Iterative Decoding methods for Image communication under PBNJ

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Abstract :

In this paper, we propose two iterative methods for image communication under PBNJ (Partial Band Noise Jamming). Our system use the property of image pixels which has high correlations between adjacent pixels and employ the forward error-correction coding (FEC) for system's channel coding. The iterative scheme is based on the information after image processing and information before decoder, at the same time, we also combine the information in channel to compute symbol reliability and using those information to restore the transmitted image. By evaluating the peak signal to noise ratio (PSNR) values of the transmitted images, the results show that the performance of our system is better than that without iterative scheme.

Keywords: *Reed-Solomon code, frequency-hopping, partial band noise jamming, iterative scheme.*

I. INTRODUCTION

In wireless transmission, in order to resist the interference or channel effect, frequency-hopping spread spectrum (FH-SS) system is a common technique to be considered. By difference hopping rates, FH-SS is divided into two different structures: fast frequency hopping system (FFH) and slow frequency hopping system (SFH). A FFH system uses the diversity of frequency and time, so the performance is better than that of SFH. On the other hand, the SFH system needs an extra mechanism of protection to enhance the anti-jam capability. Among many techniques, forward error-control coding is a good choice. Pursley and Stark [1] analyzed the result under PBNJ environment and decoded the RS code by errors-and-erasures decoding to improve the error probability. Su and Jeng [2] considered different jamming models in RS code SFH/MFSK system. They compared the effect of different jammers and analyzed the relationship between the hopped rate, the interleaver sizes and the code rate, which under different jamming models. Jiang and Narayanan [3] verified that scheme of iterative decoding truly increased the performance of decoder. In recent, researches about Reed-Solomon code in SFH system focus on adding other communication techniques to improve system efficiency or analyzing error probability. Until 2009, Jeng and Su [4] not only analyzed the data, but also proposed a scheme combining the RS code FH-SS system with image filter to restore image in jamming environment.

In this paper, we extend the work of [4] and propose two iterative schemes for image transmission. First method, we compare the codeword after image processing and before the RS decoder then establish a threshold. Second method, we use ratio threshold test (RTT) to compute the reliability from channel and combined with first method to establish a new threshold. More detail about two iterative methods will be describe on Section III.

The rest of this paper is organized as follows. Section II gives a general description of the proposed iterative methods of RS coded SFH/MFSK system. Section III introduces the structure of iterative schemes. Simulation results and related discussions are given in Section IV. Finally, we summarize our major results in Section V.

II. SYSTEM DESCRIPTION

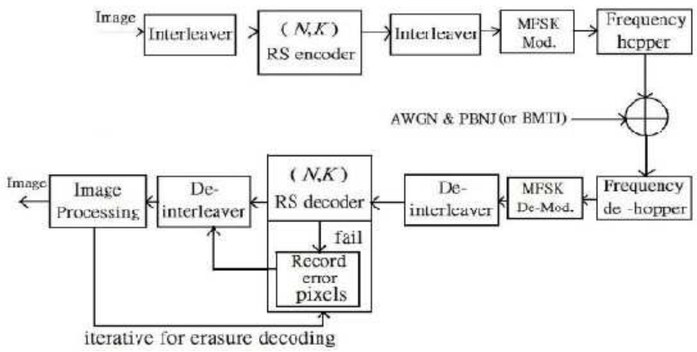


Figure 1. Block diagram of image communication for RS coded SFH/MFSK systems with iterative decoding.

Fig.1 is a block diagram of system model with iterative decoding. We consider the 8bits colored bitmap as our transmitted image. RGB color model is used for the pixels of image. In this model, a pixel is composed of different intensities(from 0 to 255) of the red (R), green (G), and blue (B) colors.

At transmitter, two-interleaver is employed [4]. 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 as shown in Fig. 2. It is easy to perform error correction for RS code and deal with the error pixels for image filters. Without this interleaver, burst errors will decrease the performance of the image filter because error pixels need to be restored from the adjacent correct pixels.

In RS encoder, we extended the codeword length N to match the modulated signal dimension (M), N = M. So the RS encoder output sequence is symbol-interleaved. After RS 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 be converted into random errors. Then, the coded symbol is transmitted by MFSK modulator and followed by a frequency hopper.

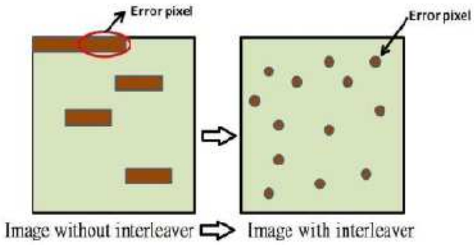


Figure 2. The influence of the first interleaver for the transmittied image.

