

Effect of Doppler Shift frequency on the performance of 2x2 OSTBC-OFDM System

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ABSTRACT

In this paper the effect of the Doppler shift frequency on the performance of the 2x2 MIMO system has been studied and presented. A system with two transmits antennas and two receive antennas has been used. Accurate and efficient channel estimation which plays a key role in MIMO-OFDM communication system has been implemented using pilots and training sequences. To guarantee a much more reliable and robust transmission over a hostile wireless channel, a convolutional codes have been added to the 2x2 MIMO-OSTBC-OFDM system as a Forward Error Correction (FEC) codes. Two types of convolutional code rate have been used (1/2 and 2/3) depending on the type of modulation. To make this code more robustness against channel impairments; interleaving has been used with the convolutional code. The system has been evaluated for four types of QAM modulation (4-QAM, 8-QAM, 16-QAM, and 64-QAM) as a baseband modulation. The system has been evaluated for three different values of Doppler Shift frequency (5, 50, and 100) Hz. The simulation results demonstrated the performance of the systems over Flat and multi-path Frequency-Selective fading channels, assuming the channels are with No Line Of Sight (NLOS), so the channels are Rayleigh fading channels. The results show that when the Doppler Shift Frequency increased the BER also increases and when Doppler Shift Frequency is 5Hz, the performance of the system is better for four types of QAM modulation and in the two cases of Flat and multi-path Frequency-Selective fading.

1. INTRODUCTION

The Future wireless mobile systems will aim to support high quality of services and high data rates by employing techniques that can enhance channel capacity [1]. The transmitted data is interfered by channel noise, Co-Channel Interference (CCI) when transmitted, and these noises and CCI affect randomly and suddenly on all transmission bits. Diversity techniques, including spatial, frequency, and time domain diversity, have been suggested to decrease the channel fading effect. There are many techniques and algorithms to mitigate the CCI effect also. Sufficiently spaced antennas are an attractive source of diversity since they do not typically incur in bandwidth expansion as in frequency division diversity, and does not incur delays as in time diversity. Though spatial diversity is available at transmitter and receiver, it may not be possible to get much diversity gain at mobile terminal because of the limitations in space and power [2]. Space Time Coding (STC) systems process transmit and receive signal waveforms in temporal, spatial and coding dimensions to deliver high data rates with diversity and coding gains, and MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increasing transmitted power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, WiMAX etc. [3].

Orthogonal Frequency Division Multiplexing (OFDM) is the vehicle that drives modern digital communications. Its high spectral efficiency and resilience toward multipath distortion has made possible the increased data rates required in many devices. It is used in many systems including DSL, IEEE802.11a, g, n (Wi-Fi), digital radio, digital TV, IEEE802.16 (WiMAX), and 3G, 4G, and Long Term Evaluation (LTE) cell services [4]. MIMO with OFDM reduces the equalization complexities by transmitting different data on different frequency levels to gain spectral efficiency and error recovery features, which will offer high spatial rate by transmitting data on multiple antennas and transmission in Non-Line-of sight (NLOS). Thus the MIMO-OFDM technique is used to achieve diversity. It utilizes the three basic parameters that is frequency (OFDM), time (STC) and MIMO in spatial. The MIMO-OFDM is the reproductive and highly famous services for wireless broad band access. The combination of MIMO and OFDM accumulates the purpose of each and every scheme that provides the high throughput [5].

2. Space Time Coding (STC)

Space–time coding is a coding technique used in wireless communications to transmit multiple copies of a data stream (generally Quadrature Amplitude Modulation (QAM) symbols) across a number of antennas to exploit the various received versions of the data to improve the reliability of the communication. In fact, STC combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible. The space–time block codes (STBCs) achieve significant error rate improvements over single-antenna (SISO) systems [6]. The STC technique is essentially a two-dimensional space and time processing method. While multiple antennas both for transmission and reception are used to improve wireless communication systems capacity and data rate in

space-domain. In time-domain, different signals can be transmitted at different time slots using the same antenna at the same time [7].

2.1 Alamouti code

The Alamouti space time coding scheme can be used to achieve diversity at the transmitter and receiver if number of antennas are involved at the transmitter and receiver. The approach as outlined by Alamouti is shown in Figure 1. The information bits are first modulated using an M-ary modulation scheme. The encoder then takes a block of two modulated symbols S_1 and S_2 in each encoding operation and gives it to the transmit antennas according to the code matrix,

$$S = \begin{bmatrix} S_1 & S_2 \\ -S_2^* & S_1^* \end{bmatrix} \tag{1}$$

In equation (1), the first row represents the first transmission period and the second row the second transmission period.

