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Original article

# Suppression method of inter-symbol interference in communication system based on mathematical chaos theory

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ABSTRACT

Inter-symbol interference (ISI) is prone to occur in the operation of communication system, which affects the quality of communication. Therefore, the suppression method of ISI in communication system based on mathematical chaos theory is studied to optimize the quality of communication transmission. Based on the analysis of the principle of ISI in communication system, it is known that multi-path delay can lead to ISI. The multi-path channel model of communication system is constructed, the multi-path component delay of the channel is calculated, and the inter-symbol interference is suppressed by setting a reasonable delay. The equalizer's weight vector of communication channel is optimized by using chaotic optimization algorithm, the optimized equalizer tap of communication channel is obtained, and the reasonable multi-path component delay of channel is calculated to effectively suppress ISI. The simulation results show that the suppression method of ISI based on mathematical chaos theory can effectively overcome the ISI of multi-path channel, improve the resolution of transmission signal and the quality of communication transmission.



## 1. Introduction

Inter-symbol interference (ISI) exists in the transmission of signals in communication systems. For example, optical communication systems need large output signal-to-noise ratio (SNR) and low bit error rate (BER). However, under the influence of propagation loss and environmental electromagnetic radiation, Doppler frequency shift is unavoidable. Doppler frequency shift affects carrier tracking and symbol synchronization in optical communication, and produces multi-path characteristics of channel, which makes communication channel vulnerable to multi-path ISI, resulting in error code and channel imbalance (Pergoloni et al., 2017). In order to avoid channel congestion caused by unbalanced communication channels, it is necessary to reduce the output error rate. The main performance evaluation index of communication system is reliability and validity. Reliability measures the quality of communication. Therefore, it is necessary to suppress ISI and improve the quality of communication. The research on suppression method of ISI is helpful to the development of communication system (Lenty Stuwart and Tamil Selvi, 2015; Yoon et al., 2015). Therefore, the research of ISI suppression technology in communication system has important practical significance.

In the past, there have been many studies on the suppression of ISI in communication systems. Scholars in this field have proposed a method to suppress the intermodulation distortion of lasers in turbulent channels to achieve the suppression of inter-symbol interference in optical fiber laser communications. BPSK symbol modulation of the channel is carried out based on the improved singular value decomposition method. Channel's spread spectrum is realized by using the theory of pulse compression through the copy correlation of the received signal. The turbulence loss is suppressed and the communication quality is improved (Yao et al., 2015), but the equalization effect of this method is not good when the communication channel is subjected to large inter-symbol interference. In addition, some scholars have proposed a method of blind channel identification with FFT method to resist order over-estimation, which can realize blind equalization estimation and ISI suppression of communication channel and improve the throughput and spread spectrum capacity of communication channel. The computational overhead of this method is large, and it is

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prone to delay and communication distortion in blind channel identification and estimation. Therefore, this paper studies the suppression method of inter-symbol interference in communication system based on mathematical chaos theory. The principle is to suppress the ISI in communication system by optimizing the equalizer tap of communication channel and calculating the reasonable multi-path component delay of channel.

## 2. Application theory of algorithm

### *2.1. Inter-symbol interference and multi-path channel analysis in communication system*

#### *2.1.1. Principle analysis of inter-symbol interference in communication system*

In the optical communication system, the optical channel is divided into direct channel and diffuse channel, that is, the optical pulse signal will arrive at the detector through different paths, and the signals of different paths will produce time delay, which will cause the overlap and crosstalk between different optical pulse signals in time (Wu et al., 2015), as shown in Fig. 1.

In Fig. 1, the signal transmitted by path 2 has a certain time delay compared with the signal transmitted by path 1. When the time delay is larger than the transmission interval of the pulse signal, the adjacent two pulse signals will be aliased when they arrive at the detector (Deng and Chen, 2017; Gao and Wang, 2017a,2017b; Jin and Mi, 2019). When accepting the sampling decision, it may lead to inter-symbol interference which not only causes the decision error, but also weakens the signal energy and reduces the signal-to-noise ratio (Akhtar et al., 2015; Li et al., 2018; Zhang et al., 2015a,2015b). Relevant studies show that the average signal-to-noise ratio (SNR) of the channel decreases due to the inter-symbol interference caused by diffuse light.

In addition to multi-path delay, channel distortion can also cause ISI. Because of the unsatisfactory channel, symbol widening and delay occur in the transmission process. In the waveform, symbol pulse trailing occurs, and the trailing of adjacent pulses overlaps with each other, which makes the receiving symbol error, as shown in Fig. 2.