At the channel, we considered not only additive white Gaussian noise (AWGN) but also partial band noise jamming (PBNJ). PBNJ spread total power PJ over the spectrum of bandwidth WJ . WSS is the totally hopping bandwidth , then the fraction of band jammed ρ= WJ /WSS (0 <ρ< 1). The transmitted symbol is interfered by a power spectrum density of AWGN. NT = NJ /ρ+ N0 when transmitted signal is hopped into jammed band. Otherwise, the PSD is NT = N0. In general, assume the entire hopped M-ary system is jammed when any channel is jammed under PBNJ.

At the receiver, the transmitted symbol is frequency dehopped and demodulated by frequency dehopper and MFSK demodulator separately. We use the Berlekamp-Massey algorithm to decode RS codeword, so we can know which codeword can be corrected or not. If the codeword are decoded fail, mark them as errors and sent to the deinterleaver. The expectative distribution of error pixels after RS decoder is shown in Fig. 3. In the end, we utilize the highly correlated characteristic of image to achieve the image restoration.

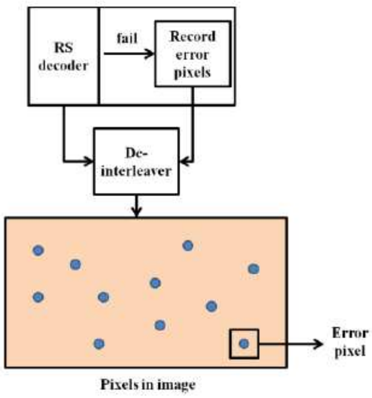


Figure 3. The distribution of error pixels in the image after RS decoder.

According to the image processing, every adjacent pixels has highly correlated. As shown in Fig. 4, *P5* is an error pixel and the adjacent pixels : *P1* ; *P2* ; *P3* ; *P4* ; *P6* ; *P7* ; *P8*, and *P9* are correct. In order to recover the error pixels, we choose the following image filters by utilizing the adjacent pixels to achieve the image restoration. Because of alpha-trimmed filter has the best performance [4], we choose it as image filter in our system.

alpha-trimmed filter : We consider the maximum pixel value and minimum pixel value from *P1* ~ *P9* exclude *P5*. Hence, we utilize the adjacent pixels and delete the maximum value and minimum value then divide by 6 to substitute *P5*, i.e.,

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

Due to the iterative scheme is our improvement, the transmitted image will be decoded many times. At first, we used errors only decoding for decoder, then rely on the output of image process to erase data by the input of RS decoder. Hence, we employ the information of erasure to do errors-and-erasures decoding. Its detailed procedure will be introduced on the next section.

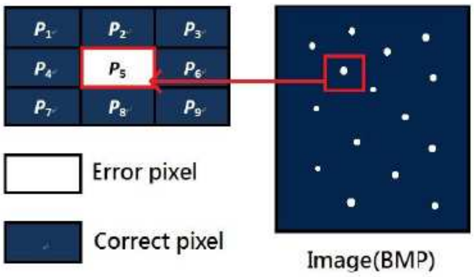


Figure 4. The distribution of error and correct pixels.

III. ITERATIVE SCHEME

The proposed iterative decoding methods for RS coded FH-SS system is described in this section. Fig.5 shows the procedure for the iterative decoding. In this system, we compared the codeword for output of image processing and the output of RS decoder, and then establish a threshold η shown in (2). If the calculated value lager than η then we mark the codeword as an erasure symbol.

$$\frac{r'(x,y)+1}{r(x,y)+1} > \eta \quad (2)$$

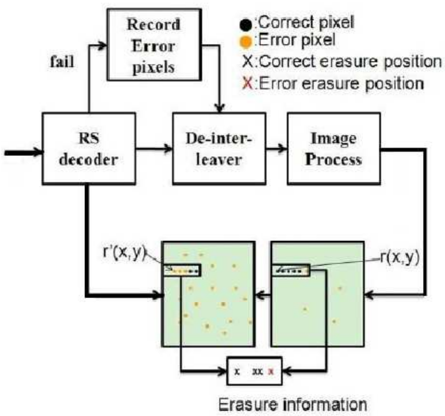


Figure 5. The procedure for iterative decoding.

r(x,y) is represents the pixel value after image process and *r'(x,y)* is the pixel value after decoder. To ensure that denominator does not equal to zero, we add 1 at denominator and numerator respectively. In Fig.5, black point represent the correct pixel, yellow point represent error pixel. There are three situations when we erase codeword. First, the black X represents a correct erasure when *r(x,y)* is correct and *r'(x,y)* is wrong. Second, the red X is wrong erasure when *r(x,y)* is wrong and *r'(x,y)* is correct. The third situation is both *r(x,y)* and *r'(x,y)* are error pixels, due to those different situations, we get the appropriate value of threshold is equal to 10. After this procedure, data will sent back to RS decoder and do second iterative decoding cycle.

