Performance Analysis of Space Frequency Block Code on Different Modulation Techniques for 4G Lte

Ni Ni May Win
Department of Electronic Engineering
Yangon Technological University,
Yangon, Myanmar

Zaw Min Naing
Department of Electronic Engineering
Technological University (Maubin)
Myanmar

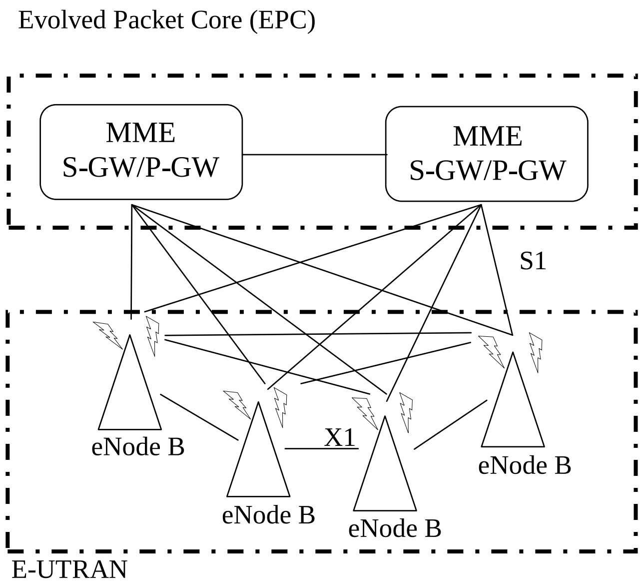
***Abstract*—One of the most promising techniques to support high data rate and high performance are recognized by using the combination of multiple-input multiple-output (MIMO) wireless technology with orthogonal frequency division multiplexing (OFDM) in the advent of 4G broadband wireless communications. This work proposes and adaptive receiver for the space-frequency block coding (SFBC) scheme with Alamouti coding and Maximum Ratio Combining (MRC) are applied over the carriers of an OFDM system. The purpose of this paper is to demonstrate the performance analysis of SFBC on QPSK, 16 QAM and 64QAM modulation to increase the signal to noise ratio (SNR) at the receiver side and to reduce the bit error rate (BER). The channel models used was Rayleigh fading channel. The performance comparisons of bit error rate probability for the SFBC-MIMO-OFDM is using two transmit and two receive antennas.**

Keywords—*Bit Error Rate (BER), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Space-Frequency Block Code (SFBC), Signal to Noise Ratio (SNR)*

I. INTRODUCTION

In wireless communication systems, the generations of mobile network are progressed step by step such as 2G, 3G and then now 4G networks. 4G LTE (Long Term Evolution) broadband wireless communication system is motivated by the huge demands for fast and reliable communications over the wireless channel; future broadband communication systems should provide data processing (low complexity), higher data rate and stronger (robust) performance. The broadband channel is a typically non-line-of-sight channel and includes much impairment such as time-selective and frequency-selective fading. To address these challenges, one promising solution is to combine two powerful technologies namely multiple-input multiple-output (MIMO) antennas and orthogonal frequency division multiplexing (OFDM) modulation techniques [1].

International Mobile Telecommunications (IMT)-2000 introduced global standard for 3G. Most of the countries were used the 3G network. But 3G network has low speed, higher latency. Third Generation Partnership Project (3GPP), the LTE is currently developing revolutionary systems beyond 3G. IEEE 802.16 based Worldwide Interoperability for Microwave Access (WiMAX) is also evolving towards 4G through 802.16m. 4G LTE is capable of delivering mobile broadband speeds up to 10 times faster than 3G. This includes real-time web browsing, online gaming, social media and video services. LTE is built upon the foundation of GSM-UMTS-HSPA technology [2]. Unlike the 2G and 3G radio access networks, which are connected to the circuit-switched domain of the 3GPP core network, the E-UTRAN only connects to the Evolved Packet Core (EPC). The EPC is a multi-access core network based on internet protocol (IP). It is defined around the three important paradigms of mobility, policy management and security. It provides user terminals with optimized handover schemes between different radio access technologies. Fig.1 is the 4G LTE network architecture.



MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: PDN (Packet Data Network) Gateway

Figure 1. 4G LTE Network Architecture [3]

Space–Frequency Block Coding (SFBC) is similar to space-time coding, with the difference is that the encoding is carried out in the frequency domain rather than in the time domains [3]. Space-frequency coding is applicable to OFDM and other frequency domain transmission schemes. Space-frequency block codes were shown to be much effective in frequency selective fading channels as the code is simultaneously transmitted space-frequency block coding with OFDM enhances the quality of transmission of wireless communications. Unlike STBC-OFDM, the source symbols of SFBC-OFDM are not coded across two symbol periods, but instead the source symbols are coded across two consecutive frequencies [4].

OFDM is a promising technology in broadband wireless communications due to its ability in mitigating multipath effects. It is commonly used for high data-rate wireless communication due to its ability to combat frequency-selective fading caused by the wideband radio fading channels and to prevent Inter Symbol Interference (ISI) and to provide sufficient robustness radio channel impairments [5]. Because of high capacity transmission of OFDM, it has been applied to digital transmission system, such as digital audio broadcasting (DAB) system, digital video broadcasting TV (DVB-T) system, asymmetric digital subscriber line (ADSL), ultra-wideband (UWB) system, IEEE 802.11 a/g Wireless Local Area Network (WLAN), IEEE 802.16 (WiMAX) systems and HIPERLAND 2 (High Performance Local Area Network) [6]. It is an excellent technique to reduce the effects of frequency selective fading by dividing the transmission bandwidth into many narrow-band subcarriers [7, 8].

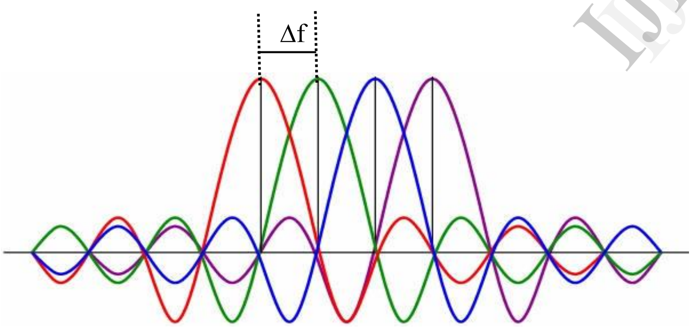


Figure 2. OFDM Subcarrier Spacing [3]

The number of OFDM subcarrier can range from less than hundred to several thousand, with the subcarrier spacing ranging from several hundred kHz down to a few Hz. Once the subcarrier spacing has been selected, the number of subcarriers can be decided based on the assumed over all transmission bandwidth, taking into account acceptable out-of-band emission [4]. Fig. 2 shows the OFDM subcarrier spacing.

Fig.3 is the multipath fading channel. Fading is received signal fluctuation due to constructive or destructive combination of two or more multipath signals.

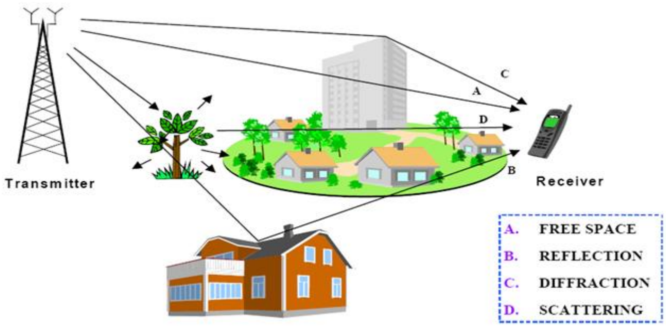


Figure 3. Multipath Fading Channel [4]

MIMO wireless communication refers to the transmissions over wireless links formed by multiple antennas equipped at both the transmitter and receiver. Space frequency block coding is a technique that promises greatly improved performance in wireless communication systems by using multiple antennas at the transmitter and receiver [9].The use of multiple transmitter and receiver can transfer more data at the same time. The effects of channel fading can be significantly reduced by using MIMO technique.

