

Exploration of Teaching Reform by Introducing Wireless Sensing into Wireless Mobile Communication Course

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Abstract

Wireless Mobile Communication is a core compulsory course for undergraduate students majoring in communication engineering. Traditional teaching mainly focuses on theoretical instruction, and practical links mostly carry out verification operations around knowledge points such as modulation and demodulation and channel characteristics, with forms dominated by software simulation and fixed experimental box verification. The course content has a low degree of integration with cutting-edge industrial applications such as wireless sensing, resulting in undergraduate students' limited cognition of the multi-dimensional application value of wireless signals. In response to this situation, this paper explores the reform path of integrating wireless sensing technology into undergraduate course teaching. Relying on the millimeter-wave radar experimental platform, application-oriented demonstration projects such as gesture recognition and human gait detection are designed, and a layered teaching framework from principle verification to scenario implementation and innovative expansion is constructed, supported by in-class discussion and group cooperative inquiry activities. Preliminary teaching practice shows that this reform has effectively improved undergraduate students' enthusiasm for course participation, helped students deepen their understanding of core knowledge such as channel characteristics and signal processing, and has a positive effect on cultivating undergraduates' engineering practice awareness and innovative thinking. It can provide reference for the teaching reform of similar communication courses for undergraduates.

Keywords

Wireless Sensing, Wireless Mobile Communication, Experimental Teaching Reform

1. Introduction

With the advancement of higher education reform in China, improving the engineering practice and innovative application abilities of undergraduate students has become the core training objective. At present, with the deepening of 6G technology research, integrated sensing and communication has become a core technical direction of next-generation mobile communication systems, and has been widely recognized as a key enabler for intelligent interaction and environmental perception scenarios (Liu et al., 2022). The application value of wireless sensing technology in fields such as intelligent interaction and behavior recognition is increasingly prominent, which also puts forward higher requirements for the knowledge system and practical ability of undergraduate students majoring in communication. Wireless Mobile Communication is a core compulsory course for undergraduate students majoring in communication engineering. Experimental teaching is a key link connecting theory and engineering practice, and its content setting directly affects the quality of undergraduates' comprehensive ability training.

At present, the experimental teaching of this course is still dominated by verification projects, mostly focusing on basic theories such as modulation and demodulation and channel fading simulation. The experimental process is fixed, the openness is insufficient, and the integration with cutting-edge disciplinary technologies is low, which is difficult to meet the practical and inquiry learning needs of undergraduate students. Integrating cutting-edge technologies and active learning methods into professional courses is a mainstream trend of current engineering education reform (Boluda-Ruiz et al., 2024). In response to this problem, combined with the teaching practice of our university, this paper explores the reform path of integrating wireless sensing technology into experimental teaching. Relying on millimeter-wave (mmWave) radar, we design inquiry experimental projects such as gesture recognition and gait detection, and construct a layered and progressive experimental system. Preliminary practice shows that this reform effectively improves the inquiry nature of the experimental course, and plays a positive role in strengthening the engineering practice ability of undergraduates.

2. Platform Selection and Layered Design of Sensing Experiments

Experimental teaching at the undergraduate level emphasizes the connection between theory and engineering practice. It should not be limited to verification operations with fixed procedures, but should cultivate students' ability to independently design experiments and analyze problems (Guo et al., 2022). On the basis of retaining the original core theoretical verification experiments, this reform adds a wireless sensing experimental module based on millimeter-wave radar. The overall three-tier architecture of "basic verification - scenario implementation - expanded inquiry" not only ensures that the experimental content closely

corresponds to the theoretical knowledge points of the course, but also reflects the inquiry and practical nature of undergraduate courses.

In terms of experimental platform selection, this reform selects millimeter-wave radar as the core carrier of sensing experiments. The signal processing principle of millimeter-wave radar is highly consistent with core knowledge points in the Wireless Mobile Communication course, such as wireless channel propagation characteristics, Doppler effect, target detection and parameter estimation. Students can directly reuse methods learned in the course, such as channel estimation, digital filtering and spectrum analysis, to process sensing signals. Meanwhile, the original point cloud data and intermediate frequency signals output by millimeter-wave radar equipment have a clear structure. There is no need to build additional complex radio frequency hardware systems, and students can focus on algorithm design and principle exploration within limited experimental class hours. This teaching idea of simplifying hardware implementation and highlighting core principle exploration has been widely verified in current radio frequency and electromagnetics practice education (Wagih & Ghannam, 2025), which is more in line with the experimental teaching objectives at the undergraduate level.

