



# Design and Implementation of Simulation Experiment of Electronic Communication System Based on MATLAB Software

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## ABSTRACT

To solve the problem of large distortions in communication systems and high error of communication bits, MATLAB offers a test design method of simulation of communication systems based on software. First, the modulation of the propagation spectrum is performed at the receiving end of the communication signal. The structure of the electronic communication system will be established according to this communication principle. Then, the channel balancing design simulation will be performed using the transmission interval equalization technology. Simulation results show that the electronic communication code error rate of this method is between 0.2 and 0.5 and remains above 0.3. Therefore, the low bit error rate of the electronic communication system in this article, the good channel balancing ratio, and the high stability of the system are more valuable for practical use.

**Index Terms**—Electronic communication, MATLAB software, system design, model construction, communication principle

## I. INTRODUCTION

MATLAB language is the most influential and dynamic software in the international scientific community today. It originated from matrix operation and has developed into a highly integrated computer language. It has powerful mathematical operation capabilities, convenient and practical drawing functions, and high integration of language [1]. Especially in the field of communication, MATLAB has obvious advantages because many problems in the field of communication involves the study of the system performance. The traditional method only constructs an experimental system and uses various instruments to measure the required data, which not only leads to spending a lot of money on the construction of the experimental system but also has a long construction cycle and the adjustment of system parameters is also very difficult [2]. The emergence of MATLAB enables the simulation of communication system to be realized by computer simulation, which avoids the inconvenience of constructing the experimental system and the operation is very simple. You only need to input different parameters to get the performance of the system under different conditions, and it also has many advantages over the traditional method in the observation of results and data storage [3].

In recent years, with the popularization of computer application, the use of computers for simulation teaching in electronic information and communication majors has attracted people's attention and it has been implemented in many colleges and vocational colleges [4]. The current simulation teaching mainly uses some software platforms with powerful simulation functions to carry out circuit simulation experiments today. This kind of simulation experiment is used to virtualize an advanced electronic workbench with a complete range of components on the computer. On one hand, it can overcome the limitations of various conditions in the laboratory, and on the other hand, it can carry out training for different purposes to cultivate students' ability of analysis, application, and innovation [5]. Electronic communication based on MATLAB software uses the bandwidth characteristics of high-frequency signals in time, frequency and space for long-range signal modulation, and transmission to achieve high-speed, large-capacity, and high-reliability electronic communication in radar communication and submarine communication,

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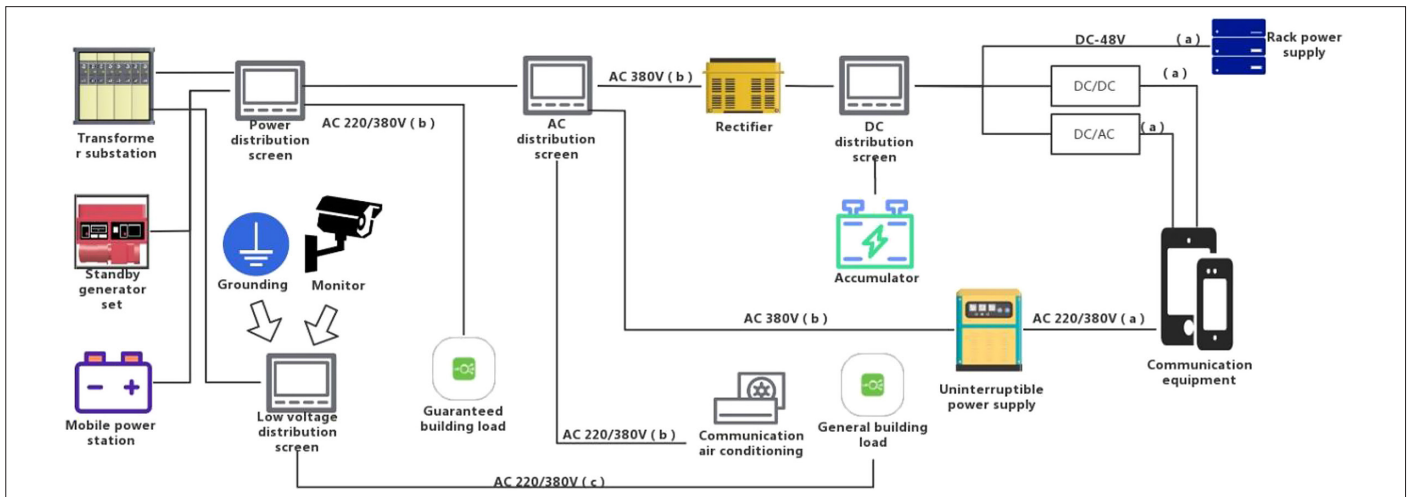
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**Fig. 1.** Composition and frame diagram of the communication power supply system.