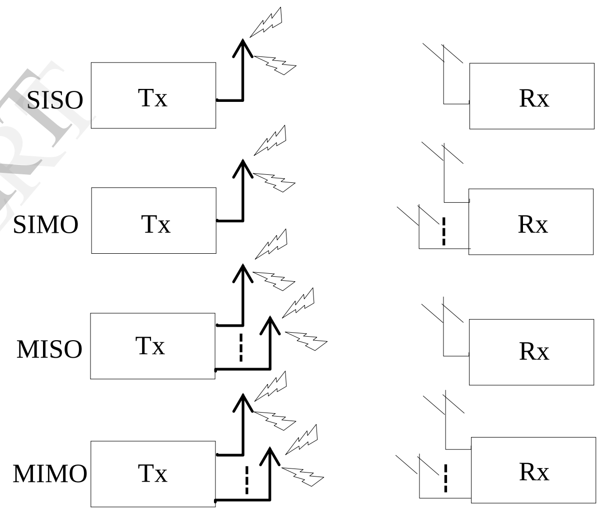


Figure 4. Types of Transceiver System [1]

The type of MIMO transceiver system is shown in Fig.4. In MIMO communication, multiple antennas are used to increase throughput and immunity to fading, interference, and noise [10]. OFDM combined with MIMO technology is an attractive for modern mobile communication systems due to its ability to support high data rates, large capacity, and robustness to multipath fading. And then, the Maximum Ratio Combining (MRC) is the optimum way to use information from different paths to achieve decoding in an Additive White Gaussian Noise (AWGN) channel [11].

The receiver corrects the phase rotation caused by a fading channel and then combines the received signals of different paths proportionally to the strength of each path. Since each path undergoes different attenuations, combining them with different weights yield an optimum solution under an AWGN channel. In a Rayleigh fading channel, the MRC performance is the best.

II. System Model for SFBC-MIMO-OFDM Transceiver

In SFBC-OFDM transceiver system, transmitter is composed of encoder, puncture, interleaver, modulation mapper, space-frequency block coding encoder and orthogonal frequency division multiplexing (OFDM) modulator.

Decoder, depuncture, deinterleaver, demapper and space-frequency block coding decoder and OFDM demodulator are at the receiver side that is shown in Fig.5.Fig. 5 is the proposed block diagram of SFBC-MIMO-OFDM transceiver system.

A. Transmitter

The encoding process consists of a concatenation of an outer Reed-Solomon (RS) code and an inner convolutional code (CC) as a Forward Error Correction (FEC) scheme. Data is put into the source encoder. This means that data passes through the RS encoder first, and then, it goes across the convolutional encoder. It is a flexible coding process due to the puncturing of the signal, and allows different coding rates. The last part of the encoder is a process of interleaving to avoid long error bursts. All wireless communication systems use a modulation scheme to map coded bit when the signal has been coded. Different types of modulation schemes used in SFBC-OFDM transceiver are QPSK, 16QAM and 64QAM. These modulated symbols are modified using SFBC coding technique in order to reduce fading. After adding the corresponding pilots and training bits, the resulting symbols are multiplexed and multi-carrier modulated by using OFDM and forward to the radio transmitter. When the data is passing over a wireless radio channel, the data is corrupted by noise or fading.

