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BER Performance of QAM and QPSK Modulation Technique for DCT Based Channel Estimation of STBC MIMO OFDM

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Abstract. Consumer demand for high speed data communication system is increasing day by day. However the major challenges for wireless communication system are Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) that occur during data transmission. This interference will distort signal and increase error rate in the system. Combination of Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) give a reliable high data rate. Discrete Cosine Transform (DCT)-based channel estimation is used in STBC MIMO-OFDM and simulated using MATLAB software. The system performance is compared with multiple antenna configuration and different modulation technique. Multiple antenna configurations that involve during simulation are 2x2, 4x4 and 6x6 while modulation techniques are Quadrature Amplitude Modulation (QAM) and Quadrature Phase Shift Keying (QPSK). This simulation will prove that the higher number of transmit and receive antenna, the lower BER for the system.

1 Introduction

Nowadays, wireless broadband communication system is well known throughout the world. Demanding for wireless network technologies were increasing years by years and it is proven by over past few years, data rates for wireless network increasing approximately from 10Kbps to 10Mbps and beyond. It is full responsibility to achieved higher capacity of wireless communication system with better performance. Wireless broadband communication system is a system where signal been transmitted from transmitter to receiver passing through space. Throughout this system there should be degradation in terms of system performance that needs to be enhanced.

MIMO technology had become the advance technology in communication system where using multiple antennas at both transmitter and receiver in order to send many data at one time and increase the capacity of data transmit. MIMO-OFDM been introduced because of [1] its ability to enable high data rate transmission over multipath and frequency selective fading channel. OFDM is a method used as multi-carrier digital modulation technique [2]. This technique where dividing the high-speed information signal into multiple narrowband subcarrier channel. The multiple subcarrier channel transmit simultaneously at different frequency in parallel and waveforms are orthogonal to each other where it overlapping and not interfere with adjacent subcarriers. OFDM is robust against narrowband interference [3], has high spectral efficiency and reduce ICI (Inter Carrier Interference). Combination of MIMO and OFDM system can give high data rates, speeds and high spectral efficiency [1] which needed for future broadband communication system. Channel estimation is important in order to maintain and recover the signal at receiver from noisy channel by using accurate channel estimator. Previous researcher [4] also use DCT instead of DFT. FFT introduced by Joseph Fourier shows FFT is a simple algorithm that allows conversion back and forth between the frequency domain and the time domain. In [5], shows that DCT is enhance of the DFT and FFT. This paper will analyze the performance of the DCT-based channel estimator in MIMO-OFDM wireless communication system. QAM and QPSK is used in MIMO OFDM as a modulation scheme and compare it which modulation scheme works the best for MIMO-OFDM using DCT-based channel estimation.

2 Methodology

2.1 MIMO system

Multiple Input Multiple Output (MIMO) had become advance technology in communication system. A radio antenna technology that uses multiple antennas at the transmitter and receiver enables to send many signal paths as antennas carry the data [6]. MIMO had increase the system capacity and user data rates without using additional power or bandwidth. Spatial multiplexing is one of the fancy versions of MIMO where different data is fed to the multiple antennas and sends the information in parallel. At the receiver it is able to separate these data out and combine it back together.

In MIMO system, a transmitter sends multiple streams by multiple transmit antennas. The transmit streams go through matrix channel which consist of all N_tN_r path between the N_t transmit antennas at the transmitter and N_r receive antennas at the receiver. Then, the receiver gets the receive signal vectors by the multiple receive antennas and decode the receive signal vectors into the original information [7].
MIMO system can be modeled as

$$Y = Hx + n \tag{1}$$

which x is the transmitted symbol from each antenna and Y is the received signal at the receiver. H is the channel matrix for multiple antennas. H channel can be express by matrix according to the number of transmit and receive antennas and n were the channel noise, AWGN channel.

$$H = \begin{bmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_t} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,N_t} \\ \vdots & \vdots & \cdots & \vdots \\ h_{N_r,1} & h_{N_r,2} & \cdots & h_{N_r,N_t} \end{bmatrix}$$

H channel indicates the number of transmit and receive antennas, as the number of antenna increases for transmit and receive antenna, increases the transmit stream of MIMO channel.