Long-wave communications, Beidou satellite navigation, and other fields have a wide range of application value. Electronic communication systems based on MATLAB software are affected by strong multipath characteristics and severe inter-symbol interference, resulting in high signal transmission error rates and poor channel equalization performance. For this reason, an optimized design of electronic communication systems is required. Fig. 1 shows the composition and frame diagram of the communication power supply system.

Based on this study, we offer an experimental design method for simulating an electronic communication system based on MATLAB software in order to solve the problems of the current electronic communication system. The results show that the electronic communication system in this article has a low bit error rate, good channel smoothing ability, and high system stability [6].

## II. LITERATURE REVIEW

With the maturity of MATLAB communication and signal processing professional function libraries and professional toolboxes, they have gradually become familiar to experts, scholars, and engineers in the field of communication technology. They are more widely used in communication theory research, algorithm design, system design, modeling simulation, and performance analysis verification. The application in other aspects is also more extensive [7]. Ombaka and others believe that MATLAB, the most popular high-level language for engineering, numerical, and scientific calculations in the world, is one of the most commonly used languages in the virtual simulation of communication systems. Simulink in the MATLAB environment has a wealth of system modeling and simulation. The dynamic simulation integrated environment toolbox for analysis and the graphical user interfaces (GUI) in MATLAB provide a visual rapid development environment. Users can quickly generate various GUI controls through the mouse, thus helping users to easily design various graphical user interfaces that meet the requirements [8]. Solanki and others used the above-mentioned functions of MATLAB to completely realize the communication theory experiment to be completed on physical equipment. It can not only display abstract theoretical knowledge in various forms such as graphics, text, data, etc. but also provide a friendly interface for experimental teaching

and an easy-to-operate virtual environment [9]. Zhao and others provided verification equipment for the communication principle course experiment. Although it helped the students to understand the course knowledge to a certain extent, with the reform and development of the course, the drawbacks of the experiment box were gradually revealed, the scope of the experiment box hands-on operation was restricted, the experimental design was not ideal, and the experimental accuracy was low, so MATLAB technology was proposed and applied to the simulation experiment of the communication principle course [10]. Jiang et al. studied the use of traditional communication principle simulation experiment methods and found that the traditional method has a poor simulation effect on communication signals, which directly affects the teaching effect of communication principle simulation experiments [11]. Chen et al. inferred the performance of the original system through the results of the simulation model, so as to provide a reliable reference for the establishment of information or the transformation of the original system [12]. Ivaniga et al. used the simulation results to measure the feasibility of the scheme, from which the most reasonable system configuration and parameter settings were selected, and then applied to the actual system. This process is the simulation of digital modulation technology in mobile communication [13]. Mitra et al. carried out circuit simulation experiments with the help of some software platforms with powerful simulation functions. This kind of simulation experiment is used to virtualize an advanced electronic workbench with a complete range of components on the computer. On the one hand, it can overcome the limitations of various conditions in the laboratory, and on the other hand, it can carry out training for different purposes to cultivate students' ability of analysis, application, and innovation [14]. Jiang et al. proposed a homodyne coherent optical communication system based on a reflective electro-optic modulator. In order to test the performance of the system, OptiSystem software and MATLAB code were used to simulate the effect of a 100Gb/s dual-polarization quadrature phase-shift keying system. Through digital signal processing, chromatic dispersion, polarization mode dispersion, and nonlinear damage are compensated [11]. Liu et al. reviewed three aspects of acquiring status, control strategies, digital controllers, and new valves through sensors or indirect acquisition technology and online maintenance through data interaction and fault diagnosis [15]. Grillanda et al. have shown

