Performance Analysis of Diversity Selection Combining Technique in Rayleigh Fading Channel

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Abstract. This paper discussed a performance analysis of diversity selection combining technique in Rayleigh fading channel, in wavelet domain. It proposed diversity selection combining (DSC) method to combat errors during image transmission on wireless channels. The aim of using DSC in the system is to improve the performance of the system. The testing of the system was done by conducting experiment. The experiment was done by testing BER and PSNR. The result showed that BER was decrease to 13.4% in average compared to the system without DSC. PSNR was increased to 2.2 dB in average. The result of this simulation showed that the system with DSC in the image transmission system improved the system performance significantly when comparing to the system without DSC.

1. Introduction

In wireless communication, multiple propagation paths exist from transmitter to receiver due to reflection, diffraction, and scattering of wave by different objects. Signal copies received through different path can undergo rapid attenuation, distortion, delays and phase shift over a short period of time due to constructive or destructive interference occurring at receiver [1-2]. In destructive interference signal power decreases significantly and this phenomenon is called as fading. The multiple propagation path are time-varying. This results in multipath time-varying fading channel. The time-varying nature of channel is the major constraint for reliable wireless transmission. Multipath fading results in severe performance degradation in terms of error probability and poor reliability of wireless communication system. [2]

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 [3-9]. The Transmission in telecommunications system, the information in form of data, sound, image and video will be transmitted from the transmitter to the receiver via communication channel. During transmission, the degradation of the quality information might be happened due to the interference, delay spread, attenuation, noise and fading [10-12].

In order to improve the system performance, in the case of significant fading, different methods are used, but diversity techniques are most frequently applied [3-9]. Diversity techniques can be used to improve system performance in fading channels. There are several different types of diversity techniques that are commonly used in wireless communication systems. Diversity transmission is
based on the principle of using multiple copies of the transmitted signals that are statistically independent. The most commonly used techniques of combining signals after application of diversity techniques are: diversity selection combining (DSC), maximum ratio combining (MRC), and Equal Gain Combining (EGC) [5-7].

The idea of diversity is to combine several copies of the transferred signal passing independent fading in order to increase total receiving power [13-14]. Different types of diversity provide different methods of combining. In this paper, DSC is used for improve system performance in fading channels on wavelet domain. Selection combining is based on the principle of selecting the best signal among all the signals received from different branches at the receiver [15]. In this method, the receiver monitors the SNR of the incoming signal using switch logic. In figure 1, there are M independent Rayleigh fading channels providing M diversity branches, the weighted of each branch is adjusted to provide equal average SNR for each branch, co-phased is not required. The branch with the highest instantaneous SNR is connected to the demodulator. Instantaneous selection in not possible, therefore practical diversity selection system should be designed with small time constant of the selection circuit than the fading rate.

![Figure 1. Diversity Selection Combining](image)

Several methods for transmitting images over wireless channels have been proposed in the literature. Most of these are compressed image transmission based on discrete cosine transform (DCT) or wavelet transform[15]. This image transmission method can be divided based on error concealing techniques, error resilient image coding, error correction / detection methods, and hybrid methods. For the error concealing techniques method [16-18] is attempt to hide errors that degrade the perceptual quality of the image after the image has been received. While for the error resilient method [16-18], image makes the transmitted data stream less sensitive to wireless channel errors, so when the data arrive at the receiver, they are easier to recover from errors in the bit stream. For the error correction / detection methods [16-18], it uses different types of error coding to combat the errors which has been introduced during wireless transmission, whereas the hybrid method [16-18] uses a combination of the three methods described above.

This paper proposes SPIHT [19] compressed image transmission using the DSC technique in the wavelet domain. This technique can improve the effect of fading and noise with DSC. For image transmission over wireless channels, two or more diversity channels can be utilized to obtain multiple bit streams at the receiver, where each bit stream independently representing the image data. Then these bit streams can be combined in the wavelet domain to improve the perceptual quality of the received image.

2. Material and methods

In this research, DSC is used to obtain a better quality reconstruction image, when compared to reconstruction images without using DSC. DSC which used in this image transmission system works on wavelet domain which aims to improve the image quality.

2.1. The design system

The design system for this research is given in figure 2.
Figure 2. The system design used in the performance analysis of diversity selection combining technique in Rayleigh fading channel.

In the system, the combination of blocks is used by selecting the best blocks from the 2 transmission channels. By using DSC, the bit streams received from the uncorrelated diversity channels are divided into blocks and compared on a block-by-block basis. For each new block, the coefficients of the composite wavelet transform are updated based on the received bits [15]. If the coefficients reconstructed from one block are judged more likely, then all of the coefficients from the more likely block are placed in the composite wavelet transform [15]. If all of the chosen coefficient blocks are error free, then the reconstructed image will be error free. Two block-based diversity rules were developed. The first block-based diversity rule only selects blocks of bits, from one bit stream based on a measure that is dependent on wavelet transform characteristics. Figure 3 is the DSC based on block rules.

