the obtained spatial spectrums were encoded to the expected one sequentially from lateral to longitudinal directions. Finally, DOA information can be determined using the obtained two-stage encoded spatial spectrum. Experimental results illustrated that there is indeed complementarity among the employed narrow-band DOA estimation methods, and this complementarity can be exploited to significantly improve the performance of the traditional ISSM method.

6052-Direction-of-Arrival Estimation Using Joint Sparse Reconstruction Based on Acoustic Vector Array

Bingjie Yin, Qu Liu
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Abstract— A novel method for underwater acoustic signal direction-of-arrival (DOA) estimation based on acoustic vector sensor array is herein proposed. By using the sparse representation and joint sparse reconstruction technologies, the proposed method could distinguish the adjacent signals and estimate the DOAs precisely. Comparing with other vector sparse reconstruction methods, the proposed method firstly constructed the sparse representation model in terms of the covariance matrix, which had sparse columns via vector orthogonal addition. And then due to the spatial sparse characteristic and the consistency of the signal, obtain the joint sparse vectors. At last, estimate DOAs by solving the norm minimization constraint problem. The proposed method needn't require any pre-processing or DOA pre-estimation. Simulation results show that the proposed method has high-resolution accuracy and good resolution ability.

5953-Array Gain of a Nested Array in Spatially Uncorrelated Noise

Ran Cao, Xuan Zhou, Jingwei Yin, Longxiang Guo
College of Underwater Acoustic Engineering in Harbin Engineering University

Abstract—Spatial resolution will be improved with the increment of the aperture in array signal processing. In order to obtain high resolution, a large number of sensors are needed for the uniform linear array (ULA), resulting in the high hardware cost and computational complexity. Therefore, using fewer sensors to achieve the same half-power beamwidth as ULA and to suppress grating lobes has an important application value in underwater acoustic engineering. In this paper, the nested arrays (NA) are introduced for achieving similar performance to the ULA with fewer sensors. A multiplicative beamforming method of the NA is proposed, and a coherent processing technique is presented for improving the array gain (AG). The performances are compared with the beam patterns of the ULA and NAs using conventional beamforming method and the proposed multiplicative beamforming method. Through the coherent product processor, the AG is improved by the coherent integration of signals and the incoherent suppression of noise. Through simulation results, it can be concluded that a small NA with P+Q-1 sensors can yield an AG as high as that of a large ULA of PQ elements.

4994-High Resolution Near-field Localization Method based on a Special Combination Linear Array

Yanyan AN, Zhigang SHANG, Fengmao YANG, Bo ZHANG, Yongjiao WANG
CETC Institute of Electronic Science

Abstract—In order to achieve the high-precision positioning of underwater target from the close range, in this paper, a special combination of the linear array, which is composed of multiple mutually perpendicular sub-arrays, is proposed to overcome the problem of port and starboard ambiguity of a single linear array. And based on this special combination, an optimized MVDR near-field high resolution positioning method is proposed. Based on the matrix decomposition principle of MUSIC method, the covariance matrix of data received by the array is decomposed to obtain the signal subspace corresponding to the signal component and the noise subspace orthogonal to the signal component. Using the orthogonality of the two subspaces, the covariance matrix of the array output is optimized, and the optimized covariance matrix is used for MVDR focused beamforming to further improve the focusing and positioning performance of MVDR. Theoretical analysis and simulation results show that the combination of the special linear array can effectively overcome the fuzzy problem of target location. The positioning performance of the MUSIC near-field positioning method is higher than that of MVDR focused beamforming positioning method. The further processing of the covariance matrix can improve the performance of MVDR focused positioning method. The sea test further proves the effectiveness of the method.

4883-Focused beamforming based on GPU

Yuan An, Yaohui Lyu, Ning Tang, Hengping Yan
Ocean University of China

Abstract—Noise and abnormal sound are common in daily life and industrial production, whose existence usually is accompanied by malfunction, so noise source localization has become a hot issue. Self-power spectrum removal focused beamforming is a beamforming sound source localization method based on microphone array. But its massive calculation restricts its application in practice. In order to solve this problem, this paper implements the focused self-power spectrum removal beamforming algorithm based on the Computing Unified Device Architecture (CUDA), and designs experiments to verify the accuracy and operating efficiency of the algorithm. By comparing the sound map generated by the CPU-Based algorithm and the algorithm implemented in this paper, the accuracy of our algorithm is verified. By comparing the processing time of focused beamforming with different signal samples and the scanning surface resolution, the results show that the computation time of our algorithm is 2 orders of magnitude lower than the CPU-based algorithm spent, and the average GPU/CPU acceleration ratio can reach more than 300.