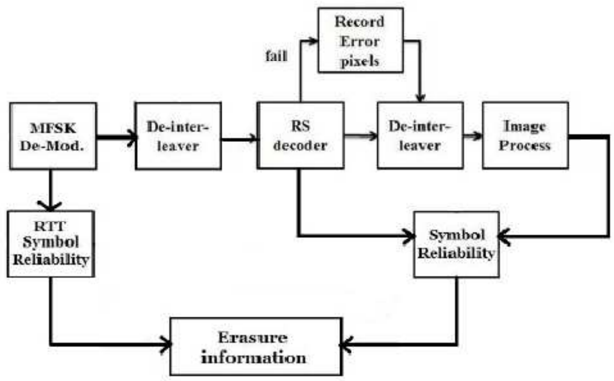
From[5], the ratio threshold test (RTT) can be used for symbol reliability measure. (3) is the mathematical model of RTT theory, *Pmax* is the largest symbol energy in MFSK channel, *Psec* is the second large symbol energy in channel. From energy distribution, a symbol which with most energy contains most information, assume a channel isn't interfered by noise, the maximum energy must much larger than the second. Consequently, we compute the symbol reliability and combine (2) to be a new threshold (4) shown in Fig.6, if the value larger than η, mark it as an unreliable symbol to erase. By doing experiments, we suggest the value a=0.6, b=0.4

$$0 \leq \frac{P_{sec}}{P_{max}} \leq 1 \quad (3)$$

$$a \times \frac{r'(x,y)+1}{r\,(x,y)+1} + b \times \frac{P_{sec}}{P_{max}} > \eta \quad ,0 < a,b < 1, a+b=1 \quad (4)$$

RS code has ability to correct *t* errors and erase *2t* error positions, so we can increase the correct ability of decoder by erase *2t* error positions. But the quality of image may decreased when erase too many times, to solve this problem, we stop erase when erase more than *2t* error position.

Figure 6. The procedure for establish threshold



IV. SIMULATION RESULTS

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

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

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

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, the expression of image distortion is smaller. The criterion of image property is listed as follows:

PSNR > 40 dB, image quality is excellence.

35dB < PSNR < 40 dB, image quality is good.

30dB < PSNR < 35 dB, image quality is acceptable

PSNR < 30 dB, image quality is too bad.

The simulation results for iterative scheme of RS code SHF/MFSK system under PBNJ is based on the following parameters. We set the codeword length and the modulated symbol dimension are both 256 and employ the (256,130) extended RS code. We consider alpha-trimmed filter for our image processing and choose the colorful image as transmitted image shown in Fig. 7, its size is 1600×1200 pixels.

Figure 7. transmitted imge (1600×1200 pixels)

The channel environment of received images in RS code SFH/MFSK system is under SJR=5, SNR=8, ρ=0.3. Compared to the original image, Fig.8 is more fuzzily since the heavy noise in channel modal, the PSNR value is 32.13dB. Fig.9 shows the received image by alpha-trimmed filter without iterative scheme [4]. The PSNR are 72.44dB. Fig.10 shows the performance of our system with first iterative decoding method. Fig.11 shows the performance of our with second iterative decoding method, the respective PSNR values of them are 75.68 dB, 77.82 dB. By comparing the above PSNR values from difference system models, the scheme we proposed with iterative decoding method is better than the scheme without iterative decoding methods.

Figure 8. the received image without image process and iterative scheme under SNR=8dB,SJR=5dB, ρ =0.3; PSNR=32.75dB.

Figure 9. the received image processed by alpha-trimmed filter without iterative scheme under SNR=8dB,SJR=5dB, ρ =0.3 ; PSNR=72.44dB.

Figure 10. the received image processed by alpha-trimmed filter with iterative scheme under SNR=8dB,SJR=5dB, ρ=0.3,I=6; PSNR=75.68dB.

Figure 11. the received image processed by alpha-trimmed filter with iterative scheme under SNR=8 dB SJR = 5dB, ρ =0.3; PSNR=77.82dB.

V. CONCLUSION

In this paper, we propose two iterative schemes for image transmission. One, we compare the codeword after image processing and before the RS decoder then establish a threshold. The other, we use ratio threshold test to compute the reliability from channel and combined with first method to establish a new threshold.

Finally, both the iterative schemes are better than that without iterative scheme [4], according to our simulation results, the PSNR value of images can be increased 3~5 dB than that without iterative scheme. Moreover, the second method which is combined both information on the decoder and channel is better than the first one.

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