in their work through a very small active volume, Surface Normal Electro Absorption Modulators (SNEAMs) can achieve ultra-wide electro-optical bandwidth (>>65 GHz). We display 25 Gbit/s modulation and 1 VPP driving voltage on the packaged SNEAMs, as well as ultra-high rate modulation and bare chip at 107 Gbit/s [16].

**III. RESEARCH METHODS**

**A. Electronic Communication Channel Model**

The electronic communication system performs spread spectrum modulation at the receiving end of the communication signal. When the modulation bandwidth exceeds the bandwidth of the wireless channel, the spectrum of the spread signal is directly removed to restore the original information and realize remote signal transmission. According to this communication principle, an electronic communication system is constructed. The structure is shown in Fig. 2. Suppose the input initial code element of the electronic communication system is  $C_0 = C_{N/2} = 0, C_{N-n} = C_n^*, n = 0, 1, 2, \dots, N / 2 - 1$ , then the high-frequency electronic signal sequence transmitted on another independent path is as shown in formula (1):

$$x_k = \sum_{n=0}^{N-1} C_n \cdot e^{j2\pi kn/N}, k = 0, 1, 2, \dots, N - 1 \tag{1}$$

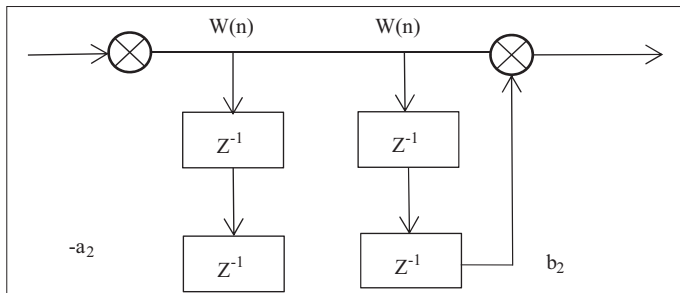
The rapid frequency hopping method is used to offset the fading phase shift, and the simplified electronic communication signal can be obtained as shown in formula (2):

$$x_k = \sum_{n=0}^{N/2-1} 2 \left( a_n \cos \frac{2\pi kn}{N} - b_n \sin \frac{2\pi kn}{N} \right), k = 0, 1, 2, \dots, N - 1 \tag{2}$$

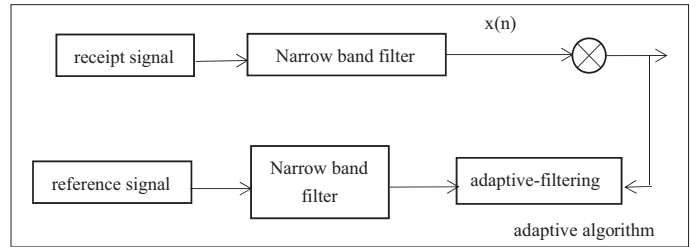
If  $S_o(t) = a_0 \delta(t)$  arrives at the receiver, the communication signal sampling is completed by the matched filtering method, and the symbol timing sampling signal  $S(t)$  of the communication system is composed of the gain pulse of the branch, expressed as the formula (3):

$$S(t) = a_0 \sum_{i=1}^N \alpha_i \delta(t - \tau_i) e^{jw_c t} \tag{3}$$

In the formula,  $N$  is the number of communication paths;  $\tau_i$  and  $\alpha_i$  are the frequency shift keying delay and delay spread coefficient of the  $i$ th channel, respectively;  $w_c$  is the diversity gain frequency. The transfer function difference of the entire electronic communication system is as shown in formula (4):



**Fig. 2.** System structure of electronic communication.



**Fig. 3.** Block diagram of the electronic communication channel model.

$$e(n) = d(n) - u^T(n)w(n) \tag{4}$$

When crosstalk has a serious impact, a powerful receiving technology is used to obtain frequency-domain data signals, thereby realizing the construction of electronic communication channel models. The process description is shown in Fig. 3.

