# The implementation of Automatic Adaptive Equalizer Based on LMS Algorithm

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***Abstract*—In this paper, the inter-symbol interference and eliminating method are introduced. After analyzing the principle of adaptive equalization, we designed an adaptive equalizer using the LMS algorithm, and constructed a simulation system using MATLAB. Then we analyzed the convergence speed and mean square error characteristic of the adaptive equalizer by changing the step length factor to test the performance of the algorithm.**

***Key words- self-adaptive filter; LMS algorithm; MATLAB***

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## 1 Introduction

Multi-path effect in the wireless data communication process causes inter-symbol interference. Inter-symbol interference is believed to be the main obstacle in high-rate data transmission in wireless communication channel, and equalization is an effective technique for inter-symbol interference. Normally, adaptive equalizer can track the time variation of channels [1], compensating distortion of channels to a certain extent, so as to against fading and improve the quality of transmission. This paper first simply introduced the cause of inter-symbol interference, and then introduced a kind of common method of erasing inter-symbol interference, and finally we established a simulation model and verified it.

## 2 Inter-symbol interference

Time-variable, the multi-diameter and the decline are the inherent characteristics of numerous wireless channels. In digital communication system, the data mark is modulated to a carrier and be spread. When the signal passes through more than a diameter channel, the signal detention will produce a neighboring signal called inter-symbol interference (ISI), which overlaps in time domain. This kind of disturbance will affect seriously on the digital communication performance.

Inter-symbol interference (ISI) is a main factor affecting the reliability of digital signal transmission [2]. ISI will cause the data influencing each other, resulting in phase distortion. In order to overcome the distortion caused by ISI, we often use the signal processing technology called channel equalization in communication system. Equalization technology is the technology which can weaken inter-symbol interference signals and complete the original signal reconstruction by using equalizer technology with filter or other technology. Equalizers rebuild the original signal and remove the ISI through the filter or other technology to improve the reliability of the data transmission. In the wireless digital communication, equalizer is an indispensable link. Because the wireless channel is time-variant, the equalizer must be able to track real-time information of channels. The equalizer should adjust adaptively in order to match the channel.

Data transmission system and adaptive equalizer are shown in fig.1, $a_k$ is the send code at the beginning of the scale. The signal was mixed up with many sorts of noises in channels, so distortion occurs certainly. The output of terminal signal channel modem is shown in fig.1, receiving signal is the response of each symbolic data, that is

$$x(t)=\sum_k a_k h(t-kT_s) \quad (1)$$

If the received signal is sampled in the moment t=nTs, so starting from the above formula

$$x(nT_s)=a_n h(0)+\sum_k a_k h(nT_s-kT_s) \quad (2)$$

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The first one on the right formula is the useful signal, it can be used to determine the level of received signal value; the second one is the summation item, also it is not equal to zero, it reflects the mutual influence between codes, so-called inter-symbol interference (ISI). And adaptive equalizer is used to offset the inter-symbol interference [3]. Essentially, the adaptive equalizer play the role of inverse filtering, and the data was recovered from the x (t) is shown in fig.1.

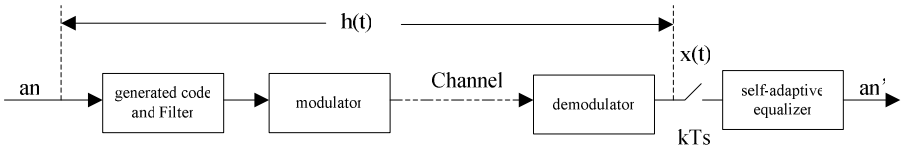


**Fig.1** Data transmission system and adaptive equalizer

# 3 The adaptive equalization technique

Delay spread caused by multi-path fading resulted in the interference between code elements in high-speed data transmission. Currently the most effective approach solving the ISI in this transmission system is called adaptive equalization techniques. Adaptive equalizer can constantly adjust gain in accordance with some algorithms from the digital signal during transmission [4][5], in order to accommodate the random channel, and keep the equalizer working in the best state. It contains two work modes, which are called training mode and tracking mode. Classic training sequence is a pseudo random binary signal or a fixed wave signal sequence, followed by user message code sequence. Adaptive equalizer of receiver estimates channel characterization by recursive algorithm. Then it adjusts the filter parameters to compensate channel character distortion. The choice of training sequence should satisfy the condition that receiver equalizer can adjust filter parameters in the worst channel situation. Hence after training sequence, the parameters of equalizer are approximate to optimal value, which assures reception of the user data. The equalizer adaptive algorithm can track changing channel, then the adaptive equalizer keeps on changing the filter characterization [6]. The adaptive equalizer diagram is shown in fig.2