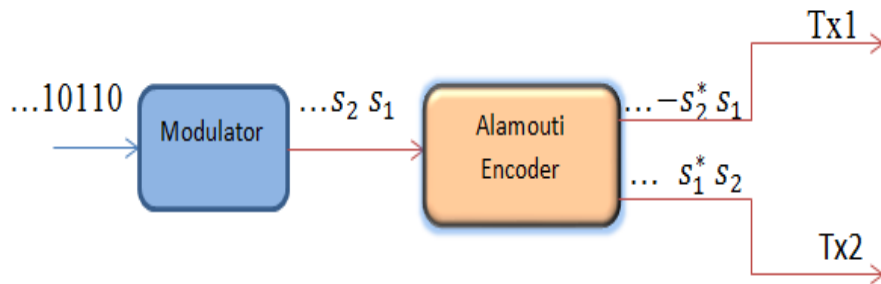


Figure 1: Alamouti Space-Time Encoder block diagram.

During the first symbol period, the first antenna transmits S_1 and the second antenna transmits S_2 . During the second symbol period, the first antenna transmits $-S_2^*$ and the second antenna transmits S_1^* .

At the receiver the signals after passing through the channel can be expressed as,

$$r_1 = s_1 h_1 + s_2 h_2 + n_1 \tag{2}$$

$$r_2 = -s_2^* h_1 + s_1^* h_2 + n_2 \tag{3}$$

Where, n_1, n_2 are independent complex variables with zero mean and unit variance, representing Additive White Gaussian Noise (AWGN) samples at time $t = 1$ and $t = 2$, respectively, h_1 is the path gain between the first transmitted antenna and the received antenna h_2 is the path gain between the second transmitting antenna and the received antenna and r_1, r_2 are the received signals at the two time slots [8]. And the estimated symbols are as shown below:

$$\tilde{s}_1 = r_1 h_1^* + r_2^* h_2 \tag{4}$$

$$\tilde{s}_2 = r_1 h_2^* - r_2^* h_1 \tag{5}$$

3. Convolutional Code

Convolutional codes are linear codes, many telecommunications applications have used convolutional codes because of their ability to deliver good coding gains on the AWGN channel for target bit error rates around 10^{-5} [9]. So it is a powerful and widely used class of codes, which are used in a variety of systems including today's popular wireless standards (such as 802.11) and in satellite communications.

Convolutional codes are often preferred in practice over block codes, because they provide excellent performance when compared with block codes of comparable encode/decode complexity. Whereas block codes take discrete blocks of K symbols and produce there from blocks of N symbols that depend only on the k input symbols, convolutional codes are frequently viewed as stream codes, in that they often operate on continuous streams of symbols not partitioned into discrete message blocks [10].

When the encoded information is transmitted over the channel, it is distorted; the convolutional decoder regenerated the information by estimating the most likely path of state transition in the trellis. The receiver, of course, does not have direct knowledge of the transmitter's state transitions. It only sees the received sequence of parity bits, with possible corruptions. Its task is to determine the best possible sequence of transmitter states that could have produced the parity bit sequence. This task is called decoding, a decoder that is able to infer the most likely sequence is also called a maximum likelihood decoder. The Viterbi decoder finds a maximum likelihood path through the Trellis [11]. In this paper two types of convolution code rate have been used depending on the type of modulation as in the Table 1.

Table1: Convolution code rates for different types of modulation

Modulation	Convolutional Code rate (R_c)
4-QAM	1/2
8-QAM	2/3
16-QAM	1/2
64-QAM	1/2

4. Interleaving

Interleaving plays a vital role in improving the performance of Forward Correction (FEC) codes in terms of Bit Error Rate (BER). Interleaving is the process to rearrange code symbols so as to spread burst of errors into random like errors and thereafter FEC techniques could be applied to correct them. In conventional block interleaver, the bits received from the encoder are stored row wise in the interleaver's memory and read column wise as shown in Figure 2, WiMAX uses a special type of block interleaver in which the Interleaver Depth (ID) and pattern vary depending on the code rate and modulation type [12].