**B. Analysis of Characteristic Parameters of Transmission Signal**

Using space diversity to perform discretization sampling of high-frequency electronic communication signals, taking the discrete multipath case as an example, the received signal of the electronic communication channel is obtained as shown in formula (5):

$$x(t) = \text{Re} \left\{ a_n(t) e^{-j2\pi f_c \tau_n(t)} s_i(t - \tau_n(t)) e^{-j2\pi f_c t} \right\} \tag{5}$$

The transfer function of the entire system is corrected, and the frequency domain characteristic parameters of the electronic communication signal can be described as shown in formula (6):

$$c(\tau, t) = \sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} \delta(t - \tau_n(t)) \tag{6}$$

In the formula,  $a_n(t)$  is the impulse response of the  $n$ th path channel and  $\tau_n(t)$  is the decision feedback equalization time delay of the  $n$ th path.  $f_c$  is the modulation frequency.

The signal component of  $S_i(t)$  can be obtained through maximum likelihood detection. Extend the information symbols covered by the channel inter-symbol interference to the communication signal of the smallest bandwidth. Due to the inter-symbol interference generated by the multipath channel, through the inter-symbol interference suppression, the symbol reception length parameter of the signal set is obtained, as shown in the formula (7) :

$$R(t) = \frac{\sqrt{WT}}{WT} \sin \left[ \pi WT \left( 1 - \frac{|t|}{T} \right) \right] \cos(2\pi f_0 t) \tag{7}$$

where  $WT$  is the dynamic compensation gain. Data detection is performed on the channel with inter-symbol interference. For the sweep bandwidth  $W$ , the time width of the channel in the transmission time is  $T$ , as shown in formula (8):

$$\beta = W / T \tag{8}$$

When the channel response extension time exceeds ten symbols in length, the arrival time delay of each multipath of the electronic communication becomes an integer multiple of  $TS$ , so the time-frequency

relationship of the increase of the number of symbols in the electronic communication channel is as shown in formula (9):

$$f_i = f_0 + \beta t \quad (9)$$

where  $\beta$  is the channel response expansion time. The channel frequency response has a spectral zero, and the channel propagation loss at this time is described as shown in formula (10):

$$TL = n \cdot 10 \lg r + \alpha r \quad (10)$$

In the formula,  $TL$  is the channel propagation loss and  $n$  is the propagation factor. Through the adaptive estimation of the channel propagation loss, the expression of the feedforward filtering transfer function of the multipath channel of the communication system is obtained as shown in formula (11):

$$h(\tau_i, t) = \sum_{i=1}^{N_m} a_i(t) e^{j\theta_i(t)} \delta(t - \tau_i(t)) \quad (11)$$

In order to reduce the propagation loss, the carrier frequency is often below 10 kHz. The small disturbance suppression method is used to reduce the steady-state error, and the received signal spectrum beyond the Nyquist frequency is equalized. The frequency is  $f = NMT$ , and the input analog signal spectrum with limited bandwidth is as shown in formula (12):

$$C_{T'}(f) Y_{T'}(f) = C_{T'}(f) \sum_n X\left(f - \frac{n}{T'}\right) e^{-j2\pi\left(f - \frac{n}{T'}\right)\tau_0} = C_{T'}(f) X(f) e^{j2\pi f \tau_0} \quad (12)$$

where  $X(f)$  is the bandwidth,  $Y_{\tau}(f)$  is the frequency spectrum of the sampled signal, and  $\tau_0$  is the time delay.