Figure 3. Diversity selection combining techniques based on block rules.
For each new block, the coefficient of the combined wavelet transform is updated based on the bits received. For more details, see the block diagram in Figure 3. So, if the reconstruction coefficient of a block is considered better, then the coefficient will be placed on the combined wavelet transform. If all selected block coefficients are error free, the reconstruction image will also be error free. This diversity selection combining rule is based on the selection of bit blocks \( b(l) \) from a bit stream by measuring \( w(l) \) which depends on the wavelet transformation characteristics. The rules for selecting blocks can be written with the following equation [15]:

\[
\begin{align*}
    b(l) &= \begin{cases} 
        h_i(l) & \text{if } w(l) \geq 0 \\
        h_s(l) & \text{if } w(l) < 0
    \end{cases} \\
    & \text{for } l = 1, 2, \ldots, L
\end{align*}
\]

where:

\[
w(l) = \sum_{(i,j) \text{lowres subband}} h_i'(i,j) + \sum_{(i,j) \text{detail subband}} h_s'(i,j)
\]

To determine the value of \( w(l) \), use the rules for determining the value of \( h_i'(i,j) \) for the approximation coefficient and \( h_s'(i,j) \) for detail coefficient. Here are the rules:

2.1.1. Rule of approximation coefficient

In this rule, if the absolute value of the difference in approximation coefficient at point \((i,j)\) with the approximation coefficient at point \((i,j+1)\) on channel 1 is smaller than the absolute value of difference of approximation coefficient at point \((i,j)\) with approximation coefficient at point \((i,j)\) on channel 2, then \( h_i'(i,j) \) will be worth 1. However, if the value at channel 1 is bigger than the value of channel 2, \( h_i'(i,j) \) will be worth -1. Whereas, if the value of the approximation coefficient on channel 1 is the same as the approximation coefficient on channel 2, \( h_i'(i,j) \) will be worth 0. The rules for determining the value of \( h_i'(i,j) \) can be given in the equation [15]:

\[
h_i'(i,j) = \begin{cases} 
    1 & d_1(i,j) < d_2(i,j) \\
    -1 & d_1(i,j) > d_2(i,j) \\
    0 & c_{L1}(i,j) = c_{L2}(i,j)
\end{cases}
\]

where:

\[
d_k(i,j) = |c_{Lk}(i,j) - c_{Lk}(i,j + 1)|
\]

for \( k = 1, 2 \) (number of diversity antenna). The absolute value of the difference between the approximation coefficient at a point \((i,j)\) with the approximation coefficient at a point \((i,j+1)\) or in the next column.

where: 
\( c_{Lk}(i,j) \) = approximation coefficient

2.2. Rules for detailed coefficients

The rules for the detailed coefficients are not much different from the rules for the approximation coefficients. The difference only lies in the coefficients used. The rules for determining the value of \( h_s'(i,j) \) for the detailed coefficients can be given in the equation [15]:

\[ h^j_{H}(i, j) = \begin{cases} 
1 & t_1(i, j) < t_2(i, j) \\
-1 & t_1(i, j) > t_2(i, j) \\
0 & c_{H1}(i, j) = c_{H2}(i, j) 
\end{cases} \] (5)

where:
\[ t_k(i, j) = \left[ c_{Hk}(i, j) - \left( \sum_{m=0}^{1} \sum_{n=0}^{1} c_{Hk}(2i+m, 2j+n) / 4 \right) \right] \] (6)

for \( k = 1, 2 \) (number of diversity antenna)

where: \( c_{Lk}(i, j) \) = detail coefficient

2.3. Simulation methods
This research is done by doing a simulation method with the Matlab program to get the optimum performance and system reliability, as well as design accuracy before it is implemented. The transmission method used in this research is RS Code (31, 15) in the coder and the decoder [15]. The diversity technique used is DSC [2] on the wavelet domain and the channel model used is additive white Gaussian noise (AWGN) and Rayleigh Fading [2].

2.3.1. System performance test
The system performance test in this study uses two parameters, namely BER and PSNR. BER is used to measure how many errors occurred at the receiver. PSNR is used to determine the quality of the reconstructed image at the receiver. BER and PSNR parameters can be explained as follows.

2.3.1.1. The Calculation of BER
The bit error ratio (BER) is measured by dividing the number of bit errors by the total number of transferred bits. The measurement of BER can be given by the following equation [2]:
\[ BER = \frac{n}{N} \] (7)

where: \( n \) = number of incorrect bits of information at the receiver
\( N \) = number of bits of information transmitted.