In fact, for communication systems, inter-symbol interference can be neglected at low transmission rates. This is because the signal delay is far less than the symbol period, and the adjacent symbols will not produce crosstalk. With the increase of transmission rate (Li and Zheng, 2015), the signal delay can be compared with the symbol period, or even greater than the symbol period. At this time, the aliasing between adjacent symbols will occur (Dar et al., 2015; Gao et al., 2017; Mi et al., 2015; Harraga and Yebdri, 2018). This shows that the effect of ISI on the performance of communication system increases with the increase of the rate. Relevant research results show that when the transmission rate is below 100 Mb/s, ISI has little effect on the performance of communication system; when the transmission rate of the system is above 100 Mb/s, the performance of communication system is seriously deteriorated by ISI, which can no longer meet the requirements of communication, and the ISI of communication system needs to be suppressed (Li and Li, 2015; Zhang et al., 2015a,2015b).

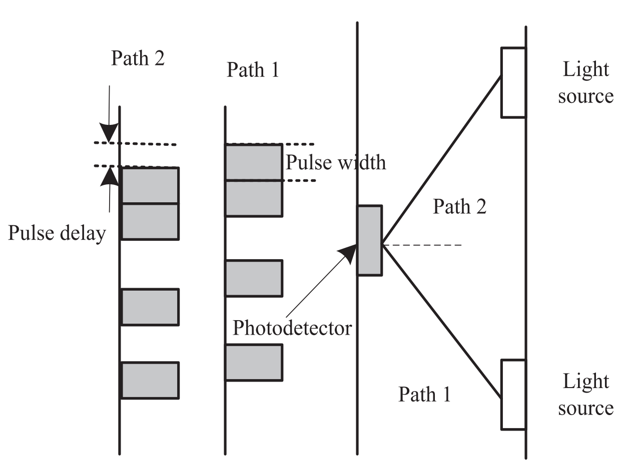


**Fig. 1.** Inter-symbol interference due to multi-path transmission delay.

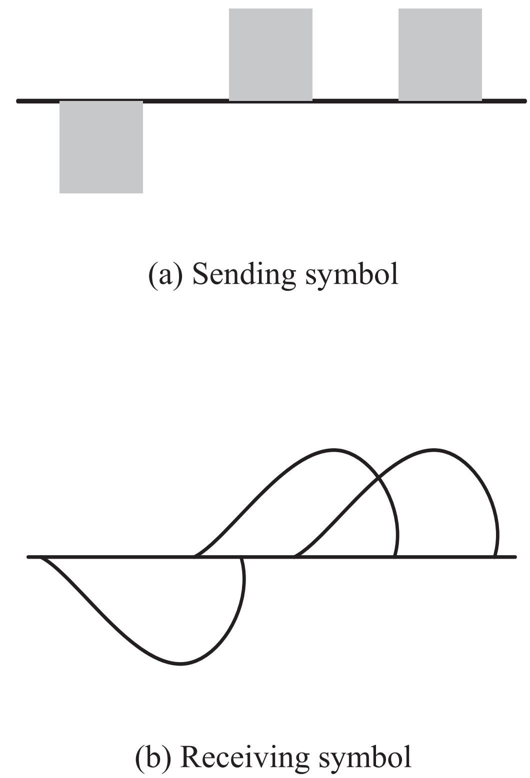


**Fig. 2.** Inter-symbol interference due to symbol broadening due to channel distortion.

#### *2.1.2. Analysis of channel impulse response in communication system*

In order to achieve the design of ISI suppression for communication system, the transmission channel model of communication system is constructed. Assuming that the maximum time interval of multi-path components is s, the communication terminal receives signal samples and generates sample sets:

$$X = DW + Z \tag{1}$$

Under the constraint of multi-path propagation characteristics, it is assumed that the energy attenuation of communication channel is as follows:

$$|s(f)| = A\sqrt{\frac{1}{2k}\left\{[c(v_1) + c(v_2)]^2 + [s(v_1) + s(v_2)]^2\right\}} \tag{2}$$

In the formula, A is the output signal amplitude of the optical fiber communication channel, f is the initial frequency of channel attenuation, $k = \frac{B}{T}$ is the slope of frequency modulation, and B is the phase offset of each path. An adaptive noise canceller is used to suppress multi-path interference. The multi-path channel model of the communication system is constructed as shown in Fig. 3.

