Image Transmission for Low-Density Parity Check Coded System under PBNJ

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ABSTRACT

The research of Reed-Solomon code (RS) for slow frequency-hopping systems have been extensively studied in recent years. Previous studies has considered to combine error correction coding with image restoration techniques to improve anti-jamming capability for image transmission. Low-density parity check code (LDPC) has become popular because of its flexibility in codeword length and better performance than those of other codes. Therefore, in this paper, we propose a image transmission system which empolyed LDPC code to replace RS code under partial band noise jamming (PBNJ). Besides, we also propose a iterative decoding scheme which integrated the information after image process and the channel information. Simulation results show that the proposed system can effectively improve the quality of the received images.

KEYWORDS

slow frequency-hopping; Low-Density Parity Check code; partial band noise jamming; image transmission; iterative decoding scheme;

1 INTRODUCTION

Frequency-hopping spread spectrum system is a common technique to resist interference for wireless transmission. According to the difference hopping rates, it can be divided into fast frequency hopping (FFH) and slow frequency hopping (SFH).A FFH system uses the diversity of frequency and time. However, the SFH system needs an extra protection mechanism to enhance the capability of antijam. Stark [1] and Pursley [2], analyzed the result under PBNJ environment and decoded the RS code by errors-and-erasures decoding to improve the error probability. Su and Jeng [3] researched different jamming models in RS code SFH/BFSK system. They compared the effect of different jammers and analyzed the relationship between the hopped rates, the interleaver sizes and the code rate, which under different jamming models. Most previous research focused on error probability or improved system efficiency by other considered communication techniques. Jeng and Su [4] not only analyzed the data, but also proposed a scheme combining the RS code SFH/MFSK with image communication to resist the interference by jammers in 2009. In 2004, Jiang and Narayanan [5] verified that the scheme of iterative decoding truly increased the performance of decoder. Therefore, in this paper, we propose the system which using LDPC code for image communication under partial band noise jamming (PBNJ). Moreover, we also considered two image transmission methods, one is iterative decoding scheme which combined the information after image processing in channel, and the other is non-iterative decoding scheme.

The rest of this paper is organized as follows. Section II gives a general description of the proposed image transmission of LDPC coded SFH/BFSK system. Section III introduces the image restoration and structure of iterative scheme. Simulation results and discussions are given in IV. Finally, we summarize our major results in Section V.

2 SYSTEM MODEL

Shown in Figure 1 is the block diagram of image communication for LDPC coded SFH/BFSK systems. We choose the 8bits colored bitmap format as our transmitted image in this paper. That is, to choose the RGB color model to represent the pixels of images.

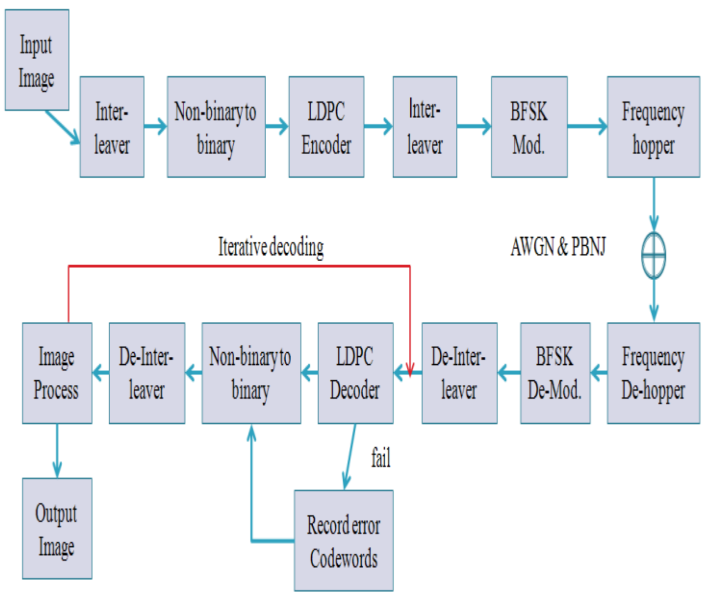

Figure 1.The block diagram of image communication for LDPC coded SFH/BFSK systems.

In this model, a pixel is represented by different intensities (from 0 to 255) of the red (R), green (G), and blue (B) colors. Therefore, a color image can be viewed as three primary color (R, G, B) images. Next, at the transmitter, we design two-interleaver. The first interleaver, is the bit-interleaver. The main function of the first interleaver is to disarrange the pixels which are highly correlated. By doing this, the consecutive data are randomized by the interleaver, and it would result in the error pixels randomly distributed after transmission. The expected error pixels distribution is shown in Figure 2.