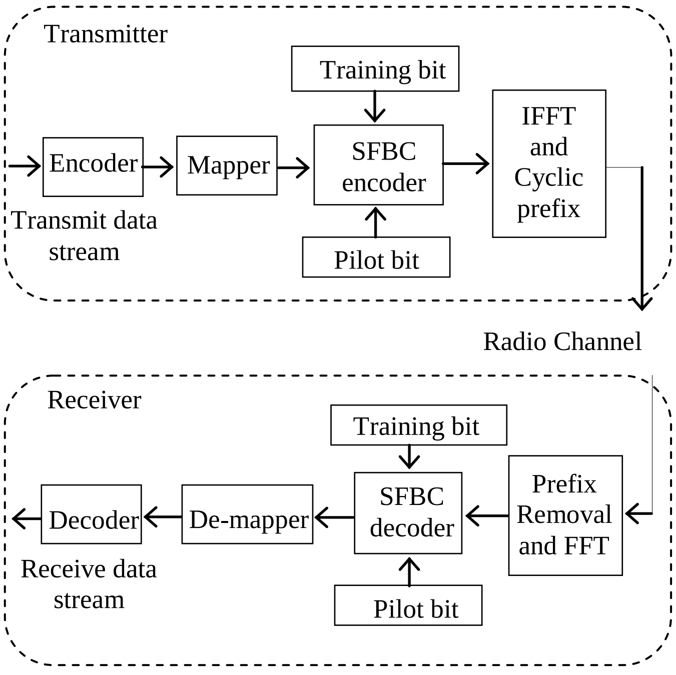


Figure 5. System Block Diagram of SFBC-MIMO-OFDM Transceiver System

B. Receiver

When the data passes over wireless channel, received signal cannot be model as a copy of transmitted signal. Cyclic Prefix of the received data is first removed and then the resulting data are demodulated. After demodulating, SFBC decoder decodes the demodulated data. The resultant data symbols are demapped according to their modulation technique. The last part of the receiver is decoder. The received data is decoded and then output the results.

The proposed system flowchart of SFBC-MIMO-OFDM transceiver is shown in Fig.6. First of all, source data and IEEE 802.16m parameters are put for physical layer and encoded with encoding method. Then the modulation type is selected either QPSK or 16QAM or 64QAM. Number of transmit and receive antenna is accepted to encode with SFBC method. In OFDM modulation, it accepts the mapped data and then assembles the OFDM frame. After assembling the OFDM frame, it used the InverseFast Fourier Transform (IFFT) algorithm to produce the OFDM modulated data symbols.

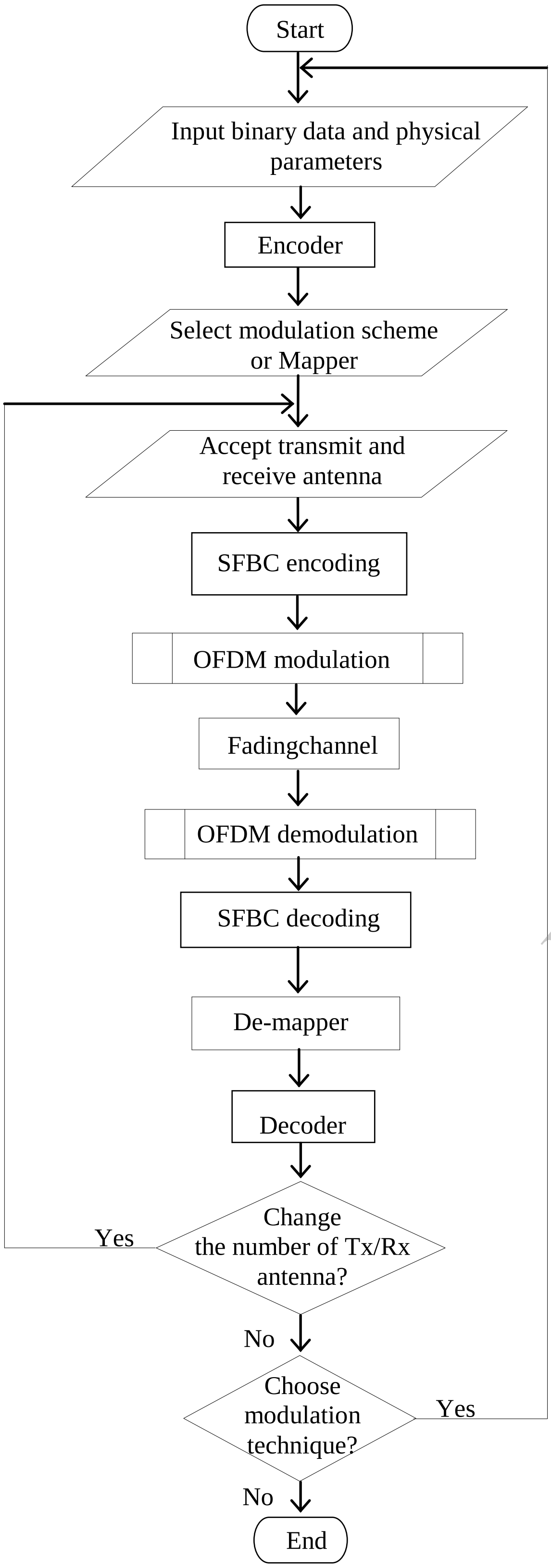


Figure 6. System Flowchart of SFBC-MIMO-OFDM Transceiver

The data receives from the receiver through the radio channel. The receiver part is reversed from the transmitter. If the number of transmit and receive antenna is not changed, the data goes to choose modulation techniques. If the modulation techniques are chosen, it inputs the data next time. And if it is not, the system is end. Then the results are carried out in phases, two transmit and two receive antennas are used for QPSK, 16QAM and 64QAM which are compared with Maximum Ratio Combining (MRC), transmit beamforming and Alamouti coding for symbol error rate.

