QIXIANG NIU



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EDUCATION BACKGROUND

2021.03-2026.03 **Northwestern Polytechnical University** **Supervisors: Prof. Wentao Shi / Prof. Qunfei Zhang** **Ph.D. in Engineering**
Research Interests: Design of Integrated Multi-Base Underwater Acoustic Detection and Communication Systems

2023.09-2025.08 **Universidad Carlos III de Madrid (UC3M)** **Supervisor: Prof. David Ramírez** **Visiting Ph.D.**
Department of Signal Theory and Communications (Signal Processing Research Group)
Funded by Northwestern Polytechnical University and the China Scholarship Council (CSC)

2019.09-2021.03 **Northwestern Polytechnical University** **Supervisors: Prof. Wentao Shi / Prof. Qunfei Zhang** **Master of Engineering**
Major: Underwater Communication and Information Sensing
Research Interests: Information fusion in integrated underwater acoustic sensing–communication systems
Admitted to Doctoral Study Ahead of Schedule in the First Year of Master's Program

2015.09-2019.07 **Northwestern Polytechnical University** **Major: Information Engineering** **Bachelor of Engineering**
GPA: 3.22 / 4 (Major Rank: 18 / 50) **Postgraduate Entrance Examination: 385/500 (Mathematics: 109; English: 64; Specialized Subjects: 149)**

WORK EXPERIENCE

2026.08-2027.08 **Nanyang Technological University** **Supervisors: Prof. Gan Woon-Seng** **Research Fellow**
Research Interests: AI-Based Acoustic Signal Processing and Noise Reduction

RESEARCH EXPERIENCE

Publications:

[1] **Niu, Q.**, Shi, W., Zhang, Q. & Zhang, D. (2026). Underwater Passive Sonar Fusion Detection Based on Sensor Bias Estimation and Classification. Digital Signal Processing, 168(Part D), 105596. (JCR: Q2)
[2] **Niu, Q.**, Shi, W., Jing, L., He C., Zhang, Q. & Tan, W. (2025). Joint Optimization of Underwater Acoustic ISUDC Waveform Design and Sparse Channel Estimation Algorithms. IEEE Internet of Things Journal, 12(20), 43756-43771. (JCR: Q1)
[3] **Niu, Q.**, Shi, W., Zhang, Q., & Zhang, C. (2024). An Improved CLEAN Direct-Wave Suppression Algorithm in Integrated System of Underwater Detection and Communication. IEEE Sensors Journal, 24(6), 8503-8516. (JCR: Q1)
[4] **Niu, Q.**, Zhang, Q., & Shi, W. (2023). Waveform design and signal processing method for integrated underwater detection and communication system. IET Radar, Sonar & Navigation, 17(4), 617-627. (JCR: Q3)
[5] **Niu, Q.,** Shi, W. , Zhang, Q. , & Wang, B. (2026). Waveform design and processing for underwater integrated detection and communication based on affine Fourier dictionary. ACTA ACUSTICA, 2026, 51(2): 501-514. (EI)
[6] Zhang, D., Chen, J., Bai, J., Wang, M., Shi, D., **Niu, Q.**, & Bernardini, A. (2025). Sound Event Localization and Classification using Wireless Acoustic Sensor Networks in Outdoor Environments. IEEE Sensors Journal. (JCR: Q1)
[7] Jia, C., Tan, W., Shen, A., Li, Z., Chen, Y., Zhao, R., **Niu, Q.** & Li, C. (2025). A PUF-Enhanced Fog-Enabled Hierarchical Authentication Protocol for Internet of Vehicles. IEEE Internet of Things Journal, 12(18), 37629-37644. (JCR: Q1)
[8] **Niu, Q.**, Ramírez, D., Shi, W. & Zhang, Q. (2025, December). Underwater Detection and Communication Integrated Waveform Design Based on P4 Encoding. In 2025 IEEE Global Communications Conference (GLOBECOM 25). IEEE.
[9] **Niu, Q.**, Shi, W., Ramírez, D., Jing, L., & Zhang, Q. (2025, March). AFDM-Based Integrated System for Underwater Detection and Communication Waveform Design. In 2025 IEEE Wireless Communications and Networking Conference (WCNC 25). IEEE.
[10] **Niu, Q.**, Zhang, Q., & Shi, W. (2022, October). Integrated Waveform Design Scheme Based on Underwater Detection and Communication. In 2022 IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC). IEEE.
[11] **Niu, Q.**, Shi, W., & Jing, L. (Under Review). AFDM-Based Waveform Design and Target Detection Framework for Underwater Acoustic Integrated Sensing and Communication Systems. IEEE Journal on Selected Areas in Communications.