2.2 Space time block code

Diversity is one of technique in multipath antennas, that used to decrease the error of the performance due to wireless fading channels. Space time frequency and spatial diversity are various type of diversity implemented in order to decrease error performance. Space Time Code (STC) system illustrate a concept of space-time diversity that employs in multiple transmit antenna. STC make used of the spatial diversity technique to encode the information into space-time code word and transmitted over symbol times decode back at the receiver. STC can be classifies into Space time block code (STBC) and space-time trellis code (STTC).

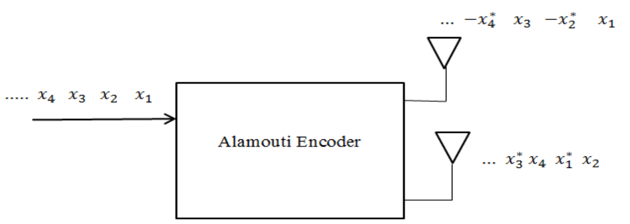

Figure 1. Alamouti code of STBC.

Alamouti code is the very first STBC which is a complex orthogonal space-time code specialized for two transmit antennas. In Alamouti, transmitted symbol are encoded within two symbol period and it will take two time-slots to transmit two symbols. Fig. 1 shows during the first period, two symbols x_1 and x_2 were transmitted from each of antenna. During the second period, the symbol are copied and transmitted again with $-x^*_2$ and x^*_1 from first and second transmit antennas. This is the orthogonally between symbol after receiving process at the receiver.

The diversity scheme example for 2x2 antenna configuration, it can be seen four copies of x_1 and four copies of x_2 at the receiver regarding to the H channel. Since the code is not interfering with each other, the code is orthogonal. Hence, the diversity order for 2x2 antenna configuration is four.

2.3 OFDM

Orthogonal Frequency Division Multiplexing is dividing the total channel bandwidth into many small bandwidth channels. The individual frequencies are carefully chosen such that they are orthogonal to each other, although the carrier can overlap [6]. Individual frequency is known as subcarriers and each of the subcarriers is modulated with a conventional scheme such ASK, PSK and QAM.

In transmission process, a data stream is converted into a parallel from high rate data stream to low rate data stream. The number of data streams corresponding to the number of available OFDM sub-carriers. Then, each of these low data rate stream is used to modulate each of the subcarrier frequencies [6] like example in the Fig. 2.

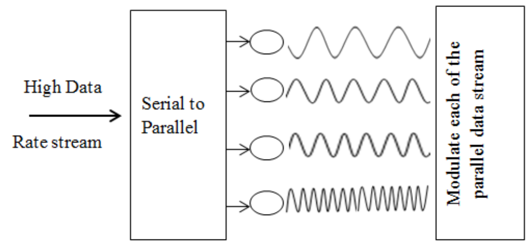

Figure 2. OFDM system

2.4 MIMO-OFDM system

MIMO OFDM system been widely used in wireless communication system such IEEE 802.11n for WLAN where the standard for wireless broadband communication and been used throughout this project. MIMO OFDM been proved [2], [8] can improve the system capacity and increase speed and high data rate. Previous researcher stated that MIMO OFDM fulfill the requirement because of its unique properties such give high data rates, high spectral efficiency and resistance towards multipath propagation [2].

In order to enhance MIMO-OFDM system performance, channel estimation been added to MIMO OFDM [2]. In this paper, DCT-based channel estimation with STBC in MIMO OFDM system is used in order to increase the performance of the system. Besides, the system also tested on the MIMO system where multiple antennas of 2x2, 4x4 and 6x6 are used in this project with different digital modulation technique.

2.5 Discrete cosine transform (DCT)

Discrete Cosine Transform (DCT) or inverse DCT (IDCT) can be expressed as a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies [3]. DCT is proved to be more efficient than DFT as mention by previous researcher[5], [7], [9], [10]. DCT are mostly used in science and engineering application such as lossy compression of audio and images (eg. JPEG). In [3], they said that DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers.