The layered design follows the principle of proceeding from the elementary to the profound and opening up step by step. Basic layer experiments focus on principle verification, guiding students to complete range and velocity dimension signal processing through millimeter-wave radar, verify core course concepts such as Doppler shift and range resolution, and establish the connection between wireless sensing and communication theory. Application layer experiments aim at typical scenario implementation, setting specific tasks such as gesture recognition and human gait detection, guiding students to master the full processing logic, and complete independent design in group inquiry tasks of signal denoising, feature extraction and classification recognition. Expansion layer experiments are open inquiry tasks, encouraging students to optimize algorithms or expand sensing scenarios combined with their own learning interests, so as to meet differentiated training needs of practical ability.

3. Layered Design of Sensing Demonstration Experiments Integrated into Classroom Teaching

3.1. Basic Principle Demonstration Module

This module is dominated by teacher-led on-site operation and demonstration, while students participate through synchronous observation and thinking, without independent hardware operation.

The core goal of basic principle demonstration is to assist theoretical teaching, visualize abstract formulas and concepts, and help undergraduates deepen their understanding of core knowledge points. This module is fully embedded in the original theoretical classroom, and is carried out simultaneously with the teaching of chapters such as wireless channel characteristics, Doppler effect, and signal parameter estimation. When explaining corresponding theories, the teacher oper-

ates the millimeter-wave radar equipment on-site for in-class demonstration. By processing the original intermediate frequency signals of the radar, the calculation results of range and velocity dimensions are intuitively displayed, and the physical significance of core formulas such as range resolution and Doppler shift is verified (Zhang et al., 2024). During the demonstration, the teacher can adjust system parameters such as signal bandwidth and chirp slope in real time, guide students to observe the impact of parameter changes on detection accuracy and resolution, and correspond boring theoretical derivation with real signal phenomena, so as to reduce the understanding threshold of core professional theories for undergraduates.

3.2. Typical Scenario Demonstration Module

In this module, the teacher completes the full-link operation and demonstration, and students participate in synchronous analysis instead of independently conducting the whole experiment.

Typical scenario demonstration takes complete sensing applications as carriers to help undergraduates establish an overall cognition from basic theory to engineering application, and is arranged after the teaching of chapters related to the whole signal processing process. Taking two typical scenarios of gesture recognition and human gait detection as cases, the teacher fully demonstrates the whole processing pipeline from original signal acquisition, denoising preprocessing, feature extraction to result output. During the demonstration, the teacher reviews the knowledge points taught in class such as digital filtering, spectrum analysis and feature classification corresponding to each processing link, disassembles the algorithm logic, and analyzes error sources and interference factors. This module guides students to actively think about the adaptation and adjustment of signal processing methods in practical scenarios, and strengthens the engineering application awareness of theoretical knowledge.

3.3. Expansion and Inquiry Demonstration Module

This module adopts the form of teacher-led demonstration and comparative analysis, with students participating in classroom discussions and putting forward optimization ideas.

Expansion and inquiry demonstration is oriented to the cultivation of undergraduate students' practical innovation ability, highlighting frontier and inquiry nature, and serves as an extension of classroom content. The teacher selects typical research problems in the field such as complex environment noise suppression, weak target feature enhancement and multi-target behavior differentiation, demonstrates the implementation effects and performance differences of different algorithm schemes, and analyzes the advantages, disadvantages and applicable scenarios of various schemes combined with the current research status in the field. Classroom discussions are interspersed during the demonstration to guide students to put forward optimization ideas combined with the learned theories, and

encourage undergraduates to think about the expanded application possibilities of wireless sensing technology in connection with their own learning interests. This module does not aim at mastering fixed operation procedures, but broadens students' professional vision through intuitive demonstration and comparison, cultivates their innovative thinking and practical ability of problem analysis and scheme exploration, and lays a foundation for subsequent graduation design and professional practice.

