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Performance analysis of error control coding and diversity in image transmission on wireless channels

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Abstract. This paper discusses the performance of using error control coding that combines with diversity techniques in the transmission of images on wireless channels to get reliable communication on noise and fading. The performance of the transmission system is not only determined by the effectiveness of channel usage, but it is also determined by the reliability of the communication system that causes noise and fading. Error control coding used in this research is Reed Solomon (RS) code, while the diversity technique used in this research is Maximum ratio combining. RS code is used to correct errors that occur during wireless transmission, while Use of diversity Maximum Ratio techniques Combining expected can affect the number of errors so that the signal transmitted to the wireless channels becomes more robust against interference caused by transmission channels. By using error control coding and diversity, the quality of image transmission at the receiver is increased.

1. Introduction

The advancement of digital image technology has triggered a rapid development in the imaging business, which leads to high demand for effective digital image storage and transmission media [1]. It happens because digital images are a type of information that has a relatively larger size than other types of information, such as text and sound [2]. In this case, compression or coding of sources becomes a solution to reduce the number of information symbols, so that it can streamline storage media and increase the transmission rate for certain channel capacities [3]. On the other hand, with a certain transmission rate, compression allows the use of channels with a smaller bandwidth width.

Set Partitioning in Hierarchical Trees (SPIHT) wavelet-based image compression method [4] is the development of the EZW (Embedded Zerotree Wavelet) method [5]. SPIHT has better performance and simpler algorithm than EZW, which using partitioned grouping for significant tests by the decreasing threshold order. With the reduced number of symbols to represent an image, the compressed image will experience a more significant impact on information damage due to noise than uncompressed images. Therefore, coding controls and error correction is necessary for the transmission of compressed images [6-10]. Reed Solomon (RS) coding is one of the alternative codings that has comparatively capabilities on correcting additional redundant data. This encoding is based on bit groups [8-12] so that it has very good error correction, especially burst errors.



In wireless communication, the signal can propagate from the transmitter to the receiver through various reflection paths, which is called multipath propagation [8-9, 13]. This phenomenon causes fluctuations in signal quality in the receiver which is known as fading. Fading is a noise that contaminates the signal by multiplying the signal, thus giving a greater impact than additive noise. Diversity technique is one of the techniques that is often used to reduce signal quality degradation due to this phenomenon. Diversity is used to improve the performance of radio channels without increasing transmission power [9]. Among all types of combining diversity, Maximum Ratio Combining (MRC) has the best performance, even though it requires more complex equipment [8-9].

Based on the studies that have been done on the use of diversity techniques, this study analyzes the performance of using error control coding RS (31, 15) type Equal Error Protection (EEP) [8-9] combine with diversity MRC in the radio frequency domain [9]. This study produces better performance compared to the three that have been done above. Where the use of RS code with EEP patterns can correct errors caused by noise, and MRC diversity combine Amplitude and phase is then given each weighing.

2. Design System

The design system of compressed image transmission SPIHT with Diversity MRC technique in Radio Frequency Domain can be seen in figure 1. The image to be transmitted is a grayscale image of 512×512 with a depth of 8 bits. Before compressing the image, it is decomposed by wavelet transformation [8-10]. The wavelet transformation image is compressed with the SPIHT algorithm [4] so that it produces the series of bit streams with the number corresponding to the bits per pixel (bpp) which is an independent variable of the system. To reduce errors that occur during transmission, the RS channel coding is used [8-10].