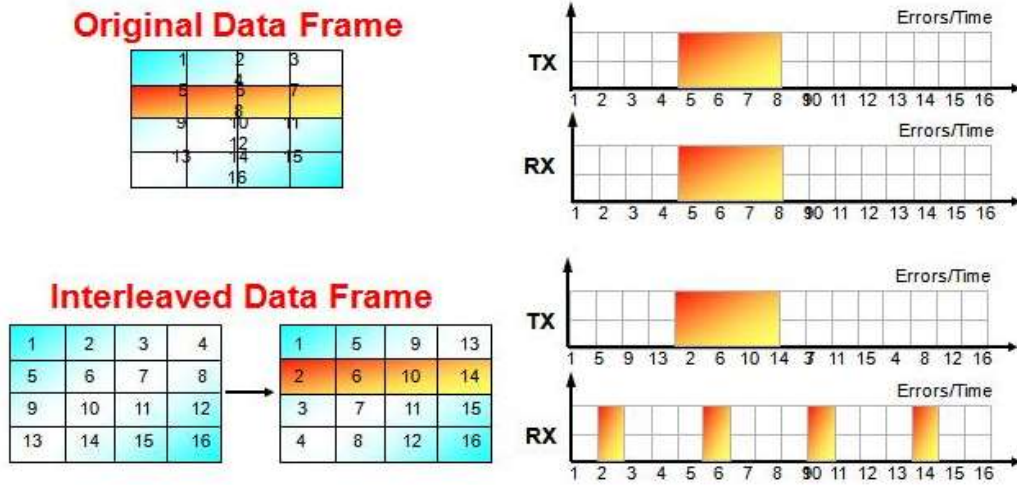


Figure 2: The operation of Interleaver

The Interleaver dimension has been choosing with the following parameters as in WiMAX system:

$$N_{rows} = 12 \tag{6}$$

$$N_{columns} = \frac{\text{No of coded bits}}{N_{rows}} \tag{7}$$

5. Doppler Shift

The Doppler Effect is the change in frequency of a wave that is perceived by an observer moving towards or away from the source of the waves. It is well-known that Doppler effects generated by high speed mobility are the major reason for the reduction of data rates in cellular systems. The Doppler Effect may occur from either motion of the source or motion of the receiver as in Figure 3.

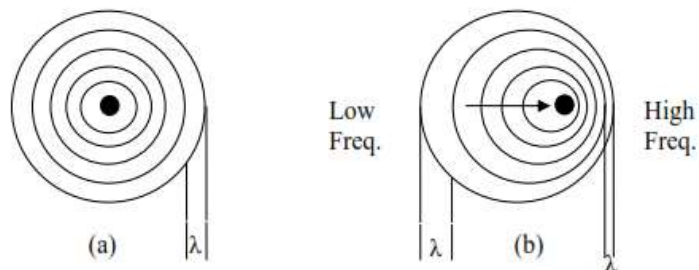


Figure 3: a) Stationary source b) Moving source

It is important to comprehend that the frequency of the signal that the source emits does not actually change, but the wavelength (λ) does; consequently, the perceived frequency is also

affected. When the receiving end moves towards the base station the receiving frequency becomes higher and when is receding the receiving frequency becomes lower (see Figure (3)). The Doppler shift in frequency depends on the velocity between the source and the receiver and on the speed of propagation of the signal. Doppler frequency is given by the formula:

$$\Delta f \approx f_c * \frac{v}{c} \quad (8)$$

Where Δf is the change in frequency, f_c is carrier frequency, v is the speed difference between the source and the receiver, and c is the speed of light in vacuum which is $3*10^8$ m/s [13]. For wireless communication, when electromagnetic wave is traveling towards or away from the receiver, the carrier frequency will be shifted, causing Doppler shift. It is noticed that Doppler shift is usually prominent when the transmit antenna is far from receive antenna [14].

6. System model

The block diagram of the wireless communication system with two transmit antennas and two receive antennas is shown in Figure 4. As it can be seen from this Figure, the generated random binary data is first encoded using binary convolutional encoder, and then these encoded data are further interleaved to avoid error bursts and increase the efficiency of FEC. M-QAM have been used for mapping the coded and interleaved data (bits) into constellation symbols. The mapped data is inserted to the IFFT Input Packing block, in this block, 8-Pilot symbols are added to the mapped data, these pilots can be used to perform frequency offset compensation at the receiver, additionally they can be used for channel estimation in fast time-varying channels. After IFFT Input Packing block, the mapped data is passed to STBC encoder to be modulated using OFDM modulation, and then transmitted by two transmitting antennas. The data passed through the channel which is affected by the presence of Additive White Gaussian Noise (AWGN) and Rayleigh fading. At the receiver side, the data is received by two receiving antennas, the data is demodulated using OFDM demodulator and linear combining is performed in STBC decoder, and then demapped by QAM demapper. The Deinterleaver rearranges the symbols and returns it back to its original form as before the interleaving process, finally Viterbi decoder uses decoding algorithm to get the transmitted data.