Using spatial beamforming for signal expansion, the iterative way of signal expansion is as shown in formulas (13) and (14):

$$f(k+1) = f(k) - \mu \cdot \rho \cdot e_{MDMMA}(k) y^*(k) \quad (13)$$

$$e_{MDMMA}(k) = z(k) \left[ |z(k)|^2 - R_{MDMMA}(k) \right] \quad (14)$$

where  $\rho$  is channel distortion interference noise.

The matched filter is used for channel distortion recombination, and the information code baud rate  $S_{\tau}(t)$  received by the sampled signal spectrum is shown in formula (15):

$$S_{\tau}(t) = S(t) * h(t) + n_s(t) \quad (15)$$

where  $n_s(t)$  is the characteristic response function of the baud rate in the local interference noise.

### C. Examples of Experimental Design and Simulation of Communication Principles

Based on the teaching content and arrangement sequence of the communication principles and systems courses, a series of simulation experiments covering the main content of the communication principles and systems courses have been developed in a series and systematic manner. There are not only confirmatory experiments

but also comprehensive and innovative experiments. The flow of the communication system can be summarized as signal generation and output, encoding and decoding, modulation and demodulation, multiple access methods, filters, and transmission medium models [17, 18]. Each design model also contains a large number of sub-modules, which basically cover the various module models used in the current communication system, and the communication system can generally establish a mathematical model. According to the mathematical model (or mathematical expression) of the communication system to be simulated, the user only needs to find the required modules from the above-mentioned model libraries, drag them to the model window with the mouse and combine them together, and set each model parameter. You can easily perform dynamic simulation [19, 20].

The simulation result can be seen from the output module. After each simulation result, you can also change the parameters to observe the changes in the simulation results. You can also generate the sub-modules you need according to your own technology, and you can encapsulate and customize the module library for calling at any time. Let us take the pulse coding modulation (PCM) experiment as an example and use MATLAB software to verify its basic principles. Pulse coding modulation technology has been widely used in digital communication systems [21]. It is an encoding method that transforms analog voice signals into digital signals and is mainly used for voice transmission. Through this experiment, we understand the working principle and implementation process of PCM encoding and decoding and understand the main indicators of voice signal digitization technology. Fig. 4 shows the simulation model of the PCM communication system. According to the mathematical model of the communication system to be modeled, the user simply needs to find the required modules from the above model libraries, drag the mouse into the model window, and adjust the parameters.

### D. AM Standard Amplitude Modulation Design

In this research, the software has MATLAB software as a simulation experiment method to design the amplitude modulation (AM) module. The AM module can process the signal, pass the signal through the superimposed current, and then process the carrier, so that the output signal becomes a conventional double-sideband AM signal. AM signal modulation model is shown in Fig. 5.

The waveform of the AM signal is proportional to the waveform of the input baseband signal, so the envelope detection method can effectively restore the original modulated signal. Both the upper and lower sidebands of the AM signal carry all the information of

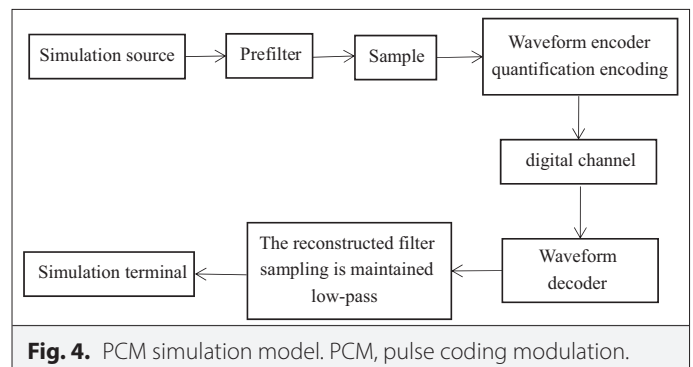
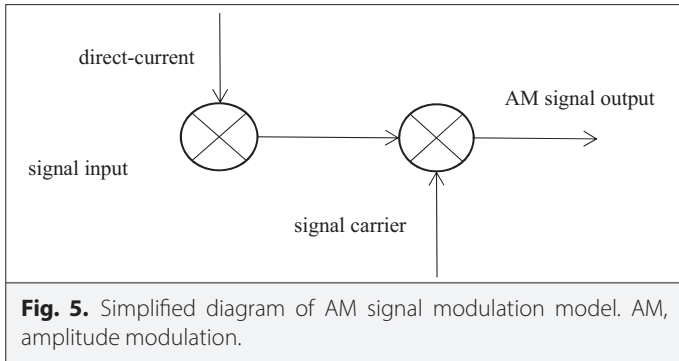