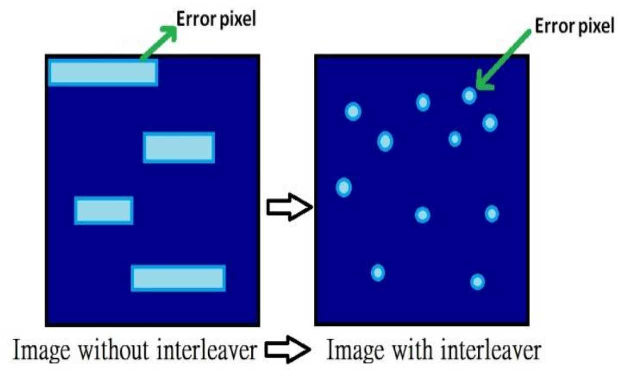

Figure 2.The influence of the first interleaver for image.

Before send to the LDPC encoder, we transfer non-binary data into binary one. After LDPC encoder, the function of the second interleaver is to convert a memory channel into a memoryless one. By doing this, the burst errors of transmitted data will convert into random errors. Then the LDPC codeword is transmitted by BFSK modulator and followed by a frequency hopper.

At the channel, we considered not only additive white Gaussian noise (AWGN) but also partial band noise jamming (PBNJ). PBNJ spread total power P_J over the spectrum of bandwidth W_J. W_{SS} is the totally hopping bandwidth, then the fraction of band jammed $\rho = W_J = W_{SS}$ $(0 < \rho < 1)$. The transmitted symbol is interfered by a power spectrum density of AWGN, $N_T = N_J/\rho+N_0$ when transmitted signal is hopped into jammed band. Otherwise, the PSD is $N_T = N_0$. In general, we assume the entire hopped M-ary system is jammed when any channel is jammed under PBNJ.

At the receiver, the transmitted symbol is frequency de-hopped and demodulated by frequency de-hopper and BFSK demodulator separately. For the LDPC decoding, when the decoding process reach the maximum decoding times and the decoding codeword does not satisfy $CH^T=0$, we mark them as error codeword and sent to the de-interleaver, each point on the map represent their error pixels. Therefore, we just utilize the highly correlated characteristic of image to achieve the image restoration. The expectative distribution of error pixels after LDPC decoder is shown in Figure 3.

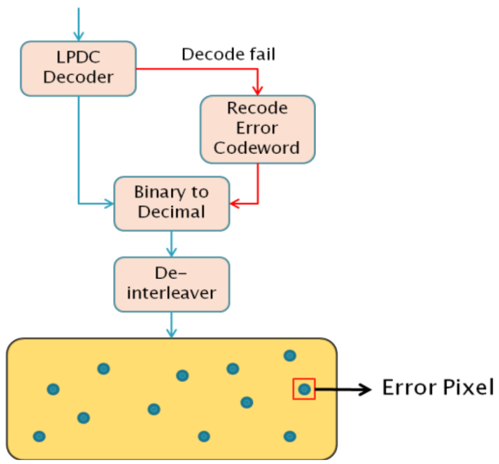

Figure 3.The distribution of error pixels in the image after LDPC decoder.

3 IMAGE RESTORATION AND TTERATIVE DECODING SCHEME

In image processing, we proposed the method to decide the errors. A image is composed of many pixels. Actually, the information in error codeword are not totally errors, there still contain correct information, so we calculate reliability of the pixels of the error codeword. Because we use BFSK modulation, so a pixel is represented by 8 bits. After decoding, we can get the probability for each bit. We use 8 bits of a pixel to calculate the reliability and compare with a threshold as shown in Figure 4.

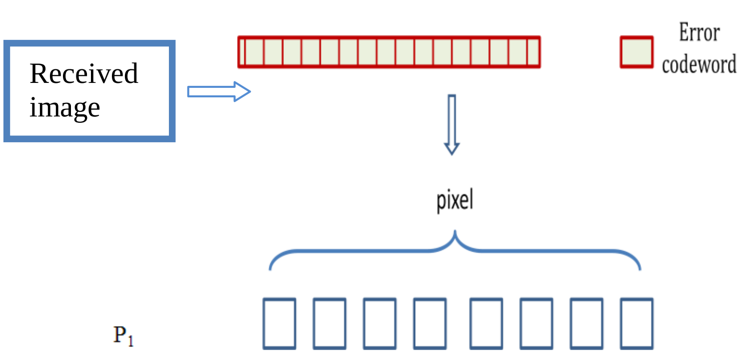

Figure 4.The method of image restoration.

$$\begin{cases} if\ bit = 1, & r_i = P_1 \\ else, & r_i = 1 - P_1 \end{cases} \quad R = \sum_{i=0}^{8} r_i < \eta \qquad (1)$$

(P_1 is reliability，η is threshold)

As mentioned above, we proposed the image restoration with non-iterative decoding scheme. If the pixel has a bit is wrong or when the reliability is smaller than the threshold, it will be treated as errors. That is, we decided the errors at first. In this image restoration, when the decoding process does not satisfy $CH^T=0$, or the value of reliability smaller the threshold. We considered unreliable information by image processing to repair.