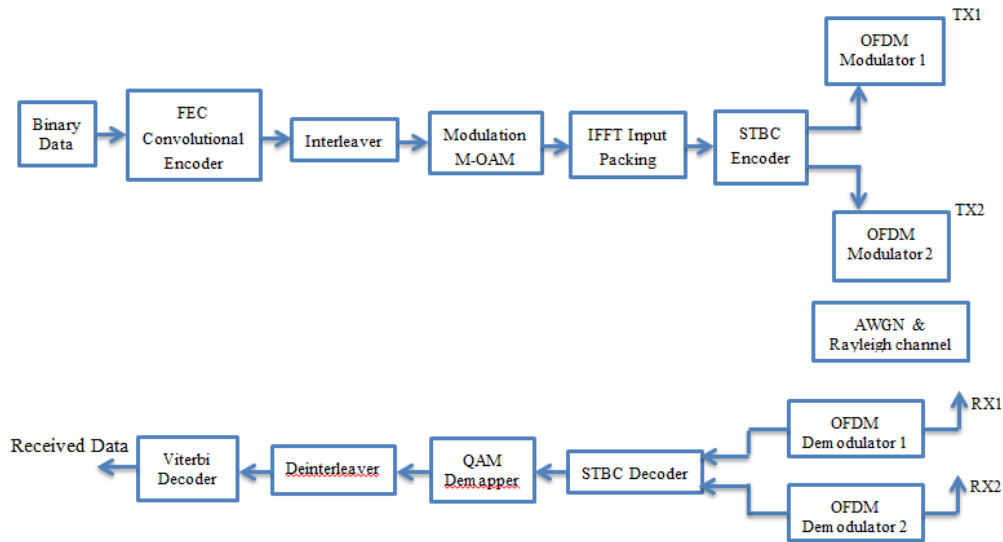


Figure 4: Block diagram of 2x2 MIMO-OSTBC-OFDM system

7. Results and Discussion

The system has been simulated using MATLAB. The performances of the proposed system has been introduced depending on Bit error rate (BER) versus signal to noise (SNR) ratio plots. The system has been evaluated for four types of QAM (4,8,16,and 64-QAM) in two cases of channels, Flat-Fading and Frequency-Selective Fading using Convolutional Code and interleaver in the transmitting side, deinterleaver, and Viterbi decoder in the receiving side. From the figures, to achieve 10^{-5} BER, the SNR ratio should be approximately 17.5dB when the Doppler frequency is 100Hz, the SNR should be 16dB when the Doppler frequency is 50 Hz, and it should be 15dB when the Doppler frequency is 5 Hz.