2.3.1.2. The Calculation of PSNR
PSNR is a useful parameter to determine the quality of reconstruction image. PSNR calculation is done by comparing the pixel value of the original image with the pixel value of the reconstructed image. PSNR shows the quality of the reconstructed image. The higher the PSNR value obtained, the better the quality of the image. The PSNR can be formulated as follows [15]:
\[ PSNR = 10 \log_{10} \frac{255^2}{\frac{1}{N} \sum_{i} \sum_{j}(p(i, j) - \hat{p}(i, j))^2} \] (8)

where: \( p(i, j) \) is the original image pixel value,
\( \hat{p}(i, j) \) is Pixel value of reconstructed image,
\( N \) is the number of pixels in image, while the 255 value is the highest value for grey scale image.

2.3.2. Research Variable
The variables used in this study are as follows:
Independent variables are the variables that can be manipulated. The independent variables used in the study are:

1. Bit per pixel (bpp). This variable represents the average number of bits for each pixel of the compressed image.
2. SNR is the variable that compares signal power and noise power in the transmission channels.

Dependent variables are the variables that change based on the changes in independent variables. The dependent variables used in the study are:

1. BER is the variable which compares the numbers of bits error with the total number of bits received. This comparison is done between the bit stream SPIHT compression results in the transceiver with the bit stream of the decoding result of Reed Solomon in the receiver.
2. PSNR is the variable which represents the degree of integrity of the reconstruction image.

3. Results and discussion

To evaluate the system performance of DSC in Rayleigh fading channel, several experiments were carried out to test the BER and PSNR values results on Boat image with a compression ratio of 0.4 bpp. BER test results are given in table 1, figure 4 and figure 5.

Table 1. The result of performance analysis of DSC in Rayleigh fading channel.

| SNR (dB) | BER Without DSC | PSNR (dB) Without DSC | BER With DSC | PSNR (dB) With DSC |
|---------|-----------------|------------------------|--------------|---------------------|
| 10      | 0.0416          | 5.1555                 | 0.0396       | 6.6709              |
| 12      | 0.0149          | 12.6969                | 0.0138       | 12.7135             |
| 14      | 0.0031          | 18.5878                | 7.6212 x 10^{-4} | 20.6474         |
| 16      | 7.4769 x 10^{-4} | 18.6310                | 4.1911 x 10^{-4} | 22.4545         |
| 18      | 1.0005 x 10^{-4} | 27.4847                | 4.9053 x 10^{-5} | 28.9533         |
| 20      | 0               | 30.5331                | 0            | 30.5331             |

Table 1 shows the simulation result of performance analysis of DSC technique in Rayleigh fading channel comparing to the system without DSC. These simulation tests are ranged from 10 dB SNR to 20 dB SNR with a compression ratio of 0.4 bpp. The results obtained from table 1 are in the form of BER and PSNR values. The analysis of BER and PSNR values is given in figure 4 and figure 5.

Figure 4. Comparison graph of BER to SNR of Boat image with 0.4 bpp with and without DSC.

Figure 4 shows a comparison graph of BER values with and without using DSC diversity. For the system with DSC, the SNR value at 10 dB decrease to 20%, at 12 dB decreased by 11%, at 14 dB decreased by 23%, at 16 dB by 32%, at 18 dB decrease to 3.9% respectively, while the SNR value at 20 dB there are no errors occurred both with and without using DSC. Thus, in the system with DSC,
the average error reduction obtained was 13%. At SNR 18 dB, the error reduction is only 3.9%. This value is very low for the system, because at SNR 18 dB, the signal power is greater than the noise power while at 20 dB SNR, there is no errors occurred both with and without using DSC. It happened because the signal power is bigger compared to noise.

4. Conclusion
The result of the experiments which were carried out to test BER and PSNR on the Boat image with a compression ratio of 0.4 bpp with DSC in Rayleigh fading channel showed that there was 13.4% in average the reduction of BER values compared to the system without DSC. The lowest decreasing value of BER was at 18 dB SNR. It happened because the power of SNR is large enough to be able to combat the disturbance of fading and noise. The PSNR value also had an average increase to 2.2 dB. However, at SNR 12 dB there was slightly improvement to 0.0166 dB on the quality of the reconstruction image. It was caused by the random nature of the fading and noise signals which was very dominant to the information signal. While, the SNR at 20 dB, there was no improvement for both BER and PSNR values because the signal power to noise ratio (SNR) had reached a maximum value. The results of this study showed that the use of DSC techniques in the wavelet domain can reduce errors and improve the quality of image reconstruction. In order to make this research be more optimal, it is recommended to develop several systems such as modulation technique improvements, error control coding techniques, and standard source coding techniques.

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