5928-Mechanism and Suppression Technology of Mandrel Fiber Hydrophone Resonance Characteristics

Xin Tie, Kang Lou, Pan Xu, Zheng-Liang Hu, Yang Zhang
National University of Defense Technology

Abstract—The mandrel frame is the most commonly used sensitizing structure for scalar fiber hydrophones, and its material properties and structure directly affect hydrophone performance. The finite element simulation model of a hydrophone is established based on the principle of acoustic-structure interaction. Additionally, the influences of the material and structure on hydrophone sensitivity and the working bandwidth are analyzed in detail. The results show that the sensitivity and bandwidth of the hydrophone restrict each other, and the inner mandrel resonance exerts the main limitation on the bandwidth. Increasing the inner mandrel thickness and reducing the inner mandrel radius can widen the working bandwidth while maintaining sensitivity. The accuracy of the model is verified by via experiments in a lake.

6038-A Matched Beam Intensity Processing Method for Estimating Source Depth using Vertical Linear Array in Deep Water

Fangwei Zhu, Guangying Zheng, Fuchen Liu
Hangzhou applied acoustics research institute

Abstract—Since the bottom vertical short array deployed in the deep sea has the advantage of strong concealment, this paper proposes a matched beam intensity processing method adapted to the bottom vertical array for the estimation of the depth of the deep sea source, derives the relationship between vertical array beamforming and source range and depth based on the principle of Lloyd mirror interference, and reveals the tracking beam space fluctuation caused by source depth modulation, proposes a deep-sea source depth estimation method based on beam intensity matched. The source depth estimation are realized by matched tracking beam fluctuation of data and tracking beam fluctuation of copy field. Based on simulation data, the effectiveness of the method of using vertical array data to match beam intensity to estimate the source depth is verified, and the depth estimation algorithm is verified based on the sea trial data of a deep sea area.

6159-Research on the Array Gain of Vertical Array of Vector Hydrophone in Deep Sea

Yan Liang, Zhou Meng, Yu Chen, Yuyao Liu, Yichi Zhang, Hongxu Liu
National University of Defense Technology

Abstract — The vector hydrophone can simultaneously measure the sound pressure and particle vibration velocity in the sound field, and its dipole directivity can overcome the ambiguity of port and starboard. In the isotropic noise field, the vector hydrophone can obtain a combined gain of 3-4.8dB. In general, vector hydrophones are often applied in the form of an array, which is ideal deep-sea acoustic equipment. Array gain describes the improvement of output signal-to-noise ratio (SNR) of an array compared with the input SNR of a single element, which reflects the sonar target detection performance to some extent. In this paper, we make full use of the multi-channel output of the vector hydrophone vertical array (VHVA). Combined with the sound pressure-vibration velocity joint processing technology, we discuss the additional gain for different vector combinations. The trial results of a 16-element VHVA in the South China Sea validate that the array gain of VHVA can be significantly increased by 2-3dB compared with the traditional sound pressure hydrophone vertical array. The research results in this paper provide a new idea for improving the target detection performance for VHVA.

6155-Distance Estimation Error in a Bistatic Positioning System Using an Acoustic Vector Sensor

Lin MA, Biao WANG, Anbang ZHAO, Xuejie BI, Xiaoman LI
Jiangsu University of Science and Technology

Abstract—The acoustic vector sensors are small in size and light in weight. It is convenient to deploy in the engineering application of small underwater platforms and is suitable for dealing with the problem of target detection and positioning in underwater distributed detection systems. Based on the bistatic positioning system model using an acoustic vector sensor as the receiver, the target distance estimation error and its influence factors are analyzed in detail. The research results show that the main influence factors of the bistatic distance estimation using the acoustic vector sensor are the baseline measurement error, sound velocity fluctuation, azimuth estimation error and time delay estimation error. In the computer simulation, the different variation surfaces of distance estimation error under specific system parameter constraints are given in detail. The theoretical analysis results provide a theoretical basis for the practical engineering application of the bistatic positioning system with the acoustic vector sensor as the receiver, and have certain engineering application research value.