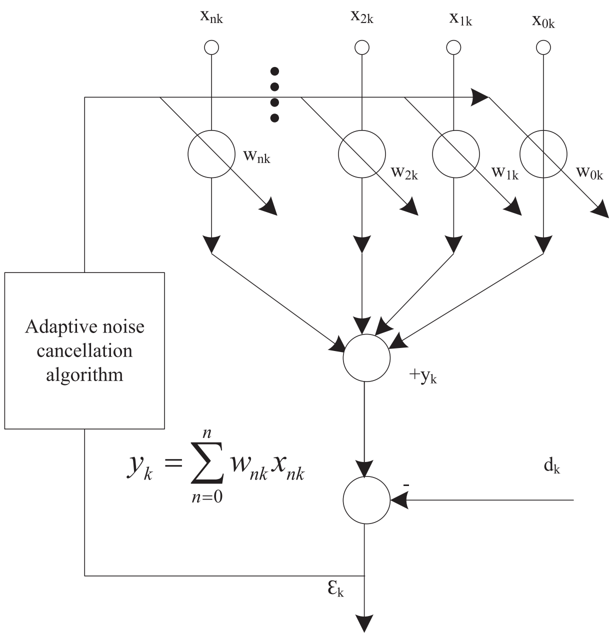


**Fig. 3.** Multi-path channel model of communication system.

In the multi-path channel model of the communication system shown in Fig. 3, the channel impulse response is expressed as follows:

$$h(t) = \sum_i a_i(t) e^{j\theta_i(t)} \delta(t - iT_s) \tag{3}$$

In the formula, $\theta_i(t)$ is the frequency doubling offset of each path, $\theta_i(t)$ is positively correlated with symbol rate $f_s$. The angle between each path and the direct path is an integral multiple of symbol width $T_s$. By adding phase offset of multi-path component, the channel impulse response of communication system is described as follows:

$$h(\tau_i, t) = \sum_{i=1}^{N_m} a_i(t) e^{j\theta_i(t)} \delta(t - \tau_i(t)) \tag{4}$$

*2.1.3. Calculation of multi-path component delay of the channel*

Because the delay of channel's multi-path component causes ISI in communication system, the delay of channel's multi-path component is calculated based on the communication channel model constructed above, and the ISI is suppressed by setting reasonable delay (Chen and Wei, 2016; Rui et al., 2016). The signal $S(t)$ received by the communication channel is composed of many pulses with different time delays. According to the phase offset of each path, the multi-path components of multi-channel are processed with time weights. According to the tapped delay line model constructed above, time-frequency characteristic decomposition is performed on different transmission paths of communication channel (Bono, 2016; Gao and Wang, 2017a,2017b; Konwar and Debnath, 2017; Pyskunov et al., 2016; Schulze, 2016; Turgut, 2016), Assuming that the arrival time delay of each multi-path is an integer multiple of $T_s$, the cluster component is taken as the initial eigenvector of impulse response, and the signal's sparsity representation model of communication system is constructed.

$$D = \left\{ d_m(t) = \sum_{k=1}^{K(m)} p(t - \tau_{mk}), m = \{1, 2, \cdots, N\} \right\} \tag{5}$$

In the formula, $\tau_{mk}$ is the impulse coefficient.

According to the sparse representation model, the *i*th path delay of communication channel for data transmission in communication network is obtained as follows:

$$\begin{aligned} f(D, W) = \lambda \| (X - DW)G \|_F^2 \\ s.t \| w_i \|_0 \leqslant k \forall i \end{aligned} \tag{6}$$

In the formula, $k$ is the sparsity of vector $w_i$, $\lambda$ is the impulse convergence factor in stable state and $G$ is the tap of equalizer in communication channel, where the tap of equalizer is an unknown variable. In order to obtain a reasonable multi-path component delay of channel, the tap of equalizer is optimized. Therefore, the mathematical chaos optimization theory is introduced to optimize the tap parameters of equalizer in communication channel.

### *2.2. Suppression method of ISI based on channel equalization optimization*

*2.2.1. Mathematical chaos optimization theory*

Chaotic optimization algorithm takes advantage of the spatial ergodicity of chaos and expresses the optimization variables needed by the system with the chaotic variables generated by the chaotic map. At the same time, the ergodic range of chaos is transformed to the definition domain of optimization variables, and chaotic variables are used to search the global optimal solution, which is regarded as the global optimal solution of optimization variables (Liu et al., 2018; Sen Gupta, 2017; Yassaee et al., 2015; Yang et al., 2018). However, there is a disadvantage of chaotic motion, that is, it does not traverse the space in a uniformly distributed way, and chaotic operators need a lot of computation to traverse all the space. The sensitivity of initial values of chaotic motion makes the domain of independent variables sensitive and affects the trajectory of chaotic motion. Therefore, the performance of chaotic optimization algorithm is unstable and takes a long time. Thus, when chaotic variables are used to disturb the current point of the weight vector, time-varying parameters are introduced, and the disturbance amplitude decreases gradually with the updating of the time-varying parameters, so as to gradually achieve the goal of local fine search near the optimal solution, and achieve the global optimal value of the weight vector.