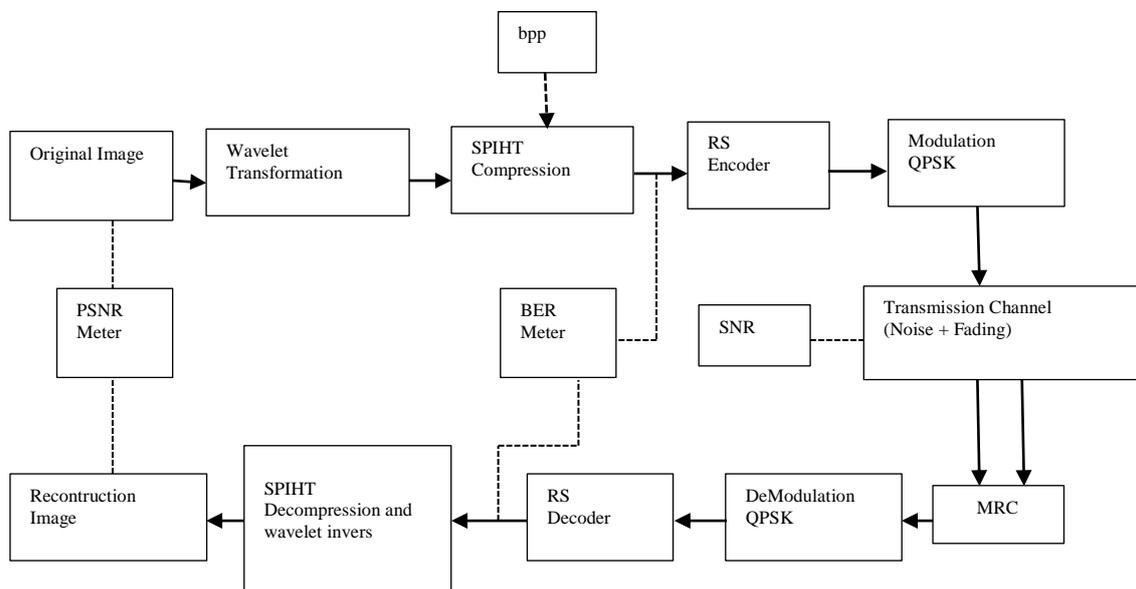


Figure 1. Block diagram of a compressed image transmission

In this system, RS (31.15) is used with the Equal Error Protection (EEP). The output of RS Code is then demodulated before it is transmitted to the wireless channel. This modulation removes the carrier component so that the signal that has been produced is in a complex form [14-15]. The equation for modulation signal is given below:

$$s_{bb}(t) = X_I(t) + jX_Q(t) \tag{1}$$

$$X_I(t) = A \cdot \cos \phi(t) \quad (2)$$

$$X_Q(t) = A \cdot \sin \phi(t) \quad (3)$$

$S_{bb}(t)$ is the equation of the modulation signal, $X_I(t)$ and $X_Q(t)$ are the in-phase and quadrature components of the information signal. Fading used in this channel model is a type of slow flat fading with Rayleigh distributed. Generating of signal fading is done by using the summing sine method as shown in the following equations [14]:

$$h_I(nT_s) = \frac{1}{\sqrt{M}} \sum_{m=1}^M \cos \left\{ 2\pi f_D \cos \left[\frac{(2m-1)\pi + \theta}{4M} \right] \cdot nT_s + \alpha_m \right\} \quad (4)$$

$$h_Q(nT_s) = \frac{1}{\sqrt{M}} \sum_{m=1}^M \sin \left\{ 2\pi f_D \cos \left[\frac{(2m-1)\pi + \theta}{4M} \right] \cdot nT_s + \beta_m \right\} \quad (5)$$

$$h(nTs) = h_I(nTs) + j \cdot h_Q(nTs) \quad (6)$$

where:

- $h_I(nTs)$ = inphase fading components
- $h_Q(nTs)$ = quadrature fading components
- $h(nTs)$ = Rayleigh fading
- M = number of multipath components
- f_D = maximum Doppler spread
- T_s = periodic sampling
- $\theta, \alpha, \text{ dan } \beta$ = random variable uniform distribution $[0, 2\pi]$

Demodulated information signal $S_{bb}(t)$ is then multiplied by the fading signal $h(nTs)$, so that amplitude and phase fluctuations occur, as formulated [14]:

$$s_{fd}(nT_s) = s_{bb}(nT_s) \cdot h(nT_s) \quad (7)$$

The receiver captures two signals that are independent on fading and noise from the transmission channel. Then, the signals from each antenna diversity are co-phased and weighted, both of which are carried out by estimation process. The co-phase process and weighting are carried out by the equation [8-9]:

$$s_{MRC1} = A_1 \cdot e^{-j\phi_1} \cdot s_{kanal1} \quad (8)$$

$$s_{MRC2} = A_2 \cdot e^{-j\phi_2} \cdot s_{kanal2} \quad (9)$$

Where A and ϕ are the weights and estimation phases of signals diversity branch, these two results are then summed to produce the signal as the results of diversity MRC.

