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MATLAB Empowering the Reform of Communication Principles Experimental Teaching

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Abstract: To adapt to the objectives and requirements of cultivating new-generation communication talents, this paper systematically reviews the common challenges of the traditional hardware-based experimental teaching model—such as outdated equipment iterations, fixed experimental scenarios, and insufficient flexibility in parameter adjustments—given the characteristics of the communication principles laboratory course, which emphasizes both theoretical and practical aspects and has a high degree of system interconnection. It then proposes a path for reforming experimental teaching through communication system modeling and simulation based on the MATLAB virtual simulation environment. Using the core knowledge point of HDB3 code scrambling in digital communication systems as a teaching case to verify its effectiveness. By simulating and displaying the long consecutive zero waveform and power spectrum distribution characteristics of the scrambled HDB3 code, the abstract logic of baseband transmission coding and signal characteristics is concretely illustrated, effectively enhancing students' professional theoretical application skills, system design abilities, and engineering practice competencies. The reusable practice paradigm developed in this exploration can provide a reference for the systematic reform of communication principles experiment teaching.

Keywords: MATLAB Simulation; Communication Principles; Experimental Teaching.

1. Introduction

"Principles of Communication" is a compulsory core foundational course for students majoring in electronic information and communication engineering. It includes two main components: theoretical instruction and experimental training. Acting as a crucial link between prior mathematical foundations, prerequisite professional courses, and subsequent core communication courses, it plays an indispensable role in helping students construct a comprehensive knowledge system in the communication field and supports their learning in future courses. This course deeply integrates foundational mathematical subjects such as advanced mathematics and stochastic processes with professional prerequisite content including circuit analysis, high-frequency circuits, and signals and systems. It is typically characterized by strong theoretical content, dense abstract concepts, complex mathematical derivations, and limited connection to engineering practice, resulting in a relatively high overall learning threshold. The course imposes stringent requirements on students' foundational knowledge in advanced mathematics and basic circuit theory. The teaching objectives expect students to achieve the integrated application of knowledge from multiple prerequisite courses in communication scenarios. The abstract process of theoretical deduction results in widespread difficulties in comprehension and a lack of motivation to learn among students. However, in the traditional teaching model, complex theoretical derivations are constrained by limited class time, and teaching methods are incapable of fully presenting them dynamically. Moreover, communication laboratory equipment is costly, available in limited quantities, and operationally complex, making it difficult for students to gain adequate hands-on experience, thereby hindering the overall effectiveness of teaching. To effectively enhance the quality of course teaching and focus on cultivating students' abilities to analyze problems and address practical engineering challenges, the introduction of MATLAB virtual simulation tools is currently a highly feasible optimization strategy.

This paper focuses on the classroom teaching and practical teaching of 'Principles of Communication,' and proposes the use of virtual simulation technology to assist both classroom and practical teaching. MATLAB simulation software is powerful and has a user-friendly interface, making it very suitable for use in the teaching of this course. By intuitively presenting the results of software simulations, the understanding of complex theories is enhanced, students' enthusiasm for learning is stimulated, their practical skills are improved, and hands-on experience is increased, ultimately providing a better approach for applied local undergraduate institutions to cultivate application-oriented talents better suited to societal needs [1].

2. Problems and Solutions

2.1. Existing Issues

(1) As a core compulsory course for electronic information majors, "Communication Principles" has a strong theoretical nature, and students generally face a relatively high threshold for understanding. This course systematically teaches the basic theories of analog and digital information transmission, covering a wide range of content and high theoretical complexity. It includes a large number of formula derivations and principle explanations, requiring students to have a strong foundation of prerequisite knowledge and abstract thinking ability. Moreover, the majority of students taking the course are encountering communication-related concepts for the first time and lack relevant knowledge accumulation, which further amplifies the learning difficulty. For example, the standard amplitude modulation (AM) and phase modulation

(PM) of analog modulation systems, as well as core concepts of digital modulation systems such as binary amplitude shift keying (2ASK), are inherently highly abstract, and the conceptual boundaries between different modulation methods are easily confused, which seriously hinders students' in-depth understanding of the relevant knowledge points.