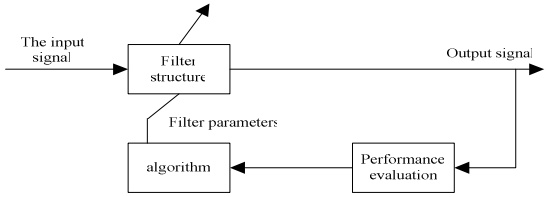


**Fig. 2** Adaptive equalizer diagram

# 4 Performance simulation

Compensating the properties of time-varying channel which are unknown using the adaptive equalizer, we need effective algorithms which can track the channel characteristic changes to update weighting number of the equalizer. There are many kinds of algorithm for adaptive equalizer, then we will design the adaptive equalizer based on LMS algorithm,

First, we should build the channel model base on multi-path channel which is high-speed and wireless [7], and then complete the performance simulation under various step factors for LMS algorithm [8]. Then compare the performance of the algorithm. The simulation model is shown in fig.3. The MATLAB simulation for the above adaptive equalizer in multi-path fading channel is completed, adaptive equalizer is designed based on LMS algorithm, we conduct the experiment under the condition DB = 25, and assume the input signal is comprised of sine wave with white noise. At the same time, the LMS algorithm is carried on the filter while its statistical simulation is 100 times, and the input signal sampling points number is 500, filter order number is 128, then we can draw the mean square error curve, and obtain the comparison results of three steps of the step length value. Convergence characteristic curve is shown in fig.4~7.