Using DCT, a complex exponential function set can be used as orthogonal basis to implement multi carrier scheme [9]. The real time high-frequency components of DFT can be reduced by DCT. DCT employs mirror extension of N-point data sequence to 2N-point data sequence, which removes the discontinuous edge [9].

The output signal of IDCT/DCT-based OFDM system written as:

i. Using IDCT-based at transmitter:

$$x(n) = IDCT[y(k)] \tag{2}$$

$$x(n) = \sum_{k=1}^{N} w(k) y(k) \cos(\frac{\pi(2n-1)(k-1)}{2N}) \tag{3}$$

$k = 1,2 \ldots., N$

where

$$w(k) = \begin{cases} \frac{1}{\sqrt{N}} & k = 1 \\ \sqrt{\frac{2}{N}} & 2 \leq k \leq N \end{cases}$$

ii. Using DCT-based at receiver:

$$Y(k) = DCT[x(n)] \tag{4}$$

$$Y(k) = w(k) \sum_{n=1}^{N} x(n) \cos(\frac{\pi(2n-1)(k-1)}{2N}) \tag{5}$$

$k = 1,2 \ldots., N$

where;

$$w(k) = \begin{cases} \frac{1}{\sqrt{N}} & k = 1 \\ \sqrt{\frac{2}{N}} & 2 \leq k \leq N \end{cases}$$

N refers to the length of data symbol obtain from modulation constellation QAM and QPSK while w(k) is the coefficient of DCT that reconstruct sequence very accurately and it is useful property for applications requiring data reduction [5]. IDCT/DCT is a Fourier-transform where transform from frequency to time domain and vice versa.

2.6 Quadrature phase shift keying (QPSK)

Phase Shift Keying is shifting the phase of carrier by modulating signal with phase measured relative to the previous bit interval. In M-ary modulation where two or more bits been grouped together to form a symbol and a signal, s(t). This project used 4-PSK where M = 2^n, n=2 shows transmitting 2 bit per symbol to be mapped into phase [10].

QPSK can be express as:

$$s(t) = A\cos(2\pi f_c t + \theta^{\circ}) \tag{6}$$

where f_c is the frequency carrier and $\theta^{\circ} = 0^{\circ}, 90^{\circ}, 180^{\circ}, 270^{\circ}$ is a modulating signal phase shift by 90° as in constellation diagram Fig. 4.

2.7 Quadrature amplitude modulation (QAM)

QAM is a modulation technique that combines with Amplitude Shift Keying (ASK) and Phase Shift keying (PSK). QAM consist of two amplitudes of wave and called quadrature when 90° amplitude are out-of-phase with each other. Bit per symbol for M-QAM level used in this project is 4-QAM. QAM can be express as:

$$s(t) = A_I \cos(2\pi f_c t) + A_Q \sin(2\pi f_c t) \tag{7}$$

A_I and A_Q were phase (I) and quadrature (Q) where the data bit stream split into I and Q are grouped together using QAM modulator and mapped into complex symbol [11]. The complex symbol been transmitted and splits up at the receiver using QAM demodulator in order to get the output data.

2.8 DCT-OFDM system

Fig. 3 shows the MIMO-OFDM system using DCT-based channel estimation. The system works with input binary data modulated by QAM and QPSK modulation scheme. The idea of converting from serial to parallel stream and modulate each of the subcarrier frequencies has been explained in OFDM system section.

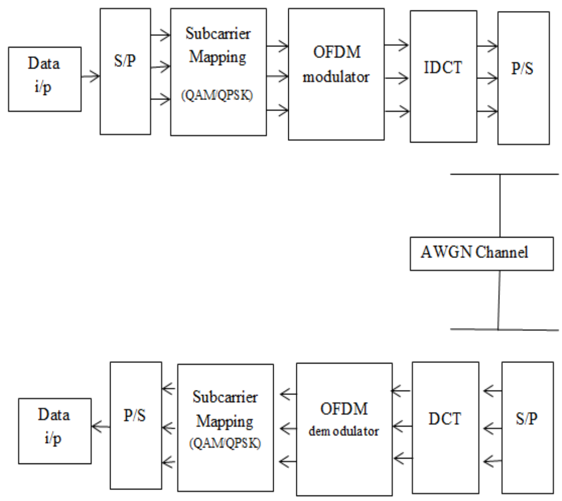

Figure 3. MIMO-OFDM system using DCT-based channel estimation.