6106-A Novel Method for the DOA Estimation of Single Vector Hydrophone based on STMV

Shuzhen Yi, Xu Wu, Yuan Gao
Shanghai Marine Electronic Equipment Research Institute

Abstract—A full-space unambiguous direction of arrival (DOA) estimation can be achieved by only using one single vector hydrophone. And it provides spatial advantage for solving the DOA estimation. The paper proposes a novel method for DOA estimation of single vector hydrophone based on the steered minimum variance (STMV) algorithm, which applies the STMV algorithm of the array signal processing to the single vector hydrophone. With the 3×1 dimensional steered matrix, the single vector hydrophone not only has the ability of high-resolution DOA estimation, but also improves the robustness of the algorithm and reduces the calculation amount of the algorithm. The simulation data and lake test data are used for experimental verification, and STMV algorithm is compared with the cross-spectrum method and the conventional beamforming (CBF) method. The research results have showed that the STMV algorithm has higher DOA estimation capability, better robustness, and lower computational complexity.

6044-Influencing Factors of Passive Synthetic Aperture Technology Based on FFTSA

Song LIU, Zhi-xiang YAO
College of Electronic Engineering Naval University of Engineering

Abstract — The beam-domain passive synthetic aperture technology is limited by a variety of influencing factors. Based on the FFTSA algorithm, this paper theoretically analyzed the source of the phase correction factor estimation error in the passive synthetic aperture technology and the influence of the related parameters on the synthetic aperture output. A simulation experiment was carried out. Simulation results showed: (1) The phase correction factor does not match the actual phase difference due to the inconsistency between the actual velocity of the array element and the theoretical velocity, which affects the accuracy of the target azimuth estimation; (2) The selection of synthetic aperture parameters such as the number of extensions of the single array element and the number of extensions can affect the main sidelobe height ratio and beam width of the passive synthetic aperture beam output. This article analyzed some factors that affect the selection of FFTSA parameters, and had certain reference significance for the use of FFSTA in the case of non-uniform speed and non-overlapping array elements.

6236-Few-shot learning with data enhancement and transfer learning for underwater target recognition

Feng Liu, Hao Ding, Daihui Li, Tao Wang, Zailei Luo, Liang Chen
National Innovation Institute of Defense Technology

Abstract—Due to the difficulty of acquiring underwater target data, the recognition of small samples of underwater acoustic targets has always been a difficult problem in the field of underwater acoustics. To solve this problem, this paper proposes a few-shot learning method based on data enhancement and transfer learning for underwater target recognition. This paper takes two-dimensional time-frequency spectrum as input, and uses a variety of data enhancement schemes, combined with transfer learning methods to achieve target classification. In terms of experiments, we used hydrophones to collect 3 times data in different sea areas as a data set for verification, including 10 types of targets. The experimental results show that our system could achieve the accuracy of 0.82.

5910-Research on Target Depth Attribute Determination Method Based on Pressure Cross Spectrum in Shallow Water

Xuejie Bi, Lin Ma, Xiaoman Li, Biao Wang, Cheng He
Jiangsu University of Science and Technology

Abstract—Aiming at the requirements for determining the depth attributes of submerged targets in shallow water, a novel target depth attribute determination algorithm using dual vertical receiving sensors has been proposed in this paper. This algorithm solves the problems that the existing algorithms generally have the disadvantages of large array aperture, limited sea depth range and limited target type range. In this paper, the theoretical research and experimental analysis of pressure cross spectrum excited by target have been carried out. The receiving depth selection method suitable for different sea conditions and the method for determining depth attributes of submerged targets whose frequencies can excite first three modes have been proposed. Secondly, the impact of waveguide parameters on algorithm performance has been analyzed, in order to verify the feasibility and robustness of the algorithm. Then, according to the performance analysis results of the algorithm, the specific applicable conditions and usage methods of the algorithm have been given. The experimental results show that when the receiving sensors are placed near the ideal receiving depths, the new proposed algorithm is suitable for the case where the line spectrum frequency can excite first three modes and for low signal-to-noise ratio conditions, but becomes more sensitive to the sound speed profile. It is only suitable for weak negative gradient conditions. The critical depth value is larger than ideal value, and it is difficult to adjust.

