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 have 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 systems 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

Keywords; MIMO; Doppler shift; OFDM; OSTBC; Rayleigh Fading Channel; Convolutional code.

I. INTRODUCTION

Future wireless mobile systems will aim to support high quality of services and high data rates by employing techniques that can enhance channel capacity [28]. 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 [37].

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. [36].

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 [7].

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 [40].
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 [41]. 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 [42].

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)[43]. 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,

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

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

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,

$$n_1 = s_1 h_1 + s_2 h_2 + n_1$$

$$n_2 = s_1 h_2^* + s_2 h_1^* + n_2$$

Where, $n_1$, $n_2$ are independent complex variables with zero mean and unit variance, representing Additive White Gaussian Noi (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 [44]. And the estimated symbols are as shown below:

$$\hat{s}_1 = r_1 h_1^* + r_2 h_2^*$$

$$\hat{s}_2 = r_1 h_2^* + r_2 h_1^*$$

2.2 Convolutional Code

Convolutional codes are linear codes that have additional structure in the generator matrix, so that the encoding operation can be viewed as a filtering - or convolution - operation. 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 $10^{-3}$ [10]. 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 [4]. 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].

2.3 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 1, 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].

3.3 Doppler Shift

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Convolutional Code rate (( R_c ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-QAM</td>
<td>1/2</td>
</tr>
<tr>
<td>8-QAM</td>
<td>2/3</td>
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</tbody>
</table>

Results and Discussion

The systems have been simulated using MATLAB. The performances of the proposed systems have been introduced depending on Bit error rate (BER) versus signal to noise (SNR) ratio plots. The system has been evaluated without using any type of error correcting codes, and in this case to achieve \( 10^{-5} \) BER