Before the signal had been transmitted, the IDCT-based channel estimation is placed at the transmitter and the sets of low data rate channels carrying the information in parallel being transmitted with multiple antennas through AWGN channel. At the receiver, the signal is change to frequency-domain by inserting DCT-based and demodulated by the OFDM demodulator. Lastly, In order to achieve original data from data stream, the QAM or QPSK demodulator is used.

3 Simulation results

Table 1 shows the parameter used for MIMO-OFDM system based on the WLAN (IEEE 802.11n).

Table 1. Parameter of MIMO-OFDM system

Parameter	Value
Antenna configuration	2x2, 4x4, 6x6
Data mapping	4-QAM/ QPSK
Channel estimation	IDCT/DCT
IDCT and DCT size	52
No of subcarrier	52
Channel used	AWGN
Frame length	100
Cyclic prefix	16

3.1. QPSK modulation

Fig. 4 shows graph of BER versus Eb/No, for QAM modulation scheme. At Eb/No=5dB, BER for 6x6 antenna configuration is equal to $1.257\text{x}10^{-2}$ while 4x4 is $5.399\text{x}10^{-2}$ and 2x2 antenna is $9.689\text{x}10^{-2}$. MIMO OFDM system of 6x6 antenna configuration has the lowest BER when using QPSK modulation technique. The performance has proven that high number of antenna can make the system become more efficient because transmitted data will reach receiver without being spread to other. Besides that, it shows that the system has also achieved high diversity order. Bits per symbol transmit for M-QAM level can be determined by $M=2^N$ where M is the QAM level and N is the bits per symbol. Higher bits per symbol sent will increase the probability of bits error.

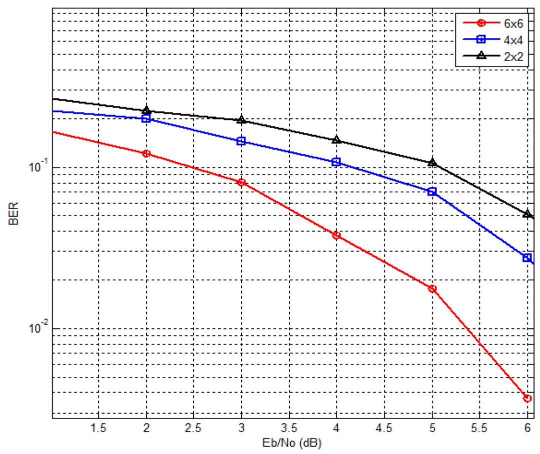

Figure 4 . BER vs. Eb/No MIMO-OFDM system using DCT-based using QAM modulation.

Fig. 5 shows graph of BER versus Eb/No for QPSK modulation scheme. At Eb/No=5 dB, BER for 6x6 antenna configuration is equal to $1.775\text{x}10^{-2}$ while 4x4 is $7.027\text{x}10^{-2}$ and 2x2 antenna is $1.058\text{x}10^{-1}$. From the result, it shows that when the number of the antenna is increasing, the BER will decrease and successfully reduce interference in the wireless system.

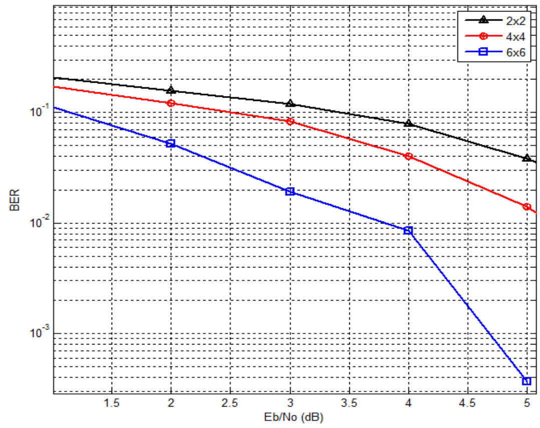

Figure 5. BER vs. Eb/No MIMO-OFDM system using DCT-based using QPSK modulation.

