MC CDMA PERFORMANCE ON SINGLE RELAY COOPERATIVE SYSTEM BY DIVERSITY TECHNIQUE IN RAYLEIGH FADING CHANNEL

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ABSTRACT

Wireless communication now has been focus to increase data rate and high performance. The multi carrier on multi-hop communication system using relay’s diversity technique which is supported by a reliable coding is a system that may give high performance.

This research is developing a model of multi carrier CDMA on multi hop communication system with diversity technique which is using Alamouti codes in Rayleigh fading channel. By Alamouti research, Space Time Block Code (STBC) for MIMO system can perform high quality signal at the receiver in the Rayleigh fading channel and the noisy system. In this research, MIMO by STBC is applied to single antenna system (Distributed-STBC/DSTBC) with multi carrier CDMA on multi hop wireless communication system (relay diversity) which is able to reduce the complexity of the system but the system performance even can be maintained and improved.

MC CDMA on multi hop wireless communication system with 2 hops is performing much better than Single Input Single Output (SISO) system (1 hop system). Power needed for 1 hop system to have the same quality as 2 hops system to reach BER $10^{-3}$ is 12 dB. And multi hop system needs orthogonal symbol to send from relay than original symbol to reach better performance. 12.5 dB power up is needed for multi hop system which sent same symbol as transmitter than relay system which sent orthogonal symbol.

KEYWORDS

Alamouti, MIMO, multi carrier, CDMA, MC CDMA, STBC, Distributed-STBC/DSTBC, diversity, Rayleigh fading, multi-hop system, SISO, relay’s diversity

1. INTRODUCTION

Wireless communication system development nowadays focused to support the services with high data rate for some the contents of multimedia such as sound, images, data and video. Moreover, the transmitted data is expected to have the better quality with a low bit error rate. To provide the interactive multimedia services, it needs a large bandwidth. However, the available bandwidth is
limited, and the wireless communication system has more complex channel characteristic than wireline.

To improve the performance of the wireless system, there should be improvement of coding scheme in the transmitter and receiver. One of them is to apply the code block in multi antenna systems, known as Multiple Input Multiple Output (MIMO). One of MIMO transmission techniques often used is Space Time Block Code (STBC) found by Siavash M. Alamouti [1]. STBC is a such technique that relies on code orthogonality, so the correlation between the antennas would be very small and has an impact to perform better quality than the system without using STBC [1].

The application of STBC was not only good for the multi-antenna system or MIMO, but also the application of STBC in the cooperative communications with multi hop can improve the system transmission performance significantly even with single-antenna [2]. The application of STBC cooperative communications is called the Distributed-STBC (DSTBC). In this research, DSTBC applied to cooperative communication with single antenna on the Rayleigh fading channels and used 2 hops for the simulation.

2. BASIC THEORY

2.1. Basic Concept of Multi Input Multi Output System (MIMO)

MIMO system is a transmission system (Tx-Rx) where the number of antenna either transmitter or receiver consists of several antenna. Many coding scheme has been performed at MIMO system to get better received signal quality. Alamouti codes is one of the coding scheme to apply at MIMO system which perform good quality.

2.2. Diversity with Space Time Block Code (STBC)

Orthogonal space time block code is transmission scheme introduced by Alamouti. Alamouti has introduced coding scheme for 2x2 or 2x1 antenna which is shown at figure 2.1 [6].

\[
\begin{bmatrix}
T_{x0} & T_{x1} \\\nt & S_0 & S_1 \\
t +1 & -S_1^* & S_0^*
\end{bmatrix}
\]

Figure 2.1: Orthogonal Space Time Block Code transmission scheme [1]
The channel at time $t$ is modelled by a complex multiplicative coefficient $h_0(t)$ from 1st transmitter antenna and $h_1(t)$ from 2nd transmitter antenna. Assuming that fading coefficients are constant across two consecutive symbols as [1]:

\begin{align*}
  h_0(t) &= h_0(t+\tau) = h_0 = \alpha_0 e^{j\theta_0} \\
  h_1(t) &= h_1(t+\tau) = h_1 = \alpha_1 e^{j\theta_1}
\end{align*} 

(2.1)

According to figure 2.1 and figure 2.2, the equation of received signal is [1]:

\begin{align*}
  r_0 &= r(t) = h_0s_0 + h_1s_1 + n_0 \\
  r_1 &= r(t+\tau) = -h_0s_1^* + h_1s_0^* + n_1
\end{align*} 

(2.2)

