Simulation and Analysis of the BER of Multi Path Rayleigh Channel

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***Abstract* — A complete digital communications process has to go through channels for transmission. But inevitably, there will be receiving error information as a result of interference and fading. In order to receive correct information as possible and improve the reliability of transmission further, the system needs to correct errors besides of modulation of the digital signals. Take Rayleigh fading channel as an example. From MATLAB simulation, it can be seen that BER is related to error-correcting code with the same SNR. Here, error-correcting code includes LDPC code and a pseudo-random scrambling . Then, a new scheme that combines the LDPC channel coding with pseudo-random sequence scrambling is proposed. The simulation results show that the scheme can improve the BER better than using LDPC coding or pseudo-random scrambling separately. That is, the scheme improves the reliability of the transmission system.**

Keywords - interference; multipath Rayleigh channel, MATLAB; Low Density Parity Check Code (LDPC), pseudo-random scrambling, bit error rate (BER)

I. INTRODUCTION

In the rapid development of information society, the digital communication occupies a large part of all means of communications. Such as smart mobile Internet, video telephony, communication between the computer and the computer, web conferencing and satellite communication all use the digital communication systems for transmission widely. Thus, the digital communication system can adapt to the requirements of today's information society. It has the characteristics of the strong anti-noise performance, error controlling, easy integration, and convenient encryption and easy to use modern computing technology for signal processing.

How to enhance the reliability of the transmission has been the focus of research. Since the mobile communication will inevitably have interference and fading, information errors will appear in the transmission system, and therefore need the digital signal correction and error detection technology. Thereby it will enhance the ability to resist interference during transmission of data and improve the reliability of transmission. Channel coding is correcting error and detecting coding for information (digital signal). Now, with the development of channel coding technology, it has been used in a lot of areas, including data storage transmissions, satellite fields.

Channel coding principle is adding some redundancy to the source of the information in the channel. The original information represents by more bits, and then it can achieve correction and error detection. But it needs to pay a certain price, that is, it requires transmitting by more bits and a longer transmission time. Shannon first proposed the concept of channel capacity in 1948, and then produced more well-known channel coding theory. Channel coding can also be called error correcting code. Now, the type of the error correcting code comprises convolution code, RS code, Turbo code, LDPC code, a pseudo-random scrambling code sequence and so on.

Literature [3] research shows that the optimized and irregular LDPC code whose code length is 10^7 and bit error rate (BER) is 10^{-6} just 0.045dB from the Shannon limit. The LDPC code's performance is much better than Turbo code and it became the closest Shannon limit pattern. Additionally, LDPC code's decoding complexity is low, with the potential for high-speed decoding, large throughput and simple description. The above advantages make the LDPC code become hot spot about channel coding in recent years.

Literatures [4] and [5] researches show that it can also reduce the bit error rate of the transmission system when we add pseudorandom scrambling code sequence in a digital transmission channel. With increasing the signal to noise ratio, bit error rate tends to zero. The following combined with literature [3] - [5], we expand research about reducing the error rate in the digital transmission system. The purpose is to improve the reliability of the transmission system further, that is, reduce the error rate of the received information further.

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II. ERROR-CORRECTING TECHNIQUES

The type of error correction codes including RS coding, convolution code, Turbo code, interleaving, scrambling pseudo-random sequence and LDPC code, etc. Next, we take LDPC code and scrambling pseudo-random sequence for example to discuss.

A. LDPC Code

LDPC code is low density parity check code and a kind of linear block code. Its characteristic is the sparseness, that is, a relatively low density parity check matrix 1. Constructing LDPC code is to construct a sparse parity check matrix. It was developed by Dr. Robert G. Gallager in 1963.

Its features are low decoding complexity, flexible structure, a good approximation of the Shannon limit performance, etc. It has become the fourth generation communication systems' (4G) strong competitor. Today, many communication standards being developed are also concerned about the LDPC code, such as satellite communications standard DVB-S2 LDPC code has been adopted as a forward error correction code. LDPC code has been widely applied including optical fiber communications, mobile communications, deep space communications, wireless LAN, satellite digital video and audio broadcasting, etc.

LDPC code is divided into binary LDPC code and M-ary LDPC code. Experimental results show that the anti burst error capability of multi band LDPC code is better than the binary LDPC and the bit error rate performance is slightly better than the binary LDPC code. Since the higher degree of complexity of Mary LDPC decoding and digital transmission mostly more uses binary signal, this paper use the binary LDPC code.

Definition 1

A LDPC code is defined as the null space of the parity check matrix H (null space), and h has the following structural properties: (1)each row has k "1"; (2) each column has a j "1"; (3) λ for any two columns with number of common "1", which is no more than 1; (4) k and j is very small compared to h n length and the number of lines.

(N, k, j) LDPC code is defined as a binary linear block code of length n and its check matrix H has fixed column weight j and k fixed row weight. That is, check matrix H has N columns and M rows. Thus, M is the number of codeword check equations and there is 2^K codeword. K is message length and K=N-M. The bit rate is $R=K/N=1-M/N=1-j/k$.