(2) The "Principles of Communication" laboratory course has long relied on pre-configured experiment boxes as the core medium, resulting in a significant lack of flexibility in experiments: the parameters of the modules inside the experiment boxes are preset and fixed, and students only need to mechanically follow the steps in the instruction manual to complete the wiring, observing the experimental waveforms at designated test points using an oscilloscope. As long as the experiment box is intact and the wiring is correct, even students with only a partial understanding of the experimental principles can obtain ideal waveform results. Due to the limitation that the parameters of the experimental box cannot be adjusted, students are unable to observe different experimental results or conduct comparative analyses through multiple parameter modifications, making it difficult to truly consolidate and deepen their understanding of theoretical knowledge through the experimental process [2]. The limitations of the traditional experimental box curing model have become apparent, and it cannot meet the needs of inquiry-based and personalized experimental teaching. There is an urgent need to address the above issues through innovations in experimental teaching methods.

(3) In addition to the lack of flexibility caused by the solidification of the experimental boxes mentioned above, the "Principles of Communication" experiments also face a dual problem of systemic defects and high operational pressure: First, the experimental content is fragmented. The existing conventional experiments mostly consist of independent verification projects such as analog modulation and demodulation, analog-to-digital conversion of signals, digital baseband signal shape conversion, and digital modulation and demodulation. They have not formed a complete link covering the entire process of communication signal transmission, making it difficult for students to establish associative understanding between different modules and technological solutions, and unable to achieve a systematic comprehension of the communication process. Second, the traditional hardware experiment mode has a high maintenance cost: consumables and equipment used in experiments, such as wires and experimental boxes, have a high wear rate. Combined with equipment damage caused by improper student operations, substantial manpower and financial investment are required for regular maintenance of the experimental stations and replacement of consumables, imposing significant pressure on the provision of practical teaching resources.

2.2. Solutions

In response to the systemic deficiencies and high operational costs associated with the aforementioned traditional hardware experiments, the introduction of software simulation technology is fully technically feasible: With the widespread application and rapid development of computer simulation technology, complex communication systems can be modeled through software simulation technology. By relying on integrated simulation environments, graphic and image processing, and other technologies, visual system virtual simulation can be realized on a PC, completely replacing the software and hardware operation environment of traditional experimental procedures. Among them, the MATLAB environment provides users with an integrated platform for dynamic system modeling, simulation, and comprehensive analysis. Its built-in module library contains a wide range of functional module groups and also supports converting user-defined code with specific functions into functional modules. Different modules can be organized into hierarchical subsystems, possessing inherent modular design characteristics, thereby meeting users' needs for building various customized communication systems [3-4].

In addition, MATLAB provides functional components tailored for experimental teaching throughout the entire simulation process: to meet the need for real-time observation of results during simulation, the platform includes built-in modules such as oscilloscopes and spectrum analyzers specifically designed to display output signals; for post-experiment data analysis and processing, MATLAB supports saving simulation results in forms such as waveforms and data to the workspace for subsequent retrieval and analysis. At the same time, through various visual GUI controls, the platform allows users to establish intuitive dynamic system models, ultimately creating a virtual simulation environment for experimental teaching that is both feature-rich and easy to operate.

3. The Application of MATLAB Software in the Teaching of Communication Principles

3.1. Overview of MATLAB Software

MATLAB possesses powerful numerical computing capabilities, convenient plotting functions, a highly integrated language, as well as features such as visual modeling and simulation, and has been widely applied in numerous disciplines including electronics, information technology, communications, and automation, becoming the preferred foundational tool for application development. Its Simulink simulation environment supports modeling, simulation, and full-process analysis of dynamic systems, adopting a graphical and modular modeling approach with an intuitive and clear model structure. At the same time, it includes dedicated output display and data storage modules, efficiently supporting the analysis and reuse of simulation data. In communication virtual simulation experiments, students can, based on their understanding of the composition and working principles of communication systems, independently complete the entire process of system model construction, design parameter adjustment, experiment result observation, and system performance analysis on this platform, effectively achieving the integration of theory and practice [5].