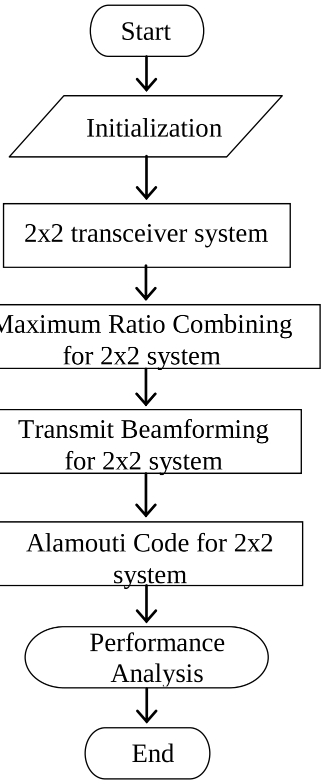


Figure 7. Flowchart of Performance Analysis

III. SPACE-FREQUENCYBLOCKCODING

Space-frequency block coding system uses on frequency domain when transmitting and receiving data. In SFBC-OFDM, a single data sequence a= [a_0, a_1,….,a_{N-1}] is applied to a Alamouti encoder where the output is mapped as

$$[a_k a_{k+1}] \xrightarrow{SFBC} \begin{bmatrix} a_k & -a_{k+1}^* \\ a_{k+1} & a_k^* \end{bmatrix}, \quad k=0, 2, \ldots, N-2 \quad (1)$$

Table I. SPACE FREQUENCY SCHEMEFOR2TX SYSTEM

Antenna	OFDM sub-channel	
T_x 1	S_0	$-S_1^*$
T_x 2	S_1	S_0^*

Table I is the space-frequency scheme for two transmit system. The mapping of the data symbols on the subcarriers for the first antenna corresponds to the classical inverse discrete Fourier transformation with

$$x_1 = \frac{1}{N_c} \sum_{n=0}^{N_c-1} S_n \, e^{\frac{j2\pi nv}{N_c}} \quad (2)$$

The data symbols of the second transmit antenna are mapped on the subcarriers as

$$x_2=\frac{1}{N_c}\sum_{n=0}^{N_c/2-1} S_{2n}\, e^{\frac{j2n(2n+1)v}{N_c}}+S_{2n+1}\, e^{\frac{j2\pi 2nv}{N_c}} \quad (3)$$

where n= subcarrier index
v= sample index
S_n= data symbol
N_c= sequence of frequency

The SFBC code for this system as the matric of M_2

$$M_2=\begin{pmatrix} s[n,2m] & s[n,2m+1] \\ -s[n,2m+1] & s[n,2m] \end{pmatrix} \quad (4)$$

The space-frequency block codes $s_1[n,m]$ and $s_2[n,m]$ can be extended as

$$s_1(n)=\left(s[n,0],-s^*[n,1],s[n,2],\ldots,s[n,N-2],-s^*[n,N-1]\right)^T \quad (5)$$

$$s_2(n)=\left(s[n,1],-s^*[n,0],s[n,3],\ldots,s[n,N-1],-s^*[n,N-2]\right)^T \quad (6)$$

These blocks are transmitted over the selected antennas. The received vector after FFT can be given as

$$R(n)=H_1^s[n,2m]R[n,2m]+H_2^s[n,2m]R[n,2m+1]+N_n \quad (7)$$

The output of the SFBC decoder is

$$\tilde{s}[n,2m]=H_1^s[n,2m]R[n,2m]+H_2^s[n,2m]R[n,2m+1] \quad (8)$$

$$\tilde{s}[n,2m+1]=H_2^s[n,2m]R[n,2m]-H_1^s[n,2m]R[n,2m+1] \quad (9)$$

IV. Simulation Results

The symbol error rate and bit error rate performance analysis of the proposed decoding algorithm for SFBC based OFDM system in high mobility is demonstrated with simulations in this section. Table II is the simulation parameters for proposed system.