B. Scrambling Pseudo-random Sequence

Pseudo-random sequence is very important in digital communication technology. The original signal added pseudo random sequence can get randomization. Although disrupted the law of the signal, but it is human disturbance and so the sink can be easily restore the original data information with the pseudo-random sequence.

It is also a way to achieve high security in the digital signal transmission system. The specific process is as follows.

First, add the original signal and the pseudo-random sequence (cycle is very long) which is artificial then it can generate a new sequence. But the new sequence requires more bits to represent. Later, before the sink receives the information, add the new sequence again and the same pseudo-random sequence. Then you can restore the original information transmitted. The original waveform information added the scrambling pseudo-random sequence is shown in Fig1.

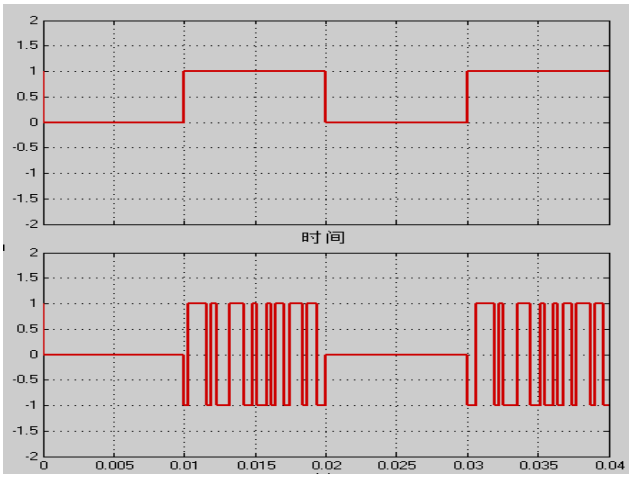

Figure 1 The original message and added the pseudo-random sequence waveform comparison chart

It can be seen from Figure 1 that joining the pseudo-random sequence randomizes the original signal and it will require more bits to represent. In addition, it changes the laws of the original information and it has a high degree of confidentiality in the transmission channel. In short, after adding the pseudo-random sequence can both reduce the error rate of the transmission system, but also can improve the security.

III. RAYLEIGH FADING CHANNEL MODEL

Rayleigh fading channel [7] which seriously affects the quality of the mobile communication system is a very important channel model .In the mobile communication

system, the source and sink are in a state of constant motion and the relative movement will produce doppler shift. Doppler shift is related to the speed and direction of movement and it is shown as equation (1):

$$f_d = \frac{v}{\lambda}\cos\theta = \frac{v \times c}{f}\cos\theta \quad (1)$$

v is the relative velocity of the source and sink. θ is the angle between the direction of motion and source and sink line. λ=c/f is the carrier wavelength.

Rayleigh fading channel model assumes that there is no line of sight between the receiver and transmitter .So that the radio signal is attenuated, reflected, refracted, diffracted and then there are a lot of scattering components which is statistical independence .And these scattering components' azimuth which reaches the receiver antenna obeys uniform distribution within the scope of ($0 \sim 2\pi$).It is seen from the above assumptions, rayleigh fading channel model is suitable for using in wireless channel in the central area of a city.

Rayleigh distribution's probability density function (PDF) is shown in equation (2):

$$f(x) = \frac{x}{\sigma^2} e^{-\frac{x^2}{2\sigma^2}} \quad (2)$$

In the formula, σ represents the root-mean-square value before receiving electrical signals in the envelope detection. σ^2 represents the average power before receiving electrical signals in the envelope detection.

Rayleigh fading with the formula can be expressed as the equation (3):

$$y[m] = h[m]x[m] + w[m] \quad (3)$$

In the formula, $h[m]$ is the fading process. Rayleigh fading meets the condition $h[m] \sim CN(0,1)$, that is, the variance is normalized to 1. $w[m]$ is the noise which is independent and subjected to the same distribution.

IV. SIMULATION AND ANALYSIS

A. BER Simulation under the Rayleigh Fading Channel

The structure diagram of the Rayleigh fading channel added LDPC coding is shown in Figure 2. Block diagram consists of five parts: Source (source module), LDPC Coder (LDPC encoding module), Channel (channel module), LDPC Encoder (LDPC decoding module) and Sink (sink module).

Joining pseudo-random sequence in transmitting is similar to adding LDPC in the channel. It just need to replace LDPC encoding module and decoding module with the pseudo-random sequence module.

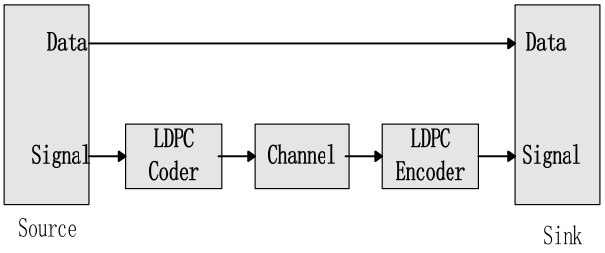

Figure 2 The structure diagram of Rayleigh fading channel added LDPC coding

In the Rayleigh fading channel model, it needs to add LDPC code and pseudo-random sequence respectively in the channel. Then we will simulate with MATLAB and the simulation is shown in Figure 3.