5787-Research on Submarine Pipeline Detection based on 3D Real-time Imaging Sonar Technology

Bo Zhang, Zhigang Shang, Yongjiao Wang, Donghai Wang, Mouye Wang, Yanyan An
China Academy of Electronics and Information Technology

Abstract—The detection and recognition of underwater preset structure is an important topic in the detection of potential safety hazards in underwater engineering. At present, the detection of underwater preset structure is mainly based on multi-beam sounding technology. In this paper, the submarine pipeline is taken as the research object, and a new detection method based on 3D real-time imaging sonar technology is proposed, which realizes the underwater environment acoustic high-precision real-time target detection and fine target analysis. First of all, the underwater target detection data is obtained by using 3D imaging sonar, high-precision integrated navigation, tide gauge, CTD and other equipment. Secondly, the attitude correction, sound velocity correction and depth compensation of 3D imaging data is carried out, and the bilateral filtering combined with threshold filtering is used to filter the data. Finally, combined with advanced point cloud data processing algorithms and edge data extraction based on eigenvalues, accurate identification, positioning and status analysis of submarine pipelines are achieved. The results of practical engineering detection show that this method has the advantages of high resolution, real-time imaging and excellent imaging quality. The detection image is stereoscopic and clear, which can provide more detailed description of underwater target contour. The data processing and analysis method adopted in this paper can track and identify the submarine pipeline quickly and accurately, and detect the areas with potential safety hazards such as exposed or suspended pipelines, which provides scientific basis for the timely management of pipelines. This paper provides a new detection method for submarine pipeline detection, which has applicability and popularizing value.

4870-Contrast Study of Side Scan Sonar Image Enhancement Methods

Yang Zhang, Haisen Li, Jianjun Zhu, Li Zhou, Baowei Chen
Harbin Engineering University

Abstract—Aiming at the problems of grayscale distortion, low contrast, and unobtrusive targets of side-scan sonar images, this paper uses five image enhancement methods for comparative experimental analysis. Analyzed five image enhancement algorithms: histogram equalization (HE), grayscale stretching (GS), mean filter (MF), Retinex (MSR) and wavelet transform (WT). Experiments were performed on three side scan sonar images. Experiments show that the three methods HE, GS, and MSR can effectively improve the image quality to a certain extent. The image enhancement effect of the MF method is not obvious, and the effect of the WT method is poor.

6096-Cognitive continuous tracking algorithm for centralized multistatic sonar systems

Shuping Lu, Yang Chen, Fangxiang Chen, Feng Ding, Ranwei Li
Hangzhou Applied Acoustic Research Institute

Abstract—This paper proposes a novel detection and tracking algorithm to improve the performance of continuous tracking of submarine for multistatic sonar systems. The algorithm focuses on a centralized fusion architecture and a cognitive closed loop. In the following trail of submarine, the future trajectory of the submarine and its echo intensity for different transmit-receive combinations are roughly predicted, where the target echo model is assumed to be a priori. These predicted echo intensity is fed back to the frontend detection and tracking processes. Then the proposed algorithm could adaptively adjust the key parameters of the centralized fusion rule. Moreover, the track management strategy is also adjusted based on the feedback information. At the beginning of another cycle after tracking, the future trajectory and the echo intensity of the target are predicted again. We use numerical simulations to evaluate the behavior of the proposed algorithm. It is demonstrated that the cognitive approach achieves a better performance of continuous tracking compared with the conventional non-cognitive method in terms of track probability of detection and track fragmentation rate.

6055-Deep-sea source ranging method by Modified General Regression Neural Network

Yuqing Jia, Yaxiao Mo, Wenbo Wang, Shengming Guo, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—To improve the accuracy of deep-sea source ranging, this study proposes a deep-sea acoustic source localization algorithm based on particle swarm optimization (PSO) – general regression neural network (GRNN). The method optimizes the parameters of the GRNN model using the particle swarm algorithm to reduce the influence of artificially determined parameters on the performance of the GRNN. The normalized sample covariance matrices associated with the acoustic source location are used as the input for the neural network model, and the acoustic source range is the output. The PSO – GRNN method is validated using the results of deep-sea experiments conducted in the South China Sea in 2017 and compares the performance of underwater target range estimation with the results of traditional matched field processing and convolutional neural networks. The validation demonstrates that the PSO – GRNN method has high prediction accuracy and strong stability and is less prone to human error than traditional methods. Therefore, the method proposed in this study is effective for underwater target ranging in deep-sea environments.