Patents:

[1] Shi, W., **Niu, Q.**, Jing, L., et al. A target detection method for an underwater integrated sensing-communication system based on AFDM signals.
[2] Shi, W., **Niu, Q.**, Zhang, Q., et al. A Method for Designing Integrated Underwater Detection and Communication Signal Waveforms Based on P4 Coding Technology. Patent No. 2025107261392.
[3] Shi, W., **Niu, Q.**, He, C., et al. A Deviation Estimation and Classification Fusion Method Based on Underwater Multi-Base Passive Detection. Patent No. 2024112037212.
[4] Shi, W., Zhang, Q., **Niu, Q.**, et al. An Integrated Underwater Detection and Communication System. Patent No. 202310799519X.
[5] Zhang, Q., Shi, W., **Niu, Q.** A Design and Processing Method for Transmitted Signals in Integrated Underwater Detection and Communication Systems. Patent No. CN115987744B, 2022113608363. (Authorized)

Monographs:

[1] Shi, W., Jing, L., & **Niu, Q.** (Expected 2026).Theory of Integrated Underwater Acoustic Sensing–Communication System Design.

PROJECT EXPERIENCE

[1] Research on Target Detection Technology for Integrated UUV Detection and Communication Based on Underwater Acoustic Communication Signals (Funded by NSFC, Key Participant)
[2] Theoretical and Key Technologies for Cooperative Detection of Moving Targets Based on Underwater Sensor Networks (Funded by NSFC, Key Participant)
[3] Underwater Acoustic Detection and Communication Technology Based on Mobile Platforms (Funded by National Key R&D Program, Participant)
[4] Research on Target Detection Technology for Torpedo Guidance and Communication Integration (Funded by National Key Lab Foundation, Participant)
[5] Research on Underwater Target Detection Technology Using Non-Circular Signals for UUV Side Array Systems (Funded by NSFC, Participant)

RESEARCH SKILLS

- Proficient in using MATLAB and Python for simulation, and familiar with basic C++ programming. I have used MATLAB to develop simulation code for research papers, upper-computer programs for projects, as well as simple application development.
- Proficient in using AI tools such as ChatGPT and DeepSeek, and in leveraging them appropriately to support research and improve research efficiency.
- Proficient in using LaTeX and Overleaf for intelligent and professional document typesetting.
- Assisted my supervisor in the peer review of papers for top-tier journals such as IEEE Internet of Things Journal, IEEE Transactions on Communications, and IEEE Transactions on Signal Processing, and served as an invited reviewer for Signal Processing, IEEE IoTJ and the IEEE International Conference on Communications.
- Assisted the supervisor in mentoring undergraduate capstone projects and provided guidance to master's students on thesis writing and related project research.

RESEARCH PROGRESS

Integrated Waveform Design Methods:

- An integrated waveform is proposed for underwater continuous-wave sonar systems by combining a generalized sinusoidal frequency modulated (GSFM) probing waveform with communication baseband phase modulation. The communication baseband phase is embedded into the GSFM continuous active sonar signal to construct a fully shared integrated waveform. This waveform is capable of carrying enhanced communication information while preserving the range velocity resolution and bearing estimation performance of the GSFM probing component. In addition, a reasonable parameter range for the GSFM carrier in the integrated system is derived and discussed. *(Journal papers [4], [10] and invention patent [5])*
- An integrated underwater acoustic waveform with multi-symbol loading based on affine frequency division multiplexing (AFDM) has been proposed. Multiple AFDM subcarrier symbol groups are embedded within a single pulse, significantly increasing the communication rate without extending pulse duration or bandwidth. The detection performance is analyzed in the range–Doppler domain via the wideband ambiguity function. To mitigate the sensitivity of the ambiguity function to communication bits, a Reed–Muller based complementary sequence coding scheme is designed, yielding waveforms with complementary coding properties. In complex time-varying underwater acoustic channels, the proposed waveform achieves bit-error-rate performance comparable to conventional AFDM, while providing higher communication capacity and more stable detection performance. *(Journal paper [9])*
- To address the difficulty of simultaneously achieving high resolution and robustness to time variations for integrated detection and communication waveforms over underwater doubly selective channels, an integrated waveform design method based on an overcomplete wavelet–affine Fourier dictionary has been proposed. A non-orthogonal overcomplete dictionary with joint coverage in time, scale, and frequency is constructed, and a joint optimization model combining sparse representation with modulation constraints is formulated. By constraining the sparse coefficients to lie in a given communication constellation, the designed transmit waveform can both reliably carry information and maintain sparsity. The resulting waveform exhibits low autocorrelation sidelobes and excellent delay–Doppler resolution, and outperforms waveforms constructed from conventional Fourier, affine Fourier, or wavelet dictionaries, achieving higher detection probability and better sensing performance even at relatively low SNR. *(Journal paper [5].)*
- For underwater doubly dispersive channels, an AFDM-centric integrated waveform is optimized. The discrete ambiguity expression of the AFDM waveform is derived, and a P4 polyphase code with good autocorrelation is selected as the baseline. Amplitude-limited phase perturbations are introduced on the P4 sequence and on DAFT-domain symbols, and a weighted peak sidelobe level objective is formulated to globally suppress ambiguity sidelobes under phase constraints. Results show a wideband "thumbtack" mainlobe, significant sidelobe suppression under multipath and Doppler, and improved Doppler resolution and detection probability. By properly bounding the perturbations, a tunable trade-off between sensing gains and communication BER degradation is achieved. *(Journal papers [2], [8] and invention patent [2])*