3. Research Method

The transmission method used in this research is Equal Error Protection (EEP) by using the same type of RS Code (31, 15) in the coder and the decoder [8-9, 17]. The diversity technique used is referred to

the algorithm for diversity technique [8-9]. However, the channel model used is AWGN and Rayleigh Fading. Following is the design system for Diversity Combining Method for Compressed Images Transmission [8-10]

Figure 1 is the process of diversity combining that uses two diversity channels by implementing error correction and grouping the bit stream into blocks. The algorithm of this diversity is based on block chosen of bit $b(l)$ from the one-bit stream which based on the characteristic of wavelet transformation. The algorithm of MRC diversity captures two signals that are independent on fading and noise from the transmission channel. Then, the signals from each diversity antenna are co-phased and weighted by estimation process.

3.1. System Performance Test

The performance of the simulated system is tested by using dependent variable Bit Error Rate (BER) and Peak-to-peak Signal to Noise Ratio (PSNR). BER can be formulated [8-9]:

$$BER = \frac{\text{numberofbiterror}}{\text{numberofbits}} \quad (10)$$

and PSNR can be formulated [10]:

$$PSNR = 10 \cdot \log \frac{255^2}{\frac{1}{N} \sum_i \sum_j [p(i, j) - \hat{p}(i, j)]^2} \quad (11)$$

where $p(i, j)$ is the pixels of the original image, $p(i, j)$ is the image coefficient received on the receiver, and N is the number of pixels.

3.2 Research Variable

The variables used in this study are as follows:

1. Independent variables are the variables that can be manipulated. The independent variables used in the study are:
 - a. Bit per pixel (bpp). This variable represents the average number of bits for each pixel of the compressed image.
 - b. Signal to Noise Ratio (SNR). This variable is a comparison of signal power and noise power in the transmission channels.
2. Dependent variables are the variable that changes based on the changes in independent variables. The dependent variables used in the study are:
 - a. Bit Error Rate (BER). This variable is a comparison between the numbers of bits error with the total number of bits received. This comparison is made between the bit stream SPIHT compression results in the transceiver with the bit stream of the decoding result of Reed Solomon in the receiver.
 - b. Peak-to-peak Signal to Noise Ratio (PSNR). This variable represents the degree of integrity of the reconstruction image

4. Results and analysis

Table 1 is the results of image reconstruction of the compressed image transmission over Rayleigh Fading and Noise AWGN with the rate of 0.1 bpp with and without diversity. The SNRs are ranged from 10 dB to 20 dB. The result of the simulation shows that the system with diversity will obtain low BER and high PSNR when compared to the systems without using diversity.

Table 1. Transmission Simulation Results

SNR (dB)	BER		PSNR (dB)	
	With Diversity	Without Diversity	With Diversity	Without Diversity
10	0,0013	0,0851	13,254	5,453
14	0	0,0308	26,930	13,937
16	0	0,0127	26,930	16,005
18	0	0,0066	26,930	14,672
20	0	0,0040	26,930	14,330

Figure 2 shows that the use of MRC diversity techniques is very effective in suppressing errors that occur due to fading and noise. At 10 dB SNR, BER system without diversity shows a value of 0.0851 while BER system with MRC 0.0013. It means there is an emphasis on the number of errors of 98.47%. This error suppression increases at SNR 12 dB, which is 99.64% due to an increase in the ratio of signal power to noise. At SNR 14 dB and so on, the diversity MRC technique can eliminate all errors, or in other words, there is an error suppression of 100%.