4. Classroom Discussion and Cooperative Inquiry Teaching

In undergraduate course teaching, we should not only pay attention to the breadth of knowledge impartation, but also emphasize the depth of understanding and application. "Depth" requires students to not only master theoretical conclusions, but also clarify the derivation logic and applicable boundaries, and be able to analyze and solve problems combined with practical scenarios. "Breadth" requires students to step out of textbook content, understand the industrial application and cutting-edge development of technology, and establish a complete professional knowledge system. Depth and breadth complement each other and jointly support the improvement of undergraduates' comprehensive practical ability.

4.1. In-Class Discussion Teaching

Discussion-based teaching is an effective way to deepen students' understanding and activate classroom atmosphere, but it is often difficult to carry out effectively in highly theoretical communication courses due to the lack of concrete discussion carriers (Zeng, 2018). Well-designed classroom discussions can effectively break the limitations of one-way teaching, guide undergraduates to actively construct knowledge systems, and significantly improve the advanced nature and class participation of the course (Zhang et al., 2025). Millimeter-wave radar demonstration experiments provide a concrete entry point for classroom discussion. Teachers can intersperse targeted discussion questions in each link of the demonstration. For example, in the basic principle demonstration stage, after adjusting the signal bandwidth, guide students to discuss the change law and theoretical basis of range resolution; in the scenario demonstration stage, after showing the impact of occlusion and multipath interference on sensing results, organize students to analyze the causes and suppression ideas of interference.

This kind of in-class discussion combined with real-time demonstration phenomena avoids vague theoretical discussion, allowing students to think about the underlying theory with intuitive signal phenomena. It can not only deepen the understanding of knowledge points, but also exercise students' problem analysis ability and logical expression ability. For undergraduates, this interactive form also breaks the dullness of traditional one-way teaching, encourages students to actively sort out the knowledge system, and discover the connection points between theory and engineering application.

4.2. Group Cooperative Inquiry

Undergraduate training emphasizes independent inquiry and teamwork ability, and cooperative learning is an effective way to exercise these two abilities (van Helden et al., 2023). Problem-oriented group cooperative inquiry can promote undergraduates to transform theoretical knowledge into the ability to solve practical problems, and cultivate teamwork awareness and academic communication literacy at the same time (Lyu et al., 2025). Relying on the content of wireless sensing demonstration experiments, the course sets up group cooperative inquiry tasks as an extension of classroom teaching. Teachers assign open inquiry topics around typical engineering practical problems of millimeter-wave sensing, such as noise suppression in indoor multipath environments and human micro-motion feature extraction. Students work in groups of 3 to 4 people, form a complete solution through literature review and discussion analysis, and deliver reports and exchanges in class.

In the process of cooperative inquiry, students need to comprehensively apply the knowledge learned in the course, such as channel characteristics, digital signal processing and parameter estimation, to collaboratively complete problem analysis, scheme design and result demonstration. Compared with individual learning, group cooperation can stimulate different thinking perspectives, allowing students to complement each other and improve together in communication. This mode can not only deepen students' understanding of the core knowledge of the course, but also effectively exercise their abilities of literature research, teamwork and academic expression, laying a foundation for subsequent graduation design and professional practice.

The completion quality of the group inquiry task is included in the course assessment as a part of usual performance, accounting for 20% of the total course score. The evaluation dimensions include scheme rationality, literature basis, presentation performance and team cooperation.

5. Teaching Implementation and Preliminary Effect

This teaching reform is implemented for the core compulsory course Wireless Mobile Communication, which is offered to third-year undergraduate students majoring in communication engineering at our university.

5.1. Basic Teaching Settings

Course type: Core compulsory course for communication engineering undergraduates.

Student cohort: Third-year undergraduate students majoring in communication engineering.

Class size: Approximately 30 to 35 students per class.

Semester arrangement: 16 teaching weeks in total, with 2 hours of theoretical instruction per week.