*2.2.2. Weight vector optimization of equalizer in communication channel based on chaos optimization algorithm*

Chaotic variables are introduced by using carrier-like method, and chaotic variables are used to search. Time-varying parameters are introduced in the process of secondary carrier. A time-varying parameter $\Psi(t)$ is defined and introduced into the optimization variables by formula (7) and (8):

$$f_{Re}(K) = f_{Re}^* + \Psi(t)(C(K) - 0.5) \tag{7}$$

$$f_{Im}(K) = f_{Im}^* + \Psi(t)(C(K) - 0.5) \tag{8}$$

where, $f_{Re}(K)$ and $f_{Im}(K)$ constitute optimization variables, $K$ is the $K$-th iteration and $t$ is the $t$-th iteration; $f_{Re}^*$ and $f_{Im}^*$ are the real and imaginary parts of the current optimal variables; $C(K) = (C_1(K), C_2(K), \cdots, C_n(K))$ is the chaotic variable generated by the chaotic map, $n$ is the dimension of the optimization variable; and $C_i(K)$ is the $i$-th dimension value of $C(K)$. The iteration formula of time-varying parameters is $\Psi(t+1) = \lambda\Psi(t)$, in which $\lambda$ is the attenuation factor of time-varying parameters, $\lambda < 1$, and $\lambda \in [0.95, 0.999]$ is generally chosen. The initial value of $\Psi(t)$ is defined as follows:

$$\Psi(0) = (J^* - J_{\max})/\ln P \tag{9}$$

In the formulas, $J^*$ and $J_{\max}$ are the corresponding minimum objective function values and the maximum objective function values of all feasible solutions obtained in the first stage of chaotic search, so that the parameter $P$ is selected in the range of $0 < P < 1$.

The chaotic algorithm is used to solve the minimum value $J^*$ of the cost function to optimize the tap. When chaotic variables are generated, one-dimensional Logistic mapping is used to generate chaotic signals. The mapping formula is as follows:

$$C(K+1) = \rho C(K)[1 - C(K)] \tag{10}$$

In the formula, when $\rho \in [3.57, 4]$, the mapping is chaotic.

Let the objective function of the continuous object to be optimized be $J^* = J(f^*) = \min J(f)$, $J$ represent the objective function, $f_{Re} \in [d_{Re}, e_{Re}], f_{Im} \in [d_{Im}, e_{Im}]$, $f$ represents the optimization variable, $f_{Re}$ and $f_{Im}$ are the real and imaginary parts, $e_{Re}$ and $d_{Re}$ are the upper and lower limits of $f_{Re}$, $e_{Im}$ and $d_{Im}$ are the upper and lower limits of $f_{Im}$. When the number of iterations in the first stage of chaotic search is $N_1$ and the number of iterations in the second stage of chaotic search is $N_2$, the steps of optimizing the weight vector of equalizer in communication channel by chaotic optimization algorithm are as follows:

(1) The difference value of [0,1] interval is given to form vector $c(0)$ (not 0, 0.25, 0.5, 0.75, 1), $n$ is the dimension of the weight vector, the optimal solution of the channel's equalizer weight vector is set to $f^*$, and the corresponding cost function is the initial value of $f^*$ and $f_{\max}$, so that $K = 0$, $K' = 0, t = 0$.

(2) n chaotic variables are obtained by the iteration of formula (9), and their trajectories are different from each other. They are enlarged to the range of optimal variables by formula (11), (12):

$$f_{Re}(K) = s_{Re} + r_{Re}C(K) \tag{11}$$

$$f_{Im}(K) = s_{Im} + r_{Im}C(K) \tag{12}$$

where, $f_{Re}(K)$ and $f_{Im}(K)$ are the real and imaginary parts of $f(K)$, $s_{Re} = d_{Re}$, $s_{Im} = d_{Im}$, $r_{Re} = e_{Re} - d_{Re}, r_{Im} = e_{Im} - d_{Im}$.

(3) After iteration of chaotic variables, $J(f(K))$ is calculated and $J_{\max}$ and $J^*$ are retained. If $J(f(K)) \leqslant J^*$, then $J^* = J(f(K))$, $f^*_{Re} = f_{Re}(K)$, $f^*_{Im} = f_{Im}(K)$; if $J(f(K)) > J_{\max}$, then $J_{\max} = J(f(K))$, $K = K + 1$, if $K \leqslant N_1$, then turn to step (2).

(4) After the above $N_1$-step search to $J^*$, the parameter $P$ is selected, to calculate the initial value of the time-varying parameter $\Psi(t)$:, and carry $\Psi(0) = (J^* - J_{\max})/lnP$ out the second carrier according to the following formula:

$$f'_{Re}(K') = f^*_{Re} + \Psi(t)\left(C(K') - 0.5\right) \tag{13}$$

$$f'_{Im}(K') = f^*_{Im} + \Psi(t)\left(C(K') - 0.5\right) \tag{14}$$

In the formula, $f^*_{Re}$ and $f^*_{Im}$ are the real and imaginary parts of the current optimal solution $f^*$.