Integrated Waveform Signal Processing Methods:

- To address reception challenges of integrated systems over time-varying and unknown underwater acoustic channels, a unified single-channel blind source separation based receiver framework is proposed. By adding a DC offset and applying a logarithmic transform, the multiplicative mixture is converted into an additive model; subsequent whitening and iterative updates of the

separation matrix enable adaptive separation of sensing and communication components under unknown transmit waveforms and unknown channels. Simulation and analytical results indicate that the method maintains high separation accuracy in the presence of synchronization errors, multipath Rayleigh fading, and communication bit errors, yielding separated sensing waveforms whose autocorrelation peak-to-sidelobe ratio, correlation characteristics, and detection probability closely match those of the original GSFM probing waveform. *(Journal paper [4] and invention patent [5])*

- To overcome the limitation that a single-resolution dictionary cannot simultaneously capture global structure and local details, a sparse reconstruction method based on a multiresolution overcomplete wavelet–affine Fourier dictionary is proposed. The receiver dictionary is partitioned into coarse, medium, and fine layers, and sparse representations are solved hierarchically, improving reconstruction accuracy while controlling computational complexity. Results show that the multiresolution sparse processing more faithfully recovers the wideband ambiguity function and autocorrelation properties of the integrated waveform, significantly increases target detection probability, and reduces pairwise error probability compared with single-resolution approaches, thereby enhancing robustness in doubly selective underwater acoustic channels. *(Journal paper [5])*
- To address the challenge of accurately recovering AFDM signals over underwater channels, a sparse channel estimation algorithm based on an affine-Fourier dictionary is proposed. An overcomplete dictionary that captures affine modulation characteristics is constructed in the delay–Doppler domain; pilot symbols are used to estimate random phase perturbations and map them onto the dictionary atoms. By solving an ℓ_1 regularized sparse optimization, the path gains, delays, and Doppler shifts are jointly estimated, enabling high-precision reconstruction of sparse delay Doppler channels. Furthermore, upper and lower bounds on the BER of the AFDM-integrated system in underwater channels are derived, quantitatively characterizing the relationship among waveform coding, sparse channel estimation errors, and error performance. (Journal paper [2].)
- For an underwater AFDM integrated sensing–communication system, a weighted target detector based on the generalized likelihood ratio test (GLRT) is constructed. Leveraging the AFDM transmit/receive signals and the equivalent channel model, orthogonal projection matrices are designed to decompose multipath components from the received matrix, and an energy-ratio statistic is formed for detection. Path-specific weighting coefficients are further introduced so that, under target presence, high-quality paths contribute more through energy-weighted aggregation. Building on this, under total transmit power and BER constraints, a majorization–minimization procedure jointly optimizes the transmit power allocation matrix and the detector weights to maximize the noncentrality parameter of the detection statistic. Results show that, compared with unoptimized detection and conventional LoS detection, the proposed processing scheme effectively suppresses false-alarm peaks and achieves more robust underwater target detection. *(Journal paper [11] and invention patent [1])*

Multistatic Direct-Path Suppression Methods:

- To address the problem in bistatic underwater integrated sensing–communication systems where the direct path and strong multipath interference possess much higher energy than the target echo and thus drown out useful returns, an improved direct-path suppression algorithm based on a two-level windowed CLEAN is proposed. Temporally, a first sliding window aligns and segments the direct path and strong multipath components; spectrally, a second short-time window reduces the correlation between the instantaneous frequency and time of the integrated continuous waveform, rendering the amplitude and delay of each segment approximately constant. Experimental results show that, compared with conventional direct-path suppression methods, the proposed approach achieves clear advantages in normalized cross-correlation spectra, signal-to-interference ratio, spatial spectrum estimation, and echo detection probability, and is well-suited to complex underwater multipath and fading conditions. *(Journal paper [3])*

Multistatic Information Fusion Methods:

- To mitigate fusion performance degradation in underwater passive multistatic sonar networks caused by random sensor biases, heterogeneous errors, and node failures, a bias-estimation–aware classified fusion localization algorithm is proposed. Sensor bearing biases are modeled as dynamic stochastic processes and accurately estimated via maximum likelihood for prior calibration and correction. An expectation–maximization (EM) procedure then classifies sensors by statistical characteristics, followed by variable–step-size weighted fusion within and across classes, which automatically downweights sensors with large biases or abnormal behavior in the final estimate. Simulations and sea trials demonstrate that the method significantly reduces localization mean-squared error under conditions with large bearing biases, false alarms and missed detections, and extreme outliers at individual nodes. *(Journal paper [1] and invention patent [3])*