6109-Ships Classification Using Deep Neural Network Based on Attention Mechanism

Minzhang XU, Zhixiang YAO, Xiaopeng KONG, Yuanchao XU
College of Electronic Engineering Naval University of Engineering

Abstract—As a serviceable tool of underwater targets classification for sonar operators, deep neural network behaves a good work on underwater targets intelligent classification. Since the line frequencies of radiated noise supplied distinct frequency bands for different ships, a deep neural network is proposed based on an attention mechanism to improve the classification accuracy in this paper. The results show that the equilibrium classification accuracy of ACNN-QJ4 is 9.15% higher than that of non-attention network. Finally, by comparing the output features of these two networks with and not with attention mechanism, the superiority on feature extracting of the attention network proposed by this paper has been shown.

6092-A New Deep Learning Method for Underwater Target Recognition Based on One-Dimensional Time-Domain Signals

Xiaoping Song, Jinsheng Cheng, Yuan Gao
Shanghai Marine Electronic Equipment Research Institute

Abstract—How to extract effective target features from complex underwater acoustic signals and better classify underwater targets and ships has always been an important problem in the field of underwater acoustic countermeasures. Due to the complexity of underwater acoustic environment and continuous development of underwater acoustic countermeasures, the limitation of expert experience system based on traditional spectrum analysis technology is becoming more and more obvious in passive sonar target recognition. In recent years, deep learning has made remarkable progress in image recognition, speech recognition and other fields. In this paper, a new method is developed in which one-dimensional time series data is used as the input, and some popular networks such as Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) are used as deep learning models to mine intrinsic features, and Wasserstein Generative Adversarial Network-Gradient Penalty (WGAN-GP) is used to enhance the training samples data. This method has shown an excellent performance in passive sonar recognition.

5956-Modulation Recognition of Underwater Acoustic Communication Signals Based on Deep Heterogeneous Network

Weiqi Liu, Yaohui Lv, Bin Jiang, Xin Yue
Ocean University of China

Abstract—The complicated underwater environment and its variable characteristics bring certain challenges to the modulation recognition of acoustic communication signals. Traditional methods for the task are usually based on manually extracted features, which require sufficient prior knowledge and artificial cost. In this paper, considering the rapid development of machine learning technology, the original underwater acoustic signal data are compressed by PCA technique, so as to reduce the data dimension and suppress the noise interference. On the basis, a deep heterogeneous network combining hybrid dilated convolutional networks and Long-Short Term Memory network is built to automatically capture the hidden features of data series to achieve the modulation recognition of 4 underwater acoustic communication signals recognition, including OOK, 2FSK, 2PSK and QPSK. Under different SNRs, the simulation experimental results show that the proposed network is valid and robust to identify 4 modulation modes. In the actual experiment, recognition accuracy of 91.171% confirms the effectiveness of the proposed network for modulation classification.

6183-Experimental Verification of Vertical Line Array Shape Estimation Based on Single Normal Mode Extraction

Peng Tan, Licheng Lu, Qunyan Ren, Desen Yang
Acoustic Science and Technology Laboratory

Abstract—The shape of the long line array is required to correct signal processing data and locate underwater targets precisely. In this paper, the warping transform form with waveguide invariant (β) is adopted to extract the single normal mode (3rd and 4th) through the compression processing broadband sound source signal of the vertical line array, which is based on underwater acoustic propagation sea trial data conducted in shallow waters of the South China Sea in November 2017. This method verifies the relationship between the single normal mode phase for the vertical line array sound field and shape. The results are consistent with the vertical line array attitude sensor measurement method.