(5) The second carrier of chaotic variable is searched carefully and $J(f(K'))$ is calculated. If $J(f(K')) \leqslant J^*$, then $J^* = J(f(K'))$, $f^*_{Re} = f_{Re}(K') f^*_{Im} = f_{Im}(K')$; otherwise, give up $f_{Re}(K')$ and $f_{Im}(K').K' = K' + 1, \Psi(t+1) = \lambda\Psi(t)$, $t = t + 1$.

(6) If the termination condition $K' > N_2$ is satisfied, then the search is stopped and $J^*$ and the corresponding global optimal solution $f^*$ are output; otherwise, step 5 is returned.

Therefore, the above steps (1)-(6) are the process of optimizing the weight vector of equalizer in communication channel by chaotic optimization algorithm, and the output result $f^*$ is the tap of equalizer. Based on the tap of equalizer, reasonable multi-path component delay of channel is set to effectively suppress intersymbol interference.

## 3. Results

In order to verify the performance of the proposed method in improving communication quality, simulation experiments are carried out. The experiment takes the optical fiber communication system as the simulation object, and tests the effect of the proposed method to improve the BER and output SNR of the communication system. In the experiment, C++ and Matlab 7 are used to design the method to suppress the inter-symbol interference of the communication system. The normalized amplitude and relative delay of the channel in the simulation are set in Table 1. The comparison methods in the experiment are the interference suppression method based on PTS-Clipping and the interference suppression method based on time-weighted.

Previous studies have shown that the effect of ISI on the performance of communication systems increases with the increase of the rate. Table 2 shows the relationship between the rate and bit error rate of the experimental communication system.

From Table 2, it can be seen that the BER of experimental communication system increases with the increase of communication rate, which is consistent with the relevant research results. When the communication rate is lower than 100 Mb/s, the BER is always lower than 5%, and the ISI is lower. When the communication rate reaches 100 Mb/s, the BER reaches 6.5%, showing a higher trend. During the whole test process, the BER of communication is always proportional to the communication rate. When the communication rate reaches the maximum of 150 Mb/s, the error rate of the communication system reaches 11.5%. Therefore, the ISI suppression test is carried out for the experimental communication system.

### 3.1. Analysis of inhibition effect

According to the above simulation environment, the proposed channel model is four groups. The BPSK modulation signal is used to test the communication performance. In the test, the symbol rate of the transmitted number signal in the optical fiber communication system is 2.4 kBaud, the carrier frequency is 5 kHz, the pulse arrival rate in the communication channel cluster is $2.4 \times 10^9$ pulse/s, the multi-path resolution in the transmission channel is 0.3 ns, and the SNR is 0 dB. The obtained signal of optical fiber communication is shown in Fig. 4.

Fig. 4 shows that the original communication signal is interfered by ISI, which affects the equalization and transmission

**Table 1**
Multi-path channel parameters for communication systems.

| Channel model | Channel Model Conditions | Multi-path Amplitude Parameter | Multi-path Delay Parameters (Ts) |
|---|---|---|---|
| Model 1 | The delay is less than the bandwidth of the optical fiber. | 1.2, 0.3, −0.2, 0.13, −0.11 | 0.2, 0.4, 0.5, 0.6, 0.8 |
| Model 2 | The delay difference is greater than the bandwidth of the optical fiber. | 1, 0.3, −0.2, 0.12, −0.13 | 0, 1.1, 2.2, 3.3, 5.9 |
| Model 3 | Delay difference equals fiber bandwidth | 1, 0.4, −0.5, 0.16, −0.17 | 0, 1.1, 2.2, 3.4, 4.5 |
| Model 4 | Hybrid delay difference | 0.2, −0.3, 0.13, −0.12 | 0, 0.4, 1.5, 3.0, 3.3 |

**Table 2**
Relation between communication rate and bit error rate in experimental communication system.

| Time/s | Communication rate (Mb/s) | Communication BER/% |
|---|---|---|
| 3 | 50 | 1.0 |
| 6 | 60 | 2.3 |
| 9 | 70 | 2.9 |
| 12 | 80 | 3.8 |
| 15 | 90 | 4.7 |
| 18 | 100 | 6.5 |
| 21 | 110 | 7.8 |
| 24 | 120 | 9.4 |
| 27 | 130 | 10.5 |
| 30 | 140 | 11.2 |
| 33 | 150 | 11.5 |