Fig. 4. PCM simulation model. PCM, pulse coding modulation.



the original modulated signal, so the AM signal can be regarded as a double-sided band signal with a carrier, and the bandwidth of the AM signal is twice the bandwidth of the original signal [22].

**IV. RESULTS AND DISCUSSION**

MATLAB software is used for simulation experiment. The communication protocol of electronic communication adopts IEEE802.11 protocol, the symbol radiation radius of electronic communication is  $r=270$  m, the symbol rate is 1 kBaud, the high-frequency electronic carrier frequency is 3 kHz, and the same frequency electronic interference is assumed to be one group chirp signal interference. The order of the feedforward filter is 24, the order of the feedback equalizer is 3, and the signal-to-noise ratio is  $-10$  to  $0$  dB. Sampling is performed at 13 and 23 symbols, respectively. The radius of the same frequency electronic interference is 550 m, and the threshold of channel transmission is 0 to 50 m/s[23, 24]. According to the test environment and test plan set above, the simulation experiment method test process is completed to obtain the following test results, and the passed data are shown as follows.

Adopt baud interval equalization technology to design channel equalization, after multipath channel equalisation processing, output the local carrier and modulated wave signal of electronic communication as shown in Fig. 6. It can be seen from Fig. 6 that the electronic communication system channel of the method in this paper is very balanced, which improves the communication transmission capacity of the signal, and the signal has a good balance after passing through the multipath channel [25, 26]. Fig. 6 shows that the high-frequency electronic remote communication system has low code error rate, good channel equilibrium performance, high system stability, and has better practical application value.

In order to verify the superiority of this method, compared with the traditional method, the comparison result of bit error rate is shown in Fig. 7. It can be seen from Fig. 7 that the electronic communication error rate of the method in this paper is between 0.2 and 0.5, while the traditional method is much higher than the method in this paper and remains above 0.3. Therefore, this method improves the stability of communication system and the accuracy of communication transmission. Table I. shows the experimental processing time for the proposed model and the traditional method.

**V. CONCLUSION**

In this paper, MATLAB is applied to the communication principle experiment with an example, which can analyze the characteristics