6161-Simulation and measurement of an acceleration sensitivity for a fiber-optic vector hydrophone system

Jiangfei Hu, Duanming Li, Song Ge, Mingxue Gu
Shanghai Marine Electronic Equipment Research Institute

Abstract—To content acceleration sensitivity need of threedimensional fiber-optic inertial vector hydrophone, numerical calculating Matlab and finite element simulating approaches are firstly proposed to research on. By simulating, it gets the relationship curve between acceleration sensitivity Ma and sensing frequency f0, with the work frequency 20Hz-2000Hz and acceleration sensitivity 28.7dB in designing parameters. Secondly, the three-dimensional fiber-optic inertial vector hydrophone is fabricated with designing parameters. Finally, a fiber-optic vector hydrophone acceleration sensitivity measurement setup is built, and its acceleration sensitivity Ma is tested. In the measurement, vibration signals can successfully be detected and demodulated, when it shows that work frequency of the hydrophone is 20Hz-2000Hz and its acceleration sensitivity is 30dB, which deviation is 1.3dB from simulation. Comparing and analyzing the simulating and the measurement on Ma, the structure of a fiber-optic inertial vector hydrophone is proved to be correct and applicable. It is of great significance for designing the studying the structure and its practical application of a fiber optic vector hydrophone.

5922-Monthly and Seasonal Trends in Statistical Characteristics of Underwater Noise in Chukchi Plateau

Xuejing Mo, Hongtao Wen, Yanming Yang, Hongtao Zhou, Hailin Ruan
Third Institute of Oceanography, Ministry of Natural Resources

Abstract—In Arctic Ocean, the sea ice concentration, sea surface temperature and wind speed will change significantly with months and seasons, and then affect the characteristics of underwater noise. In this paper, the measured underwater noise data over a year period from October 1, 2018 to September 30, 2019 (local time) in the Chukchi Plateau are presented and discussed to study the monthly and seasonal statistical characteristics of underwater noise. Due to the transient sound signals generated by sea-ice activities, the underwater noise spectrum levels have a greater fluctuation during ice-cover period, and there are a large number of discrete values in the upper part of the empirical probability density diagram of noise spectrum level, which have deviated from the main distribution areas of noise spectrum level. For temperature increasing and ice-melting, the ice concentration decreases rapidly with time in summer, and the sea surface of Chukchi Plateau is in ice-free conditions for a few months. During the open-water conditions, the underwater noise of Chukchi Plateau should be dominated by wind-generated noise and it is almost unaffected by transient sounds, therefore, there are few discrete values can be discovered on the empirical probability density diagram of noise spectrum level. The mean and median values of noise spectrum levels of the four seasons have been studied and compared. The spring reaches the lowest level in mean and median values for the gradually rising temperature and lower wind speed, and it is considered to the quietest season in a year in Arctic Ocean, which is in agreement with the view of Sagers and Ballard. The attenuation trends of the mean and median values with the increasing frequency in summer are different from that of the other three seasons. The other three seasons exhibit a steeper attenuation slope than summer. The median values of noise spectrum levels measured in this paper demonstrate a higher attenuation slope compared with the results of Sagers and Ballard. The measured underwater noise is dominated by wind-generated noise in summer, therefore, the attenuation law of median values with the increasing frequency in summer is compared with that of Wenz. The noise spectrum levels decrease 4 dB/octave with the increasing frequency between 630 Hz and 2 kHz in this paper, and the result of Wenz is approximately decreasing 5 dB/octave.

5030-Preliminary study on the wind-driven ocean ambient noise in Chukchi Plateau

Hongtao Wen, Yanming Yang, Hongtao Zhou, Shiyan Wei, Hailin Ruan
Third Institute of Oceanography, Ministry of Natural Resources

Abstract—The ice-free sea areas are increased continually in the past 20 years in Arctic, however, it's of great significance to study the ocean ambient noise at ice-free sea area. From September 9 to October 24, 2017 (local time), the Chukchi Plateau was ice-free, and the ocean ambient noise data were recorded by an underwater signal recorder (USR) at 519.5 m depth for 3 min every 2 h. The correlation coefficients of noise spectrum level and sea surface wind speed are greater than 0.5 in frequencies from 31.5 Hz to 5 kHz, especially, it is greater than 0.73 when the frequency is above 80 Hz. The variation law of noise spectrum levels with time is basically the same as that of wind speed. It suggests that the ocean ambient noise is significantly affected by sea surface wind and the wind-driven noise should be the main noise source during ice-free periods. The empirical probability densities and percentile distribution of noise spectrum levels from 20 Hz to 5 kHz have been given in this paper. The distribution of noise spectrum levels is relatively concentration below 160 Hz and discrete above 160 Hz. According to wind speed, different sea states are divided. The mean values of noise spectrum levels of different frequencies under different sea states are given and compare with the Knudsen's curves. In the frequency band between 800 Hz and 5 kHz, the wind-driven noise spectrum levels decrease about 4.65 dB/octave with increasing frequency, which is slightly less than that of Wenz's result of about 5 dB/octave.