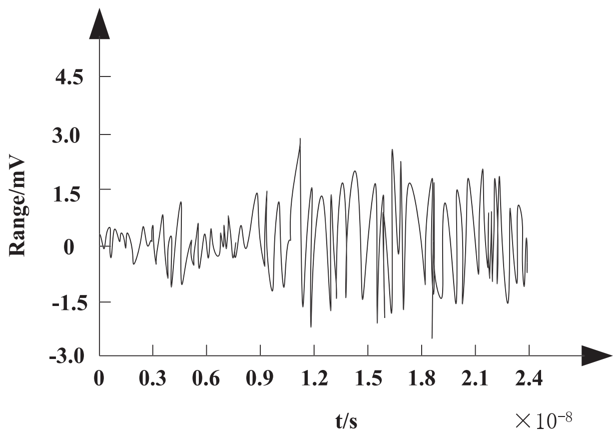


**Fig. 4.** The original communication signal waveform.

performance of the channel. Three different suppression methods of ISI are used to test the suppression of ISI. The results are shown in Fig. 5, Fig. 6 and Fig. 7, respectively.

From the simulation results of Fig. 5, Fig. 6 and Fig. 7, it can be seen that the proposed method realizes sparse signal representation, effectively overcomes the ISI of multi-path channel and improves the resolution of transmission signal. The interference suppression method based on PTS-Clipping and the interference suppression method based on time-weighted have poor performance in suppressing inter-symbol interference and cannot achieve full sparse representation of signals.

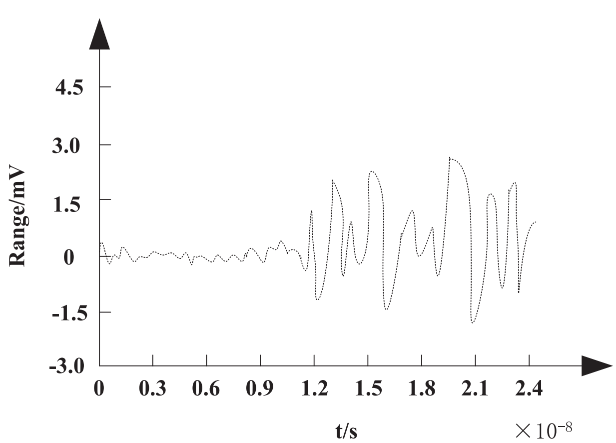


**Fig. 5.** The method in this paper.

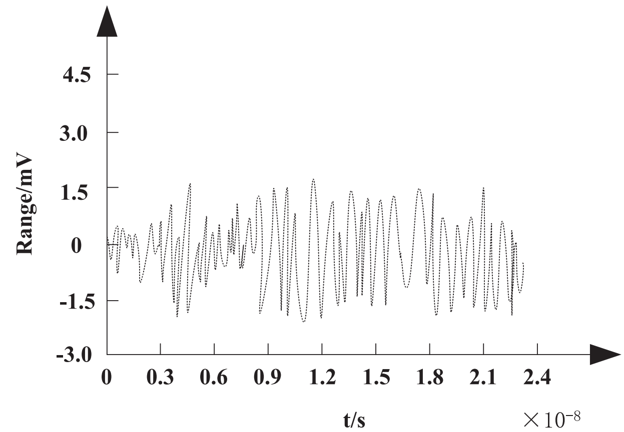


**Fig. 6.** Interference suppression method based on PTS-Clipping.

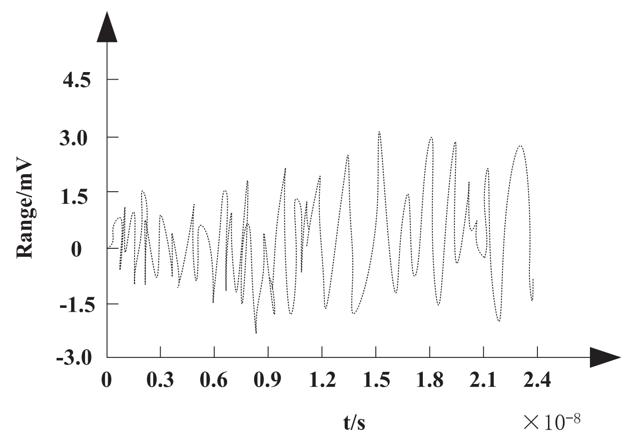


**Fig. 7.** Interference suppression method based on time weight.

### *3.2. Impulse response analysis of channel model*

In the process of communication system operation, the output results of impulse response of four channel models in the proposed method are shown in Fig. 8.

Fig. 8 shows that the optimized communication channel has better equalization ability, higher impulse response gain of output signal, and better channel resistance to inter-symbol interference.

### *3.3. Comparison analysis of bit error rate*

In order to further verify the superiority of the proposed method in suppressing inter-symbol interference in communication systems, the interference suppression method based on PTS-Clipping, the interference suppression method based on time-weighted and the proposed method are used to test the BER of communication systems under different SNR environments. The BER of communication systems under the three methods is recorded. The initial signal-to-noise ratio is set to $-60$ dB, which is limited to the length after $-20$ dB. The experimental data are used to analyze and compare the inter-symbol interference of communication systems. The simulation results are shown in Table 3.