$n_0$ and $n_1$ are complex random variable which represents interfere and noise thermal. Combiner subsystem in figure 2 will decode received signal by maximum likelihood formula as [1]:

\begin{align*}
  \hat{s}_0 &= h_0^* r_0 + h_1^* r_1 \\
  \hat{s}_1 &= h_1^* r_0 - h_0^* r_1
\end{align*} 

(2.3)
Substituting equation 2.1 to 2.3 will make a result [1]:

\[
\begin{align*}
\tilde{s}_0 &= (a_0^2 + a_1^2)s_0 + h_0^2n_0 + h_1n_1^2 \\
\tilde{s}_1 &= (a_0^2 + a_1^2)s_1 - h_0n_1^2 + h_1n_0
\end{align*}
\]  \tag{2.4}

2.3. Diversity by Distributed Space Time Block Code (DSTBC)

The application of STBC was not only good for the multi-antenna system or MIMO, but also for cooperative communications with multi hop system. It can improve the system transmission performance significantly even with single-antenna [2]. The application of STBC cooperative communication is called the Distributed-STBC (DSTBC). The system scenario is described as the situation displayed in figure 2.4.

According to figure 2.4, the equation of received signal is:

\[
\begin{align*}
r_1 &= -s_2^*h_1 + s_1h_2 \\
r_2 &= s_1^*h_2 + s_2h_3
\end{align*}
\]  \tag{2.5}

*Combiner* block in figure 2.4 makes two signals below which will be transmitted to *maximum likelihood* detector:

\[
\begin{align*}
\tilde{s}_1 &= r_1h_1^* + h_2r_2^* \\
\tilde{s}_2 &= -h_2r_1^* + h_3r_3^*
\end{align*}
\]  \tag{2.6}
2.4. Transmission Channel Decoding

\[ h(t, \tau) \]

A transmission channel generally can be defined:

\[ h(t, \tau) = \sum_{i=0}^{N-1} \{ a_i(t, \tau_i(t)) p(t, \tau_i(t)) \} \]

\[ p(t, \tau_i(t)) = e^{\frac{\pi}{2} f_d \tau_i(t) + \theta_i(t) + \frac{\pi}{2} \delta(t-\tau_i(t))} \]

where:

- \( a_i(t, \tau_i(t)) \) is gain from \( i \)-th multipath component at time \( t \).
- \( 2\pi f_d \tau_i(t) + \theta_i(t) + \frac{\pi}{2} \delta(t-\tau_i(t)) \) is a term to representate phase shifting because of propagation at \( i \)-th multipath component.
- \( N \) is propagation path number.

Doppler shifting is expressed by equation [2]:

\[ f_d = \frac{v \cos \theta}{\lambda} \]

where:

- \( v \) = relative movement velocity
- \( \lambda \) = wavelength of carrier
- \( \theta \) = angle between incoming signal direction and antenna movement direction

2.5 Multicarrier Modulation

Multicarrier modulation is defined as modulation technique in which there are several subcarrier or frequency to modulate the separate signal and every subcarrier is orthogonal each other. This mechanism is also called OFDM (Orthogonal Frequency Division Multiplexing). By this nature the signal in every subcarrier can be overlapped without Intercarrier Interference (ICI). This
mechanism can save bandwidth needs [9]. Spectrum illustration between conventional FDM and multicarrier (OFDM) is shown at figure 2.6.

![Figure 2.6: Multi Carrier Spectrum (a) No Overlap (b) Orthogonally Overlap](image)

Mathematically, group of signal $\varphi_i$, $i = 0, \pm 1, \pm 2, \ldots$, akan ortogonal pada interval [a b], jika:

$$\int_a^b \varphi_i(t)\varphi_i^*(t) \, dt = \begin{cases} E_k, & \text{jika } l = k \\ 0, & \text{jika } l \neq k \end{cases}$$

(2.9)

$E_k$ is constant resulting from integration and $\varphi_i^*(t)$ is conjugate complex from signal $\delta(l - k)$ (delta kronecker) [10], which is defined as:

$$\delta(l - k) = \begin{cases} 1, & \text{when } l = k \\ 0, & \text{when } l \neq k \end{cases}$$

(2.10)

Basis function Discrete Fourier Transform (DFT) or Fast Fourier Transform is:

$$\varphi_k(t) = e^{j(2\pi kt/T)}$$

where $k = 0, \pm 1, \pm 2, \pm 3, \ldots$, forms group of orthogonal signal at interval $(0, T)$ ($T$ = signal period):

$$\int_0^T \varphi_k(t)\varphi_k^*(t) \, dt = \begin{cases} T, & \text{jika } l = k \\ 0, & \text{jika } l \neq k \end{cases}$$

(2.11)