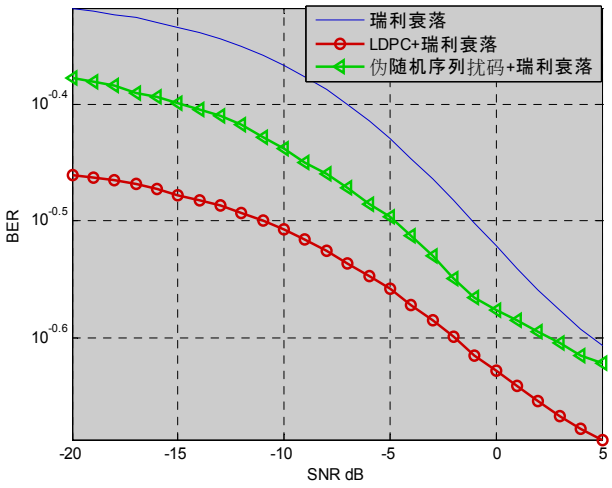

Figure 3. The simulation map added LDPC coding or pseudo-random sequence separately

The picture is the simulation map of adding LDPC coding and pseudo-random sequence in the Rayleigh fading channel. And it can be seen from the simulation diagram, in the Rayleigh fading channel, adding LDPC coding or pseudo-random sequence coding can reduce the error rate of the transmission system and improve the reliability of transmission. With the increasing of the SNR, the anti-noise performance is better. LDPC code's anti-noise performance is better than the pseudo-random sequence. From the literature [6], we can see that LDPC code's error rate is also related to the LDPC code's length and the code rate. The

short code's BER performance is worse to the long code. The code rate is lower and the performance is higher. This article's simulation is carried out in dvbs2ldpc (1/2).

B. The Scheme of Combining LDPC Code and Pseudo-random Sequence

We can see from the above simulation, in the communication system adding LDPC code and pseudo-random sequence respectively can reduce the error rate and improve the reliability of the transmission. To reduce the bit error rate further, in the Rayleigh fading channel, I want to combine LDPC code and pseudo-random sequence. The specific simulation structure is shown in Figure 4.

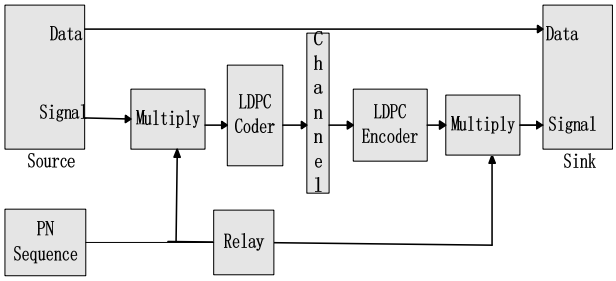

Figure 4 The simulation structure of combining LDPC code and pseudo-random sequence

The BER simulation is shown in Figure 5.

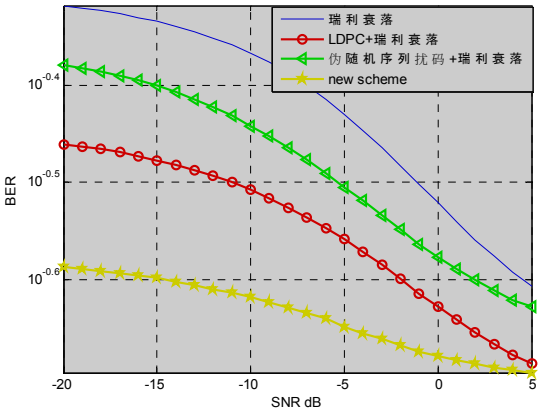

Figure 5. The simulation of combining LDPC code and pseudo-random sequence

As it can be seen from the simulation graph, in the Rayleigh fading channel, the scheme that combines LDPC code and pseudo-random sequence has lower error rate than the scheme that adds LDPC code and pseudo-random sequence respectively. That is, That is, the new scheme has a better anti-noise performance and can improve the transmission reliability further.

LDPC channel code's error rate is related to the code length and rate and the pseudo-random sequence's error rate is also related to its code length. Therefore, by adjusting the LDPC code length, rate and the pseudo-random sequence code length, can improve the reliability of the system further. The cost is to extend the information transmission time, since the channel coding needs more bits than the original information.

V. CONCLUSIONS

Firstly, in the Rayleigh fading channel, we has conducted the BER simulation about the two error-correcting code (pseudo-random sequence and LDPC code), and analyzed transmission performance. The result shows that both error-correcting codes can reduce the bit error rate of the system, achieve error correction capability, and improve the reliability of transmission. Finally, we proposed the scheme that combines LDPC code and pseudo-random sequence and simulated with MATLAB. Then we analyzed the performance. The simulation results show that this scheme can increase the bit error rate further than the scheme that adds LDPC code and pseudo-random sequence respectively. That is, the new scheme can improve the reliability of information transmission further. The program has a certain reference value for the LDPC code which is more and more widely applied.

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