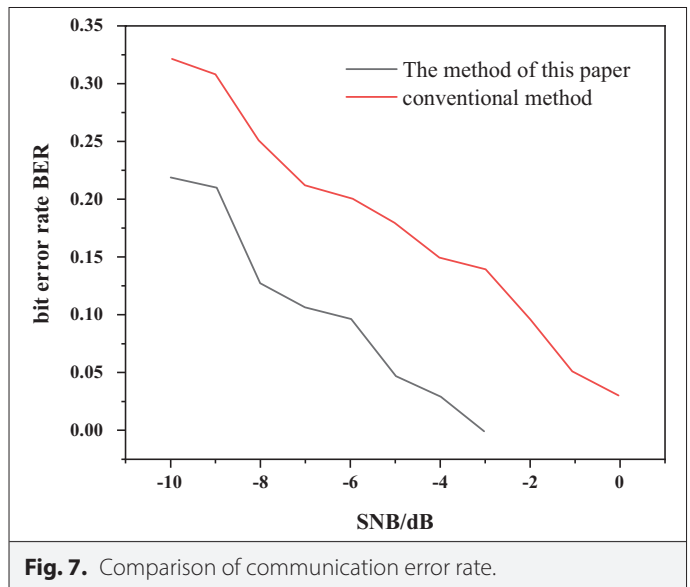
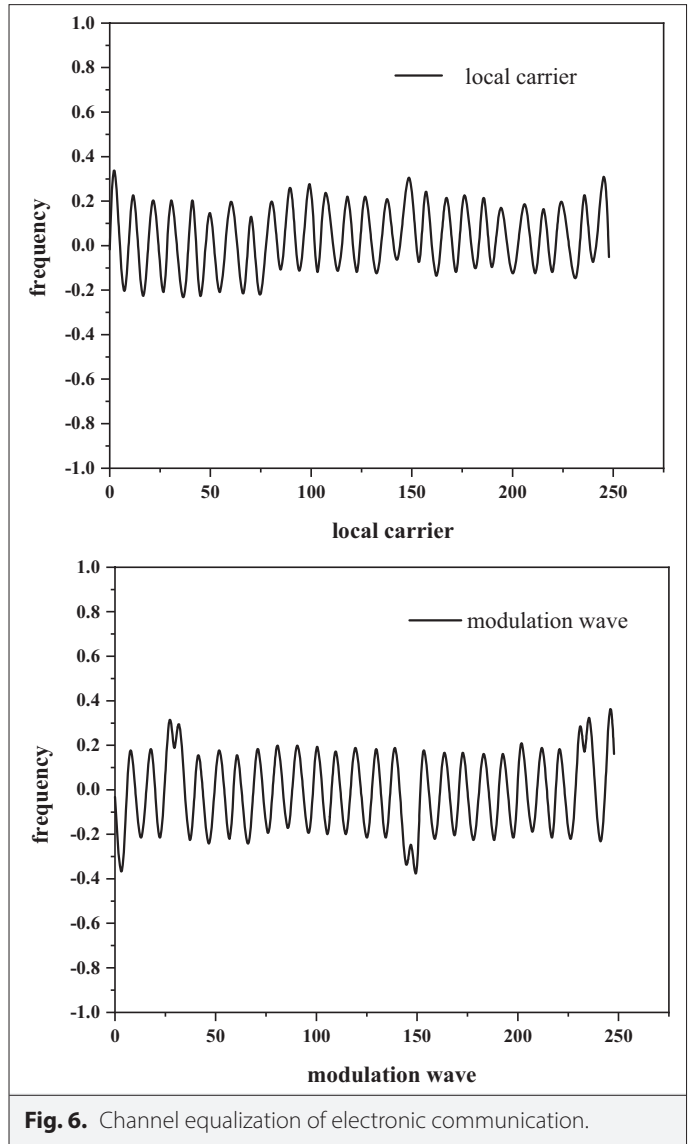


TABLE I. EXPERIMENTAL PROCESSING TIME

The Number of Experiments	Processing Time/Min	Traditional Method of Processing Time/Min
1	4.01	4.21
2	4.01	4.32
3	4.06	4.16
4	4.10	4.14
5	4.02	4.38

of various signals, the influence of various parameters on the performance of the communication system in simple language, and realize the synchronization of teaching and experimental verification. Aiming at the defects of large distortion and high communication bit error rate of traditional electronic communication system, in order to improve the performance of electronic communication system, the design and implementation of simulation experiment of electronic communication system based on Matlab software is proposed. Firstly, the channel model of high frequency electronic telecommunication system is constructed and high-frequency electronic signal transmission model is used. Then the baud interval equalization technology is used to carry out the channel equalization design; finally, the system debugging and simulation experiments are carried out. The experimental results show that the electronic communication bit error rate of the system in this paper is low, the channel equalization performance is good, and the system stability high, with better practical application value.

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