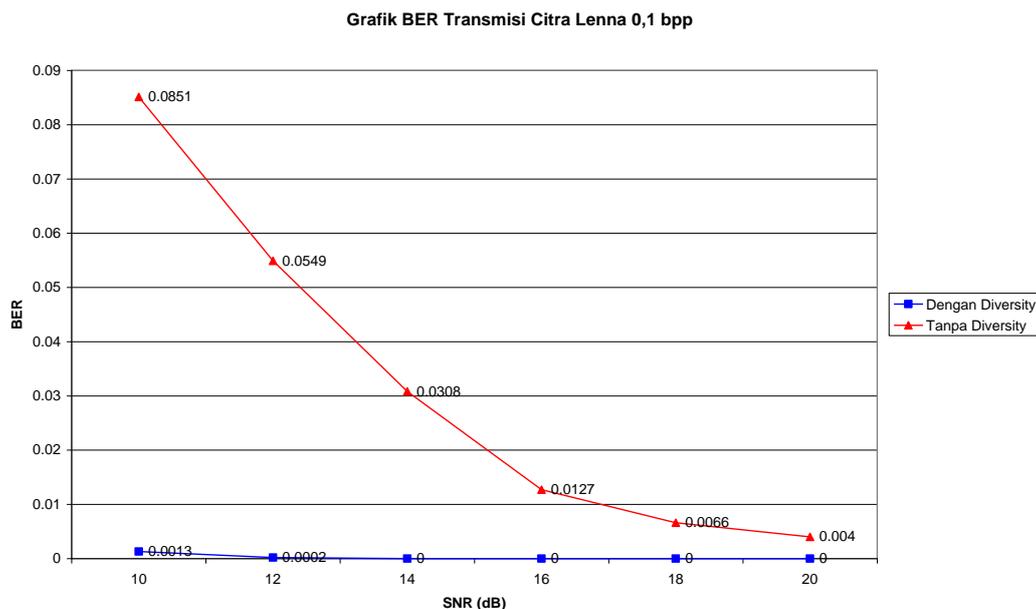


Figure 2. BER Graph image Transmission

Figure 3 shows that the diversity MRC technique is also able to improve transmission performance by increasing the PSNR. At 10 dB SNR, image transmission without diversity results in a reconstruction image with PSNR 5,453 dB, whereas with diversity produces PSNR of 13,254 dB. It means there is an increase of 7.801 dB. At 14 dB SNR, when there is no more error in the system with diversity, the resulting PSNR reconstruction image is 26.930 dB while the system without diversity is still 13.937 dB. The average increase in PSNR generated is 11.57 dB. Figure 3 shows that BER will decrease as SNR increases, both in systems with diversity and without diversity.

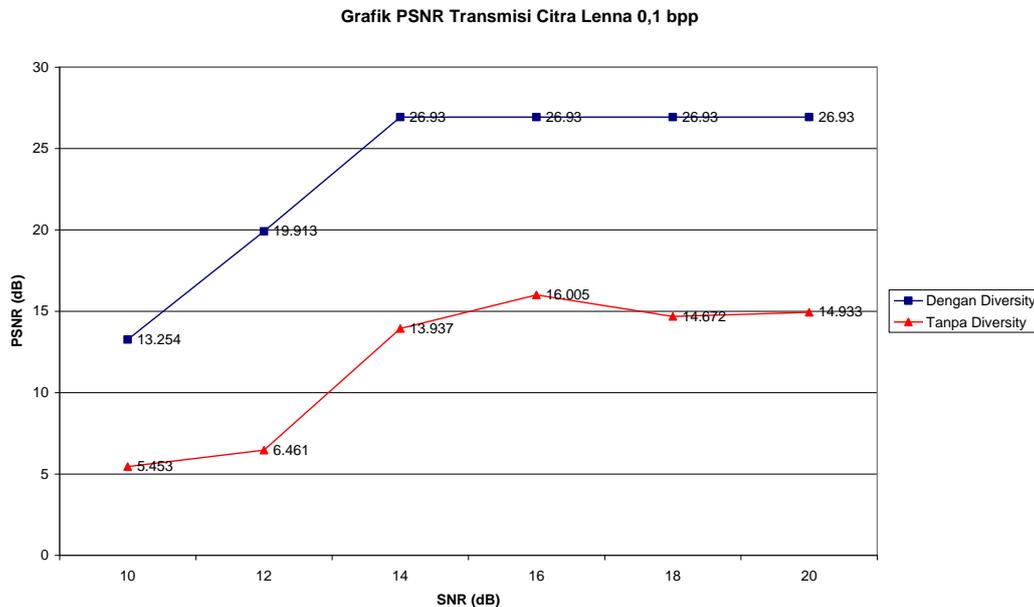


Figure 3. PSNR Graph Image Transmission

From the simulation above, it is clear that SNR improvement does not always increase the PSNR in the reconstruction image, both with and without diversity. This is because the PSNR or the quality of the reconstruction image is not only affected by the number of bits error but especially on the location of the error bits in the series of bits that will be decompressed SPIHT. By the characteristics of the SPIHT compression algorithm, which is the progressive transmission, the important information is located at the beginning, so that the damage to these initial bits will greatly affect the quality of the reconstruction image.

5. Conclusion

The use of diversity Maximum Ratio Combining technique in SPIHT digital image transmission compression is very effective in improving system performance. This technique can eliminate all bit errors at 16 dB SNR, with an average increase of 12.62 dB PSNR.

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