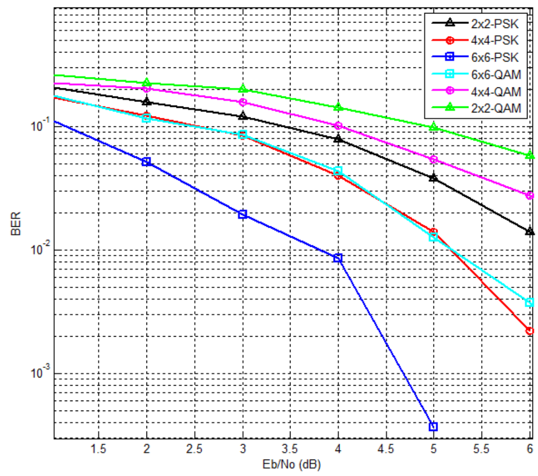

Figure 6. BER vs Eb/No graph of MIMO-OFDM system using DCT-based channel estimation with 2x2, 4x4 and 6x6 antenna configuration for QAM and QPSK modulation scheme.

Based on the Fig. 6 above, we can see the difference between performances of modulation. With 6x6 antenna configurations, QPSK has the lowest BER while 2x2 QAM has highest BER during simulation. QAM utilise both amplitude and phase variations. Although QAM is widely used in wireless communication system in terms of data carrying capacity, but QAM is more susceptible to noise compare to QPSK. This is because QAM has larger distance between constellation point compare to QPSK. Even though QAM is seen to have the same spectrum and bandwidth efficiency as QPSK but still it is difficult to demodulate in the presence of noise [12]. Addition of STBC in the system also becomes a big help for the antennas to achieve maximum diversity.

References

1. A. Kakadiya, M.M. Solanki, Analysis of adaptive channel estimation techniques in MIMO OFDM

system, International Journal of Advancement in Research & Technology, **2**, 4, April (2013).
2. P. Venkateswarlu, Channel estimation techniques in MIMO-OFDM LTE System, International Journal Engineering Research and Applications, **4**, 7, pp.157-161, July (2014).
3. S.M. Sajid, C.R. Lakshmi, DCT based improved OFDM communication, International Journal of Engineering and Innovative Technology (IJEIT), **2**, 12, June (2013).
4. V. Khare, M. Ahmed, Precoded DCT-OFDM system for Baseband and Wireless Communication using QAM modulation over AWGN and Multipath Rayleigh fading channel, Internation Journal of Research in Engineering and Scientific Applications (IJRESA), **1**, 1, Jul-Aug (2014).
5. L. Patidar, A. Parikh, BER comparison of DCT-based OFDM and FFT-based OFDM using BPSK modulation over AWGN and Multipath Rayleigh Fading channel, International Journal of Computer Applications, **31**, 10, October (2011).
6. Bridging Technologies, understanding Long Term Evolution, *Building Communication Channels (Orbitage)*, Version 3.1, March (2013).
7. P. Bhatnagar, M. Tiwari, Enhancement of OFDM system Performance with MIMO technique, International Journal of computer Technology and Electronics Engineering (IJCTEE), **1**, 3.
8. Shazeeda, T.M. Shashidhar, B.G .Anupama, FPGA based design 1D DCT/IDCT for MIMO OFDM channel estimation, European Scientific Journal, **10**, 30, October (2014).
9. S. Saleem, Q.-ul-Islam, On Comparison of DFT-based and DCT-based Channel Estimation for OFDM System, International Journal of Computer Science Issues(IJCSI), **8**, 3, May (2011).
10. Kharagpur, *Data Communication Fundamentals*, Version 2 CSE, IIT
11. C. Poongodi, P. Ramya, and A. Shanmugam, BER Analysis of MIMO OFDM System Using M-QAM over Rayleigh fading channel, in Communication and Compitational Intelligence (INCOCCI), International Conference on 2010, pp.284-288, (2010).
12. D. R. Smith, *Digital Transmission System*, Washington: Kluwer Academic Publisher, (1999).