5.2. Reform Implementation Approach

All the sensing demonstration contents are embedded into the original theoretical teaching system in a dispersed manner, without adding extra total class hours. The specific arrangement is as follows:

- 1) The basic principle demonstration module is integrated into the chapters of wireless channel characteristics and Doppler effect, with a total of 2 class hours, and is carried out synchronously with theoretical explanation.
- 2) The typical scenario demonstration module is arranged after the completion of the digital signal processing related chapters, with a total of 2 class hours, to help students sort out the full-link signal processing logic.
- 3) The expansion and inquiry demonstration module is set as the frontier extended content at the later stage of the course, with 1 class hour, to expand students' professional vision.
- 4) The group cooperative inquiry task is arranged as an after-school extended assignment, and 1 class hour is reserved for in-class report and peer discussion.

This implementation mode does not require major adjustments to the original overall teaching plan, and can be carried out under the conventional course credit hour system, with certain reproducibility.

5.3. Preliminary Teaching Effect

After one semester of teaching practice, the effect of the reform is evaluated from three dimensions: student feedback, knowledge mastery and class participation, to support the claimed teaching improvement effect.

- 1) In the anonymous course satisfaction survey at the end of the semester, 87% of the respondents agreed that the millimeter-wave radar demonstration content helped them understand abstract theories such as Doppler effect and channel parameter estimation, and 82% of the students believed that the group inquiry activity effectively improved their ability to analyze practical engineering problems.
- 2) In terms of knowledge mastery, compared with the previous grade under the traditional teaching mode, the average score of test questions related to signal processing and channel characteristics in the final examination increased by 9.3%, which reflects that students' understanding and application ability of core knowledge have been effectively enhanced.
- 3) The in-class participation rate has increased significantly. The number of students who take the initiative to speak and ask questions in class is about 60% higher than that under the traditional teaching mode. In the group inquiry tasks, many groups put forward feasible optimization schemes for indoor multipath noise suppression and micro-Doppler feature extraction, showing good innovative thinking and practical awareness.

6. Conclusion

Scientific teaching design is the prerequisite for the effective implementation of teaching methods. It is necessary to fully consider the rationality, feasibility and

effectiveness of each teaching link in combination with course objectives, teaching content and undergraduate training orientation, and implement precise control and dynamic optimization during the implementation process. This teaching reform of introducing millimeter-wave radar sensing demonstration into the Wireless Mobile Communication course has injected engineering practice and cutting-edge research perspectives into the theoretical classroom through layered and progressive demonstration content design combined with in-class discussion and group cooperative inquiry, and has achieved preliminary teaching results.

At present, the construction of Emerging Engineering Education in China continues to advance, putting forward higher requirements for the innovation ability and comprehensive literacy of high-level engineering and technological talents in the communication field. The teaching of undergraduate courses in communication engineering requires teachers to not only have a solid and profound theoretical foundation of the discipline, but also grasp the frontier trends of the discipline and industrial development, and organically integrate scientific research achievements and technological progress into classroom teaching (Ji & Yang, 2023). Practical experience and research results in the field of education and teaching can not only broaden teachers' vision of teaching research, but also help teachers re-examine the objectives and logic of curriculum design from a new perspective, and promote the continuous improvement of course teaching quality (Zhou & Li, 2020).

Despite the positive preliminary effects, this teaching practice still has several limitations. First, the number of millimeter-wave radar devices is limited, so the current teaching form is mainly teacher demonstration, and it is difficult to realize independent hands-on operation for each student. Second, this reform puts forward higher requirements for teachers' engineering practice ability and research accumulation; teachers need to continuously update their technical knowledge and experimental operation skills to ensure the quality of demonstration and inquiry guidance. Third, the current practice is only carried out in a single university, and its applicability to institutions with different student foundations and experimental conditions needs further verification. In future work, we will further expand experimental equipment, enrich demonstration scenarios, and optimize the evaluation system to improve the applicability and promotion value of this teaching model.

Only by continuously carrying out teaching research and grasping the law of undergraduate talent training and the development trend of communication technology can teachers shift from passively adapting to reform to actively exploring innovation, boldly carry out practical exploration in course teaching, continuously optimize teaching modes, and effectively improve the teaching quality of undergraduate courses and the level of talent training.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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