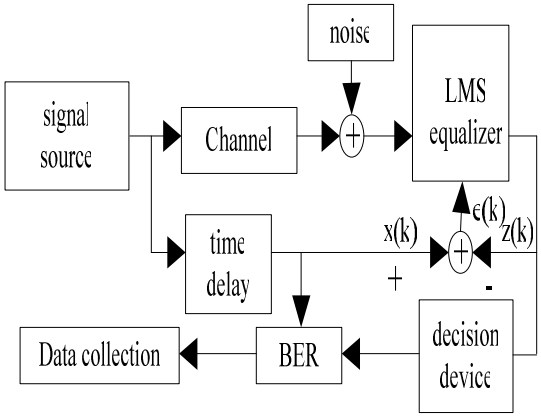


**Fig. 3** The system simulation diagram

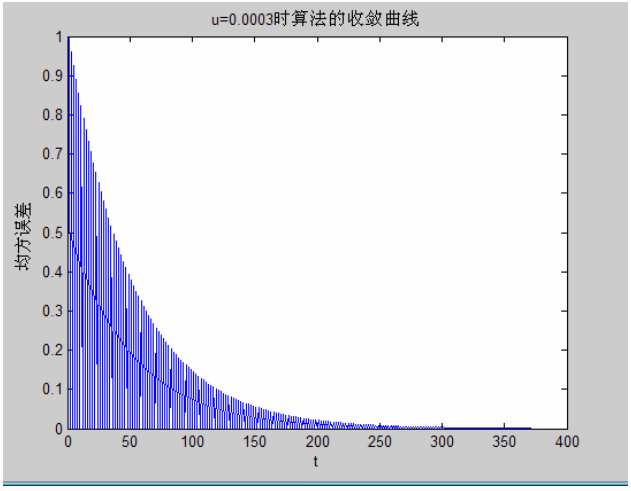


**Fig. 4** The system simulation results (u=0.0003)

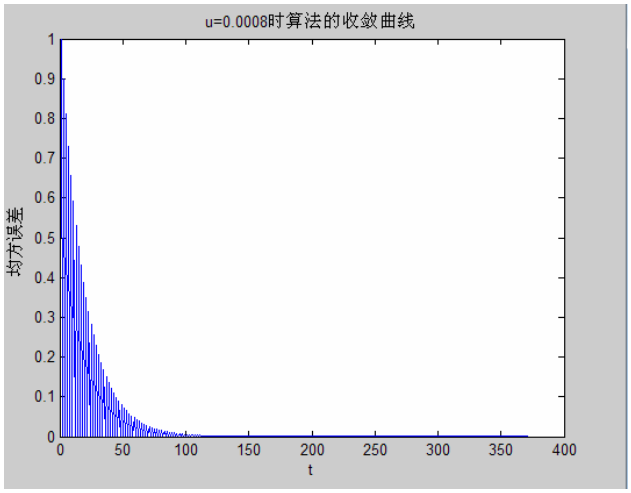


**Fig. 6** The system simulation results (u=0.0008)

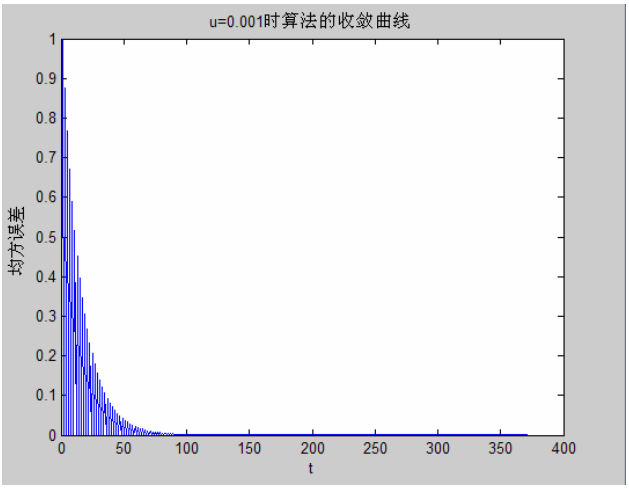


**Fig. 5** The System simulation results (u=0.001)

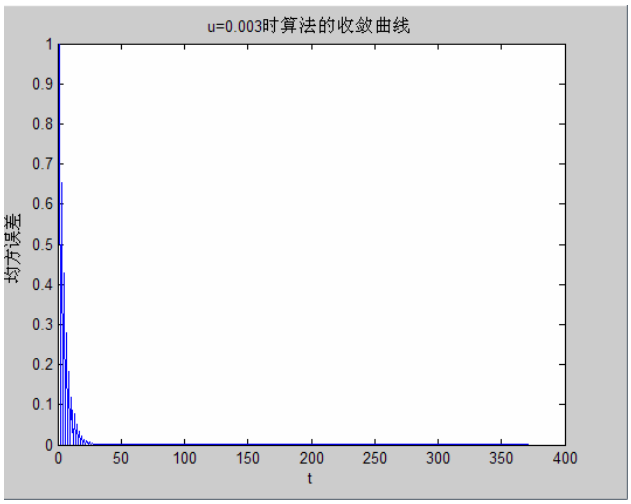


**Fig. 7** The system simulation results (u=0.003)

# 5 Conclusion

From the simulation results in Fig.4~7, we can see that when the step factor is bigger, the rate of convergence is quicker. While the step factor increases, the mean square error (MSE) also increases accordingly. If we decrease step factor, convergence velocity becomes slow and it can achieve the minimum MSE. In this paper, both give consideration to both, u=0.001 is suit to the example, so we must choose appropriate convergence factors. In LMS algorithm, the selection of u should split the difference between convergence speed and imbalance. The algorithm should be of higher converging speed and the minimum MSE.

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The running cost of the PACU is mainly of electricity, oil and mechanical wear etc. After using the conversion control system, the system is realized electricity saving, oil saving, low fault rate and small mechanical wear. The saving of the electricity and oil has been analyzed as follows:

i. Annual electric quantity saving

Here a mine with three 132KW PAC takes as a example. If the PACs work on rated speed for 12 hours and work on 60%~70% rated speed for another 12 hours every day, and electricity saving rate is 50%, then the annual electric quantity saving is

$$3\times12\times132\times0.5\times365=867240\ (\text{KW}) \quad . \quad (1)$$

ii. Annual oil saving

According to the using oil rule of "low speed then low lubrication", the converter control system can save oil 60%.

## 6.Conclusions

As for the problem of high energy consumption in compressors, we have designed the converter triple-evaporator air compressors control system. Compared with the original relays control system, the starting current and equipment wear of the new system are much reduced, besides the system is low operation cost and high automation. This system has been used in some mines such as XinYi and the energy saving is remarkable, the control technology and system can be used or referenced in other mines and corporations.

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