4973-Preliminary study on the ocean ambient noise in central Bering Sea

Hongtao Wen, Hongtao Zhou, Shiyan Wei, Ruichao Xue, Hailin Ruan, Yanming Yang
Third Institute of Oceanography, Ministry of Natural Resources

Abstract — With the increase of human activities in the Arctic, it is necessary to study the characteristics of ocean ambient noise in the Bering Sea for it is the only way to enter the Arctic Ocean from Pacific. From September 11, 2018 to April 5, 2019 (local time), an underwater signal recorder (USR) measured ocean ambient noise in the central Bering Sea at 357 m depth for 2 min per hour, and the central Bering Sea was ice-free during the experiment. It is found that there are a large number of transient sounds in the ocean ambient noise from September to November 2018. These transient sounds are inferred as anthropogenic underwater noise, but it needs to be further study to specific the noise sources. The correlation coefficients of noise spectrum level and sea surface wind speed are greater than 0.71 in frequencies from 160 Hz to 5 kHz, however, it is decreased rapidly with decreasing frequency when the frequency is less than 160 Hz, and it is only 0.45 at 125 Hz. During the experiment, the average sea surface wind speed is 10.7 m/s and the corresponding Beaufort wind force is about level 5 to level 6. At this wind speed, the mean value of noise spectrum level is about 70.3 dB at 1 kHz in this paper, however, it is about 66 dB in the Wenz curves. The mean value of noise spectrum level in this paper is greater than that in the Wenz curves under the same Beaufort wind force. It should be attributed to the long-time high wind speeds during the experiment, especially the wind speeds are greater than 8 m/s over 67% of the time. The sea waves will grow more fully and the wave breaking will be intensified for the long-time of high wind speeds, so the wind-driven noise spectrum levels may be increased and higher although at the same Beaufort wind force. In the frequency range of 500Hz to 5kHz and wind speed range of 4 m/s to 16 m/s, the attenuation slope of noise spectrum level with increasing frequency, and the increment of noise spectrum level with the doubling of wind speed, are also compared with Wenz's results.

5899-A Coupled Mode Method for Low Frequency Distant Reverberation in Deep Water Environment with Ice Covers

YIRU ZUO, BO GAO, WENHUA SONG, JIE PANG, DONGPENG MO
Ocean University of China

Abstract—A ray-coupled mode approach to low frequency reverberation is developed for an ice covered deep ocean. Three naturally distinct propagation ray groups due to the unique upper duct of the sound channel in the Arctic area are modified by the ray theory. At the scattering patches of the irregular ice cover, the ray group is decomposed into the corresponding up and down going modes, and then the scattering kernel of reverberation is derived by coupled mode theory. A typical sound speed profile is simulated, and the calculated results show that the decay rule of the long range low frequency reverberation level in the deep ocean of the Arctic area is affected seriously by the propagation effect.

6138-Test and Analysis of Compression Wave Sound Velocity Measurement in Ice by Direct Method

Jin Bai, Lianhui Jia, Chunxia Meng, Fengrui Bai
Science and Technology on Underwater Test and Control Laboratory