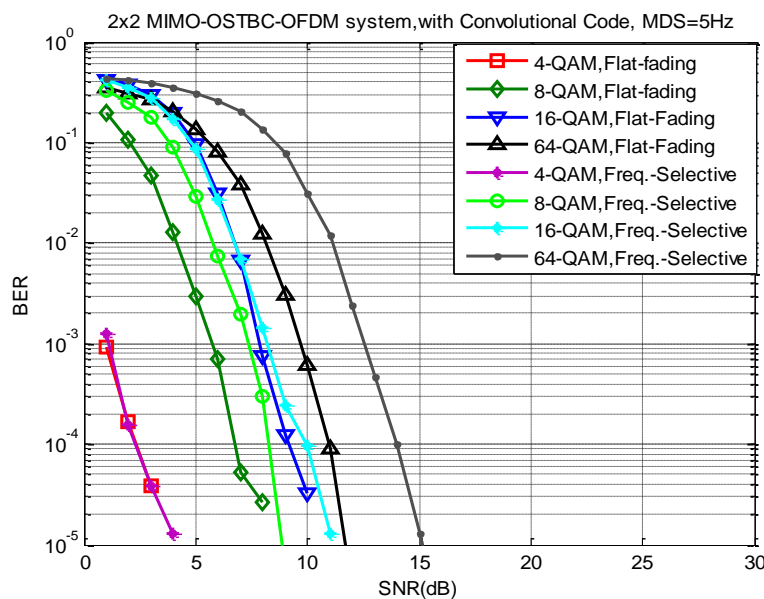


Figure 5: Performance of the coded 2x2 MIMO-OSTBC-OFDM system and

MDS=5Hz

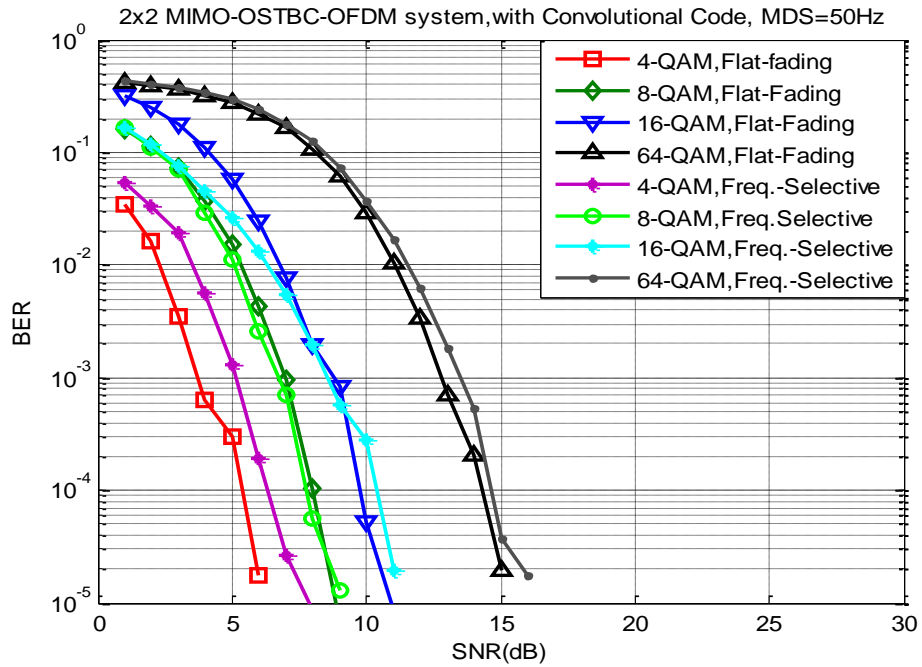


Figure 6: Performance of the coded 2x2 MIMO-OSTBC-OFDM system and MDS=50Hz

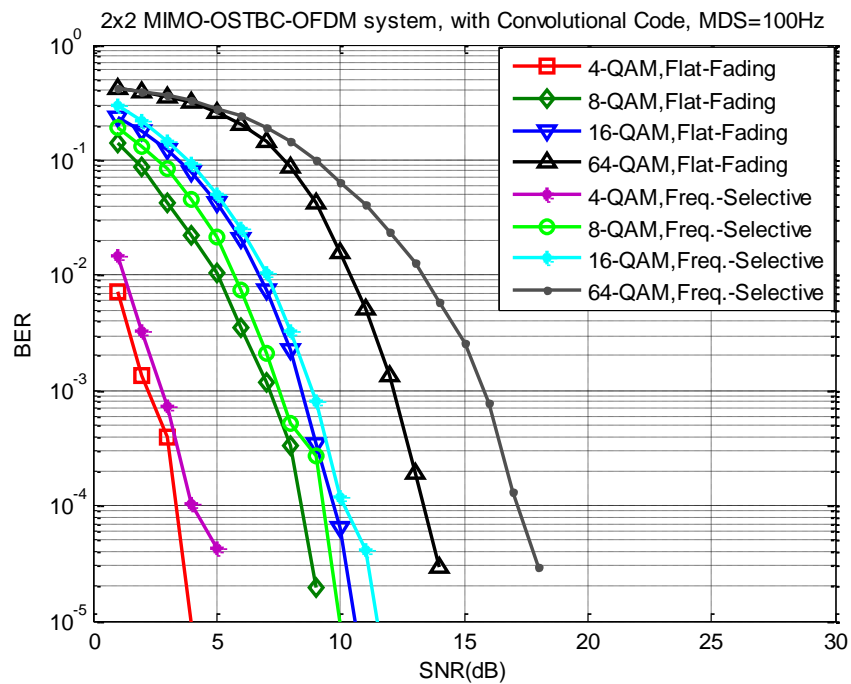


Figure 7: Performance of the coded 2x2 MIMO-OSTBC-OFDM system and MDS=100Hz

8. Conclusion

The Figures (5-7) which represent the performance of 2x2 system with FEC show better performance when MDS=5Hz than the other two values 50, and 100Hz. For example by comparing Figure 5 to Figure 7, the value of SNR in Figure 5 is 15dB for 64-QAM Frequency-Selective Fading, but in Figure 7, the value of SNR=17.5dB for 64-QAM Frequency-Selective Fading, so it can be concluded that increasing the Doppler frequency by ten times (from 5 Hz to 50 Hz) just extra 1dB is needed to achieve same SNR, and when increasing the Doppler frequency to 100 Hz extra 2.5dB is needed.

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