Besides, we proposed an iterative scheme as shown in Figure 5.We combined the information after image processing and information after BFSK demodulator. $LLR_{channel}$ is the initial likelihood ratio value for demodulated BFSK in signal. LLR_{image} is all of the bits after decoding, the value is equal to average of absolute maximum and minimum LLR in channel. The detail is shown in (2).We transfer the information after image process into binary data and set a new *LLR value* LLR_{new}. The new *LLR value* LLR_{new} is $LLR_{channel} + LLR_{image}$ as shown in (3), if the bit =1, $LLR_{image} = -LLR_{image}$. And the bit =0, $LLR_{image} = LLR_{image}$, is shown in (4). However, because the feature of the LDPC code is a linear block code, we need to fix the image of the finished result, multiplied by the LDPC code generator matrix becomes LDPC codeword, the LDPC decoder can be used to make a second decoding process.

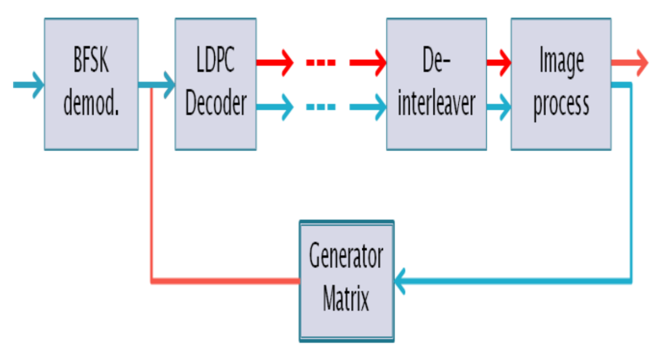

Figure 5. Iterative decoding Scheme.

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$$LLR_{image} = \frac{|LLR_{channel,max}| + |LLR_{channel,min}|}{2} \quad (2)$$

$$LLR_{new} = LLR_{channel} + LLR_{image} \quad (3)$$

$$\begin{cases} if\ bit = 1, & LLR_{image} = -LLR_{image} \\ else, & LLR_{image} = LLR_{image} \end{cases} \quad (4)$$

For to the image processing, we use the correlation among adjacent pixels. As shown in Figure 6, we assume P_5 is an error pixel and the adjacent pixels: P_1; P_2; P_3; P_4; P_6; P_7; P_8, and P_9 are correct. In order to recover the error pixels, in this paper, we choose the alpha-trimmed filter by utilizing the adjacent pixels to achieve the image restoration. As shown in [14], because of the alpha-trimmed filter has excellent performance, we choose it as image filter in our system.

Alpha-trimmed filter: We considered the maximum pixel value and minimum pixel value from P_1~P_9 exclude P_5 maybe marvelous. Hence, we utilize the adjacent pixels and delete the maximum value and minimum value then divided by 6 to substitute P_5, i.e.

$$P_5 = \frac{1}{6}\left\{\sum_{n=1, n\neq 5}^{9} P_n - (P_{\min} + P_{\max})\right\} \quad (5)$$

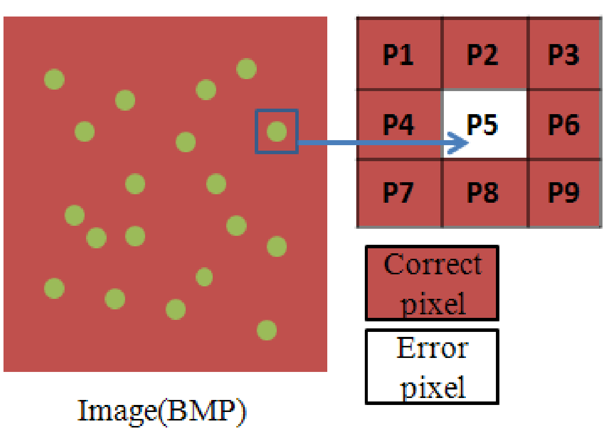

Figure 6.Error and correct pixels.

4 SIMULATION RESULT

In this paper, we consider the image quality with the peak signal to noise ratio (PSNR) value, its definition is shown as following:

$$PSNR = 10 \times \log \frac{255^2}{MSE} (dB) \quad (6)$$

$$MSE = \frac{\sum_{n=1}^{FrameSize} (I_n - P_n)^2}{FrameSize} \quad (7)$$

Peak is the maximum pixel value of the image, MSE is the mean square error, *In* is the value of *nth* pixel before processing, *Pn* is the value of nth pixel after processing, and FrameSize is the size of image. The PSNR value is bigger, it represent the image distortion is smaller.