3.2. MATLAB Simulation Optimization Analysis

To verify the effect of scrambling technology on the suppression of long strings of zeros in digital baseband transmission, this experiment counted the distribution of consecutive zeros in the original baseband data to be HDB3 encoded and in the scrambled corresponding data. The histogram is shown in Figure 1. The simulation results indicate that the original data contain a large number of long consecutive zeros, with the maximum length of continuous zeros reaching several tens of bits and occurring very frequently. Direct HDB3 encoding would not only increase the insertion frequency of violation codes and reduce coding efficiency, but also likely cause timing synchronization difficulties at the receiver. After scrambling, the length of consecutive zeros in the data is significantly compressed, with the longest continuous zeros not exceeding 3 to 4 bits, effectively eliminating almost all long consecutive zeros. This histogram intuitively presents, from a statistical perspective, the suppressive effect of scrambling on long runs of zeros, verifying that scrambling can effectively optimize the characteristics of baseband data and provide a preliminary guarantee for the reliable transmission of subsequent HDB3 encoding [6].

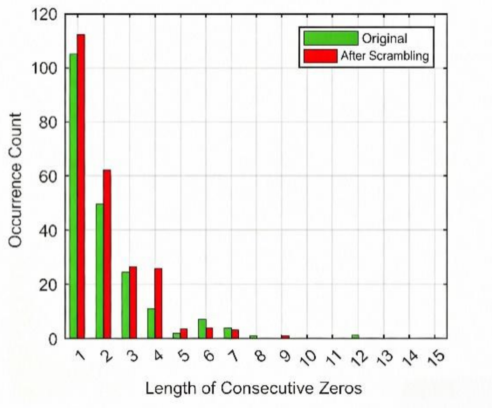

Figure 1. Histogram of Continuous Zeros

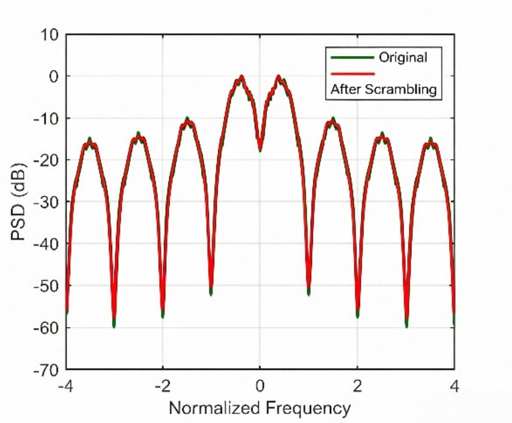

Figure 2. Power Spectral Density

To verify the spectral optimization effect of scrambling technology in baseband transmission [7], this experiment compared and analyzed the power spectral density (PSD) of the same baseband signal before and after scrambling. The results are shown in Figure 2. The power spectrum of the original unscrambled data exhibits pronounced discrete spectral lines, indicating that the signal carries strong periodic components—such periodicity generally arises from features like long code repetitions or frame structure periodicity. These discrete spectral lines can not only intrude into adjacent channel passbands causing adjacent channel interference, but also consume additional resources for synchronization timing components, thereby reducing spectral reuse efficiency and constraining the signal's compatibility in multi-channel scenarios. After scrambling code processing, the discrete spectrum of the signal is completely suppressed, and the power spectrum presents a smooth and continuous distribution, leaving only the continuous spectrum, with spectral characteristics approaching those of ideal white noise. This result verifies the effectiveness of scrambling technology from the frequency domain perspective, enhances spectral compatibility, and supports the requirements of scenarios where multiple services share spectrum resources.

4. Concluding

In order to overcome the inherent limitations of traditional communication principle experiments, this paper takes the scrambling processing of HDB3 coding in digital baseband transmission systems as the core case, using the MATLAB platform to carry out full-process virtual simulation modeling and result output, replacing traditional hardware experiment boxes to complete teaching practice. Traditional hardware experiment kits generally have drawbacks such as fixed functionalities, limited scope for parameter adjustment, high failure rates, and difficulty in reproducing extreme operating conditions. As a result, students often can only complete verification operations according to fixed procedures, making it hard for them to deeply understand the underlying principles or to develop the ability to design independently. Results indicate that this virtual simulation teaching model is student-centered, allowing students to independently complete system design and parameter tuning, thereby fully stimulating the initiative in practical learning. At the same time, by personally building full-link models and directly observing abstract phenomena such as the suppression of discrete spectra by scrambling and spectrum whitening, students not only deepen their understanding of core communication principles such as HDB3 coding, spectral compatibility, and channel interference, but also significantly enhance their problem-solving abilities and innovative thinking in stages such as troubleshooting, parameter optimization, and design expansion. The teaching effectiveness is markedly superior to that of traditional hardware laboratory models.

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