From Table 3, we can see that under different SNR environments, the three methods all reduce the BER of communication. The effect of the proposed method is remarkable. The initial ability of the interference suppression method based on PTS-Clipping and

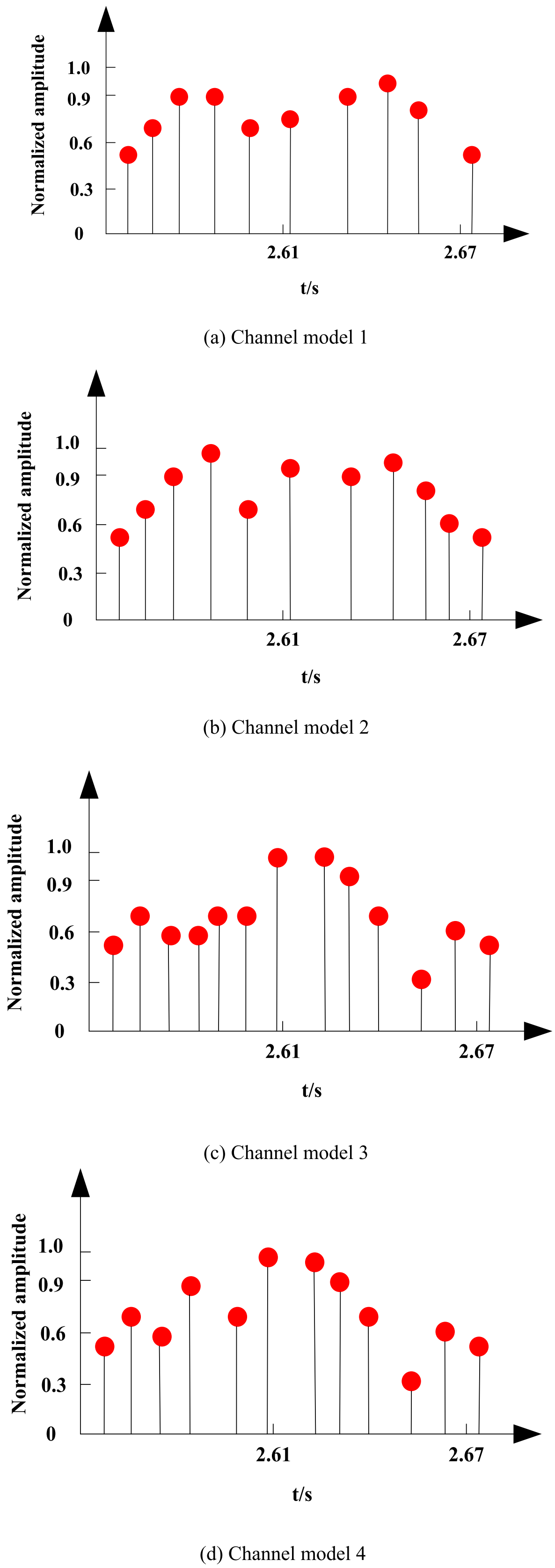


**Fig. 8.** Channel impulse response output of communication system.

the interference suppression method based on time-weighted to reduce the BER of communication is weak.

**Table 3**
Comparison of BER of different communication methods/%

| Signal-to-noise ratio/dB | Article method | PTS-Clipping Interference Suppression Method | Interference Suppression Method Based on Time Weight |
|---|---|---|---|
| −20 | 5.21 | 25.6 | 36.5 |
| −15 | 4.26 | 22.3 | 34.6 |
| −10 | 3.22 | 19.5 | 32.1 |
| −5 | 2.19 | 16.9 | 29.5 |
| 0 | 1.12 | 14.3 | 25.4 |
| 5 | 0.98 | 13.7 | 24.5 |
| 10 | 0.92 | 12.9 | 23.5 |
| 15 | 0.91 | 12.5 | 21.4 |
| 20 | 0.85 | 12.1 | 19.8 |
| 25 | 0.83 | 11.9 | 18.4 |
| 30 | 0.75 | 11.6 | 17.6 |
| 35 | 0.71 | 11.5 | 15.6 |
| 40 | 0.66 | 11.1 | 15.4 |

### 3.4. Suppression performance analysis of ISI

The performance of suppression methods for ISI is tested in terms of time, space and energy overhead. Each method completes 10 simulation tasks of ISI. The data mean is taken as the experimental result. The performance test results of the three methods under different SNR environments are shown in Table 4.