Table II. Simulation Parameters for Proposed System

Parameters	Values
Bandwidth	10M Hz
Carrier frequency	3.6G Hz
Subcarrier spacing	15k Hz
Number of subcarriers	600
Number of Tx antenna	2
Number of Rx antenna	2
Modulation schemes	QPSK, 16QAM, 64QAM
IFFT(T_x)/FFT(R_x) size	1024
Symbol time, T_b	1/f
Cyclic prefix time, T_g	G. T_b
Frame time	T_b+T_g

The performance of the proposed system is calculated depending on the BER, SER and SNR ratio plots. For each modulation types, the performance results are based on two transmit antennas and two receive antennas. The simulation results for proposed SFBC system based on QPSK, 16QAM and 64QAM are shown in Fig. 8,9,10. These figures show the relationship between the symbol error rate and signal to noise ratio.

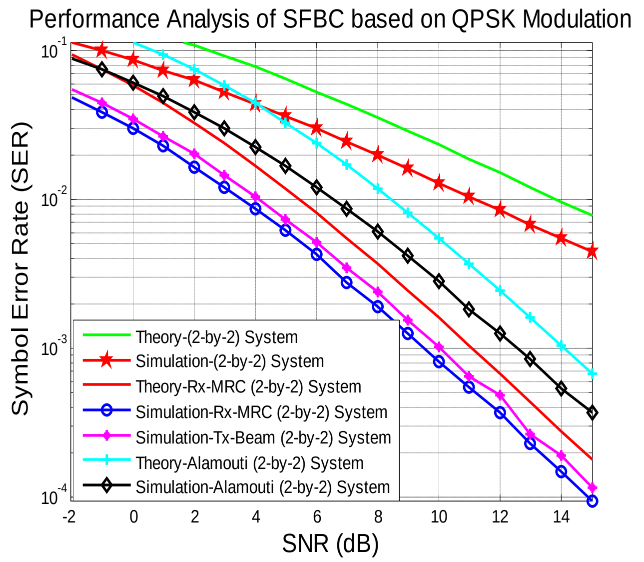


Figure 8. Performance Analysis of SFBC based on QPSK Modulation

In Fig.8, the simulation result for maximum ratio combining gets 0.0228 for 4dB on QPSK modulation.

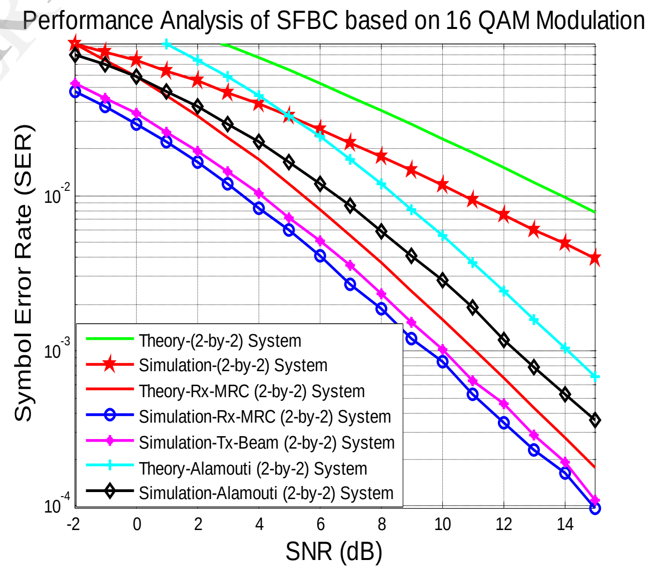


Figure 9. Performance Analysis of SFBC based on 16QAM Modulation

Fig. 9 describes for 16QAM, in which MRC gets 0.0223 for 4dB and in Fig. 10, 0.0220 for 4dB on 64QAM modulation. The maximum ratio combining (MRC) gets lower symbol error rate and higher signal to noise ratio at the receiver.