3. COOPERATIVE SYSTEM BASED ON ONE RELAY MODEL (2 HOPS SYSTEM)

3.1 Model System

The communication between the source and the user not only directly but also through the relay. So that, the received signal is the sum of the user that sent the signal directly (direct channel) and signal through the relay (the relay channel).
As shown at figure 3.1 the multi hop system introduced 2 hops, such as: 1. the hop between base station (BS) and mobile station (MS) via relay, 2. the hop between BS and MS directly without relay. Fading channel distribution realized in 2 hops are Rayleigh fading channel in i.i.d distributed. Because of Rayleigh channel, received signal performance of 2 hops system should be affected by mobility of either relay or MS velocity. Figure 3.2 explained SISO (Single Input Single Output) system model (1 hop system) in which its performance will be compared to 2 hops system performance [9].
The transmitter system of BS or SISO transmitter consists of 3 subsystems processing baseband signal as shown in figure 3.3. While relay transceiver from figure 3.1 consists of 5 subsystems which equalized, normalized, STBC encoded, and selected one block code before transmitting the signal to MS as shown in figure 3.4. As shown in figure 3.5, receiver system consists of several subsystem which decoded combined signal from BS and relay by Alamouti principal, demodulate, deinterleaved, and Viterbi decoded. Next, the data compared to the original data for counting BER performance.

The content of MC CDMA transmitter by frequency domain spreading is shown in figure 3.6. The content of MC CDMA receiver by frequency domain spreading is shown in figure 3.6.

The content of MC DS CDMA transmitter by frequency domain spreading is shown in figure 3.8. The content of MC Ds CDMA receiver by time domain spreading is shown in figure 3.9.
4. MC CDMA MULTIHOP COOPERATIVE SYSTEM PERFORMANCE

This simulation was running by several scenarios, such as:

1. Comparison between SISO, and MC CDMA with multi hop either frequency domain spreading MC CDMA or time domain spreading MC CDMA at flat fading Rayleigh.
2. Perform how much subcarrier number affected the performance of multi fading MC CDMA.
3. Perform how much subcarrier number affected the performance of multi hop MC DS CDMA.
5. Comparison performance of multi hop MC CDMA and MC DS CDMA in the different fading channel condition.

For the first scenario, the parameter implemented in the simulation has following limitation:

- Flat Fading Rayleigh
- 32 spreading code (Walsh-Hadamard)
- MS Velocity 30 km/h
- QPSK mapper
- Using 32 subcarriers (At Multicarrier system)
- Perfect Channel Estimation

The simulation result is displayed at figure 4.1.

![Multi Hop System Performance Comparison](image)
As displayed in figure 4.1, SISO has better performance when $\text{Eb/N0}$ less than 17 dB, but more than 17 dB MC DS CDMA started to have better performance than SISO system. MC CDMA started to have better than SISO at $\text{Eb/N0}$ more than 19 dB. At this simulation it is concluded that both MC CDMA in multi hop communication has a worse performance than SISO when $\text{Eb/N0}$ is still below about 18 dB. But more than 18 dB both MC CDMA has significant performance as the $\text{Eb/N0}$ raises.

For the second scenario, simulation testing was done with following parameter:

- Frequency Selective Fading Rayleigh
- 32 spreading code (Walsh-Hadamard)
- MS Velocity 30 km/h
- BPSK mapper
- Using 32 subcarriers (At Multicarrier system)
- Perfect Channel Estimation

The simulation result is displayed at figure 4.2 and figure 4.3.
For the third scenario, simulation testing was done with following parameter:

- Rayleigh Frequency Selective Fading
- 32 spreading code (Walsh-Hadamard)
- MS Velocity 60 km/h
- BPSK mapper
- Using 32 subcarriers (at Multicarrier system)
- Perfect Channel Estimation

The simulation result is displayed at figure 4.4.

For the forth scenario, simulation testing was done with following parameter:

- Flat and Frequency Selective on Rayleigh Fading Distribution
- 32 spreading code (Walsh-Hadamard)
- MS Velocity 60 km/h
- QPSK mapper
- Using 32 subcarriers (At Multicarrier system)
- Perfect Channel Estimation

The simulation result is displayed at figure 4.5.
5. CONCLUSION

5.1 Conclusion & Suggestion

1. There will need an improvement formula on MC CDMA Receiver to get better performance. Maximum Likelihood on inner code DSTBC might be improving the performance.
2. Different time symbol received should be simulated and analyzed in the next research as the real condition which needs to be anticipated.
3. Developing system with multi antenna scheme at the transmitter and receiver might perform better performance.

REFERENCES


AUTHORS

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