The data in Table 4 show that the average time cost of the proposed method is 0.9 s, which is 11.4 s and 14.7 s less than that of the interference suppression method based on PTS-Clippingand the interference suppression method based on time-weighted respectively; the space costs of the comparison methods are about 4–5 times of that of the proposed method; the energy cost of the interference suppression method based on PTS-Clipping is 6 times of that of the proposed method, and the energy cost of the interference suppression method based on time-weighted is about 10 times that of the proposed method. The data show that the proposed method has outstanding performance advantages in suppressing ISI in communication transmission.

## 4. Discussion

According to the results of ISI suppression waveform, the proposed method realizes sparse signal representation, effectively overcomes the ISI of multi-path channel, and improves the resolution of transmission signal. Fig. 6 shows that the interference suppression method based on PTS-Clipping achieves only a short sparse signal representation between 1.6 and 1.7 s $\times 10^{-8}$, and the inter-symbol interference of communication signals is not effectively eliminated at other time points. Fig. 7 shows that the interference suppression method based on time-weighted is more effective than the interference suppression method based on PTS-Clipping. In the first half of the test, the phenomenon of inter-symbol interference still exists. In the second half of the test, the bit error rate of the signal gradually presents a sparse representation trend. Compared with the original signal, the interference

**Table 4**
Performance test results.

| Signal-to-noise ratio/dB | Article method | PTS-Clipping Interference Suppression Method | Interference Suppression Method Based on Time Weight |
|---|---|---|---|
| Time cost/s | 0.9 | 12.3 | 15.6 |
| Space cost/MB | 5.6 | 25.6 | 22.3 |
| Energy cost/kJ | 1.5 | 9.6 | 15.4 |

suppression method based on time-weighted can effectively suppress the inter-symbol interference of the communication system, but compared with the proposed method, the interference suppression method based on time-weighted is not effective and cannot achieve the full sparse representation of the signal. Therefore, the proposed method can overcome the inter-symbol interference of communication system and improve the efficiency of transmission signal in communication system.

According to the analysis results of impulse response of channel model, the red solid circle in Fig. 8 represents a receiving array element, and each receiving array connected by dotted lines represents a vertical line array. The autocorrelation cumulative output of channel's impulse response is obtained. The experimental results show that the receiving array has uniform array distance and no significant aggregation phenomenon, which indicates that the channel's impulse response is balanced. The optimized communication channel has strong equalization ability, good channel equalization ability, high impulse response gain of output signal, and improves the channel resistance to inter-symbol interference.

In different SNR environments, the three methods all reduce the BER of communication. According to the simulation results, the effectiveness of three methods to suppress ISI is analyzed concretely. The results show that when the SNR is negative, the proposed method can significantly reduce the BER of communication. With the increase of SNR by 5 dB, the BER of communication decreases by 1%. Until the SNR is greater than 0, the proposed method can reduce the BER of communication. It is shown that the proposed method has a significant effect in suppressing the inter-symbol interference in communication system. The trend of the interference suppression method based on PTS-Clipping and the interference suppression method based on time-weighted is similar to that of the proposed method. However, the initial ability of these two methods to reduce the BER of communication is weak. When the signal-to-noise ratio is 20 dB, the BER of communication by using the interference suppression method based on PTS-Clipping is 25.6%, while that under the interference suppression method based on time-weighted is 36.5%. At the end of the experiment, the error rate of the communication system in this paper is stabilized at 0.66%, which is 10.44% and 14.74% lower than that of the interference suppression method based on PTS-Clipping and the interference suppression method based on time-weighted.

In this paper, the problems of ISI suppression and communication optimization in communication systems are studied, and an ISI suppression technology in communication based on mathematical chaos theory is proposed. Based on the channel model, the impulse response of the communication channel is calculated, and the multi-path component delay of the channel is calculated. According to the analysis results of the inter-symbol interference of the communication system, it is known that the multi-path component delay of the channel is prone to cause the inter-symbol interference of the communication system. From this point of view, the reasonable channel's component delay can be calculated to effectively suppress the inter-symbol interference of the communication system. In addition, this paper chooses mathematical chaos theory to study a new method to suppress inter-symbol interference in communication. It makes full use of the excellent characteristics of chaotic motion. The searching process is carried out according to the law of chaotic motion itself, which effectively avoids the objective function falling into local minimum, speeds up the optimization convergence speed of the algorithm and reduces the steady-state error. Therefore, the optimized equalizer tap value of the channel is better, and the reasonable multi-path delay of the channel can be calculated to effectively suppress the inter-symbol interference of the communication system from the perspective of multi-path delay. Finally, the simulation results show that the proposed method has good channel equalization performance and effectively reduces the bit error rate of the communication system.

According to the analysis of the principle of inter-symbol interference in communication system, channel distortion can also cause inter-symbol interference. In the future research of BER, the channel distortion can be used to suppress the inter-symbol interference and improve the communication quality.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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