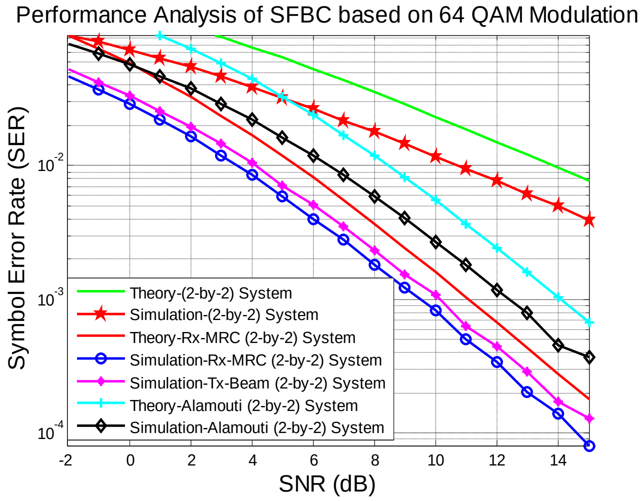


Figure 10. Performance Analysis of SFBC based on 64QAM Modulation

The comparison of bit error rate and signal to noise ratio based SFBC for different modulation using Rayleigh channel is shown in Fig.11,12,13.

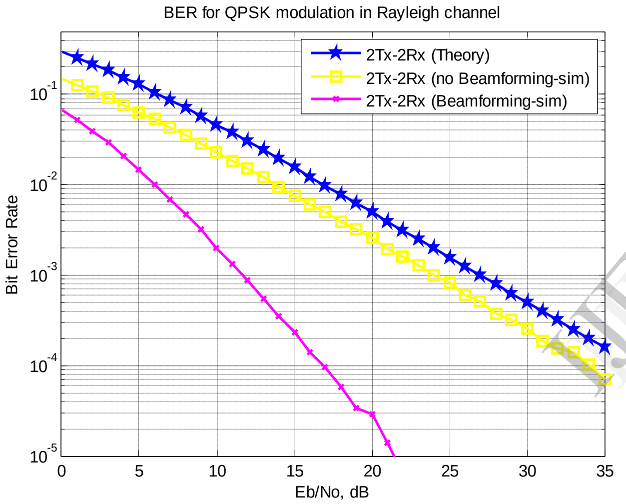


Figure 11.Comparison of BER and SNR based SFBC for QPSK Modulation

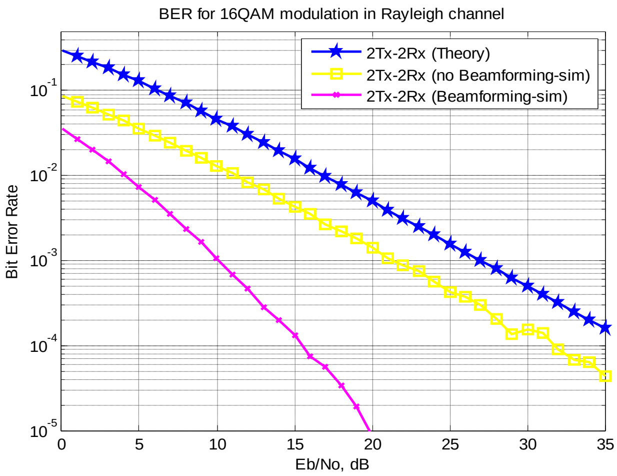


Figure 12.Comparison of BER and SNR based SFBC for 16QAM Modulation

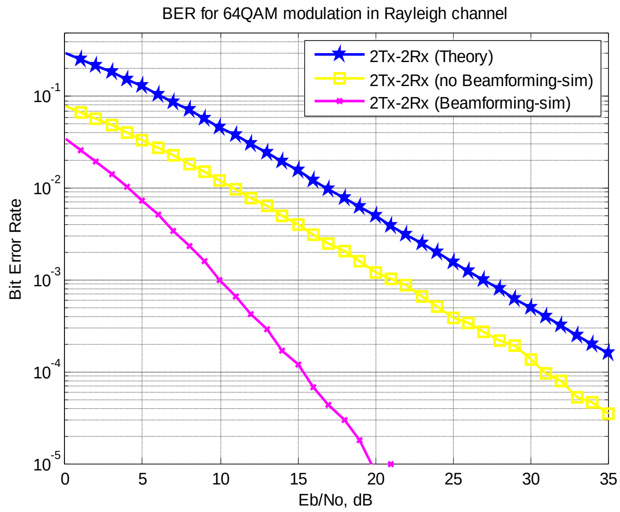


Figure 13.Comparison of BER and SNR based SFBC for 64QAM Modulation

Table III. Comparisonof Bit Error Ratefor QPSK, 16QAM and 64QAM in Rayleigh Channel