The simulation result under iterative scheme of LDPC codes SFH/BSFK system is based the following parameters. We choose EG-LDPC code as the channel encoder, the codeword length is 255 and the maximum LDPC decoding time is set to 10, the SJR is 9dB and SNR is 12dB.

The transmitted image is shown in Figure 7, which size is 400*300 pixels.

Figure 7. Transmitted image.

We proposed two image restoration methods, they are both LDPC coded SFH/BFSK system under PBNJ environment. Simulation results is shown in Figures 8~10. Figure 8 shows the performance of image without image restoration

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and iterative scheme. Figure 9 shows the performance of the received image with non-iterative scheme and the image restoration. Figure 10 shows the performance of the received image with iterative scheme and the image restoration. From the results, both proposed methods can improve received image quality under heavy jamming channel. Moreover, the received image with iterative scheme and the image restoration is better than that of the received image with non-iterative scheme and the image restoration.

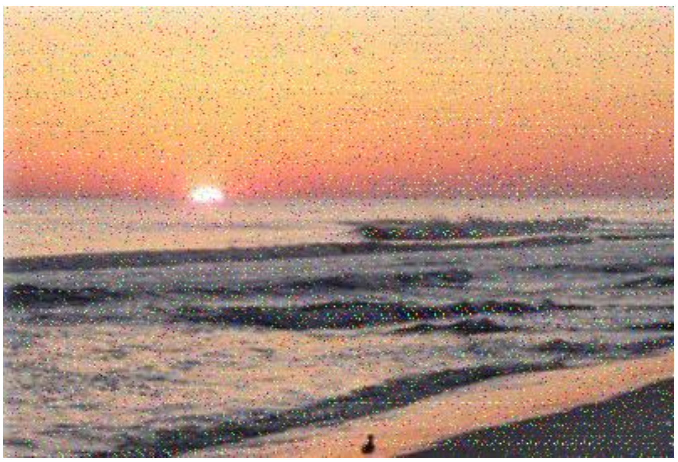

Figure 8.Received image without image restoration, SJR=9dB, SNR=12dB, PSNR=45.12 dB.

Figure 9.Received image with non-iterative scheme and the image restoration, SJR=9dB, SNR=12dB, PSNR=56.95dB.

Figure.10.Received image with iterative scheme and image restoration, SJR=9dB, SNR=12dB, PSNR=63.76 dB.

Form the performance, when SNR = 12dB and SJR=9dB, the PSNR of received image without image restoration is 45.12dB, the PSNR of image restoration with non-iterative scheme is 56.95dB and the PSNR of image restoration with iterative scheme is 63.76dB. So the received image restoration with non-iterative scheme is better than that of without image restoration, and that the received image restoration with iterative scheme is better than that of the image restoration method with non-iterative scheme.

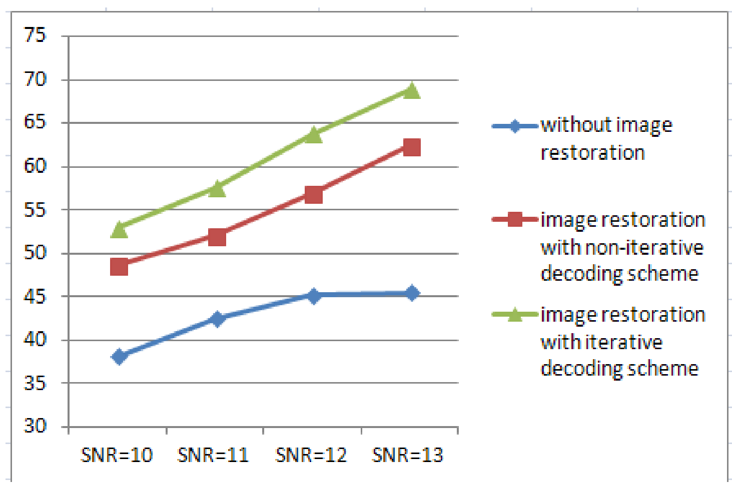

Figure 11.Performance of Received image with image restoration method and iterative scheme, SJR=9dB, SNR=10~13dB.

By comparing the PSNR value of different system model, the system with iterative scheme is certainly enhances the performance of system.

5 CONCLUSION

In this paper, we proposed a image transmission system which empolyed LDPC code to replace RS code under partial band noise jamming (PBNJ). Besides, we also propose a iterative decoding scheme which integrated the information after image process and the channel information.

According the simulation results, the performance of our proposed methods is better than that of the performance without image restoration. Therefore, in our proposed two image restorations, the performance of the image restoration with iterative scheme is better than that the performance of the image restoration with non-iterative scheme. Besides, the system with iterative scheme can improve the performance than without iterative scheme obviously.

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