Abstract—The sound velocity in ice is of great significance to the acoustic propagation characteristics of ocean channels under ice cover and the acoustic characteristics of underwater targets. Freshwater ice has a uniform crystal structure under normal conditions. The freezing process of sea ice is more complicated compared to fresh water ice. The sea ice contains a lot of bubbles, brine, solid particles and other impurities. Due to the large difference in the structure and composition of ice in different states, it is very different from the common sound transmission media in the past. Therefore, in order to accurately describe the acoustic propagation characteristics of the ocean channel under the ice cover, it is necessary to measure the longitudinal sound velocity in the ice accurately. A direct method for measuring the speed of longitudinal waves in ice is studied in this paper. The propagation time of high-frequency pulses in the ice is used in this research to determine the speed of longitudinal waves. For the same piece of ice, the method of averaging multiple measurements was used to reduce the measurement error. Six tests were performed on typical ice with different structural characteristics. The six tests were the fresh water in Songhua Lake area of Jilin Province in 2019, the high mud content sea ice in the coastal area of Bohai Bay in 2020, the low mud content sea ice in Liaodong Bay area in 2021, the artificial quick-frozen sea ice and fresh water ice at -20° C, and the summer Arctic sea ice obtained in the eleventh Arctic scientific survey in 2020. The sound velocity of longitudinal waves in ice was measured at 12kHz, 25kHz, 50kHz, 75kHz, and 100kHz. The acoustic properties of ice are determined by its own state. The measurement results have certain fluctuations, because the test results were closely related to the sample test environment and test process. The measurement results of longitudinal wave sound velocity were described by the measurement mean value and standard deviation in order to scientifically express the longitudinal wave sound velocity in ice. The test results showed that the longitudinal sound velocity in high mud content sea ice was about 3360±162m/s, 3270±78m/s in low mud content sea ice, 3769±54m/s in artificial sea ice, 3772±57m/s in lake ice, 3729±23m/s in artificial fresh water ice, and 3893±86m/s in Arctic ice. Under the same measured temperature, the compression wave sound velocities in most ice media are stable at 3750 m/s. The research methods and results in this paper provide references for related research on the acoustic properties of ice media, the acoustic propagation characteristics under ice cover and target acoustic characteristics in ice area.

6101-Water Surface Capillary Wave Simulation and Detection Using Optical Method

Zongru Li, Erzheng Fang
Harbin Engineering University

Abstract—The long-range transmission of sound waves in water has been widely discussed, where the surface of water is often considered as smooth and rigid. In theory, tiny capillary waves can be induced when mechanic waves hit the interface of two substances with different wave speeds. In this paper, the shape of water-air interface is analyzed when a far-field plane acoustic wave from underwater reaches water surface. In conclusion, the amplitude of water surface wave is at submicron level, which decreases in the exponential form, and the attenuation coefficient increases greatly with the increase of frequency. Based on theories discussed, a fusion sensing system is proposed for the detection of underwater sound source from air. To build up this system, a laser vibrometer device connected to a computer with picometer resolution, is needed. At 2nm detection threshold, this detection method is able to find a 10Hz,140dB underwater sound source at 2.45m away. It is hard for underwater structures to eliminate noise in low frequency, thus monitoring water surface capillary wave is a promising new way for underwater noise detection.

6082-Multi sensor-based array shape direct measurement approach for deep-sea vertical linear array

Wenbo Wang, Tao Hu, Qunyan Ren, Li Ma
Institute of Acoustics, Chinese Academy of Sciences

Abstract—The scale of vertical linear array (VLA) used in deep-sea is usually several thousand meters. The accurate estimation of its array is an important prerequisite for the application of VLA signal processing technology. In this paper, a deep-sea vertical array measurement method using depth sensor and azimuth sensor is proposed. Firstly, a number of depth sensors and azimuth sensors set on different depth nodes are used to obtain the tilt angle and tilt azimuth angle of deepsea vertical array at different depth nodes. Then, through polynomial curve fitting method, the inclination angle and azimuth angle of deep-sea vertical array at different depths are recursively processed. Finally, the three-dimensional coordinate position of the deep-sea VLA is calculated, and the three-dimensional formation of the deep-sea vertical array is obtained. The experimental data processing results show that the VLA shape in a 4000-meter sea area of South China Sea may be controlled by the northeast-southwest sea current and changes at any time in a 12-hour tidal cycle, and the relative variation distance of the top of the VLA can reach 500 m at most.

6173-Analysis of Acoustic Energy Distribution on the Continental Shelf Edge

Yinghua Guo, Weiqing Li, Yingchun Chen, Chunfeng Li
The key Laboratory of underwater acoustic countermeasure technology

Abstract—In the past few decades, more and more attention has been paid to sound propagation on the shelf slope. In order to solve the problem of acoustic energy distribution in the continental shelf slope area, the modeling of acoustic propagation is studied. In this paper, the main factors affecting the spatial distribution of acoustic energy in sea area of shelf slope were analyzed through numerical calculation of propagation loss of different survey lines, while environmental parameters were obtained by using temperature, salinity and depth data of typical sea area. The research results have important significance for sonar performance analysis, underwater acoustic modeling and simulation in shelf slope environment.

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