SNR / BER	5dB	10dB	15dB
QPSK Beamforming	0.0208	0.0030	3.83^{-4}
16QAM Beamforming	0.0103	0.0016	1.9^{-4}
64QAM Beamforming	0.0103	0.0016	1.71^{-4}

The bit error rate using beamforming technique shows higher signal to noise ratio. Table III is the comparison of bit error rate for QPSK, 16QAM and 64QAM in Rayleigh channel. Among the different modulation techniques, 64QAM gets lower bit error rate so it is more suitable scheme than other two modulations.

V. Conclusion

In this paper, the space-frequency block coding based MIMO-OFDM transceiver has been implemented in order to evaluate the performance under Rayleigh channel model. The performance analysis based on symbol error rate for two transmitters and two receivers met with the practical situation. The performance of the proposed algorithm for high mobility by compared with MRC detector. The simulations show that the proposed algorithm gets lower symbol error rate during the decoding procedure in this situation. The benefit of SFBC is performance improvement in wireless communication system by using multiple antennas at the transmitter and receiver. Therefore, it demonstrates that the SFBC scheme can achieve a significant performance increase for efficient data transmission over slow and fast fading environments.

ACKNOWLEDGMENT

The author would like to express the deepest thanks to her parents for their best wishes and their complete support throughout her life. The author would like to express her heartfelt thanks to her supervisor, Prof: Dr. Zaw Min Naing, Pro-Rector, Technological University (Maubin), for his valuable suggestions, constructive comments, guidance and advices throughout the development of this paper. The author would like to thank her co-supervisor, Dr. ThiriThandarAung, Lecturer of Department of Electronic Engineering at Yangon Technological University, for her remarkable and patient supervision. The author greatly thanks to all persons whom will concern to support in preparing this paper.

REFERENCES

[1] H. Bolcskei, " MIMO-OFDM Wireless Systems: Basics, Perspectives and Challenges," IEEE Wireless Comm., vol.13, aug.2006, pp.31-37.

[2] S. Sesia, I. Toufik, and M. Baker. "LTE- The UMTS Long Term Evolution," WILEY, 2009.

[3] Dahlman E., Parkvall S, and Skold J: "LTE/ LTE Advanced for Mobile Broadband" 2011 to be published.

[4] A. F. Molisch, M. Z. Win, and J. H. Winters. "Space-time-frequency (STF) coding for MIMO-OFDM systems. IEEE Communications Letters, 6(9):370-372, September 2002.

[5] Hoojin LEE, "Low Peak-to-Minimum Power Ratio Transmission Scheme for Coordinate Interleaved Orthogonal Design with Two Transmit Antennas over Time-Selective Fading Channels"., IEICE Trans. Commun., 2007, E90-B (8), 2172-2174.

[6] M.Luise and R. Reggiannini, "Carrier Frequency Recovery in All-Digital Modems for Burst-Mode Transmissions," IEEE Trans. Commun., vol.43, no.2-4, pp. 1169-1178, Feb-Apr. 1995.

[7] Arvind Kumar, Rajoo Pandey, " A Bandwidth-Efficient Method for Cancellation of ICI in OFDM Systems," Int.J.Electron. Comm, vol. 63.pp.569-575, 2009.

[8] Mohammad Azizul Hasan, "Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer", Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology, Espoo, June 2007, Helsinki University of Technology.

[9] Gutierrez and F. Bader, "Spectral Efficiency using Combinations of Transmit Antenna Selection with Linear Dispersion Code Selection".

[10] Eril G. Larsson and Petre Stoica, "Space Time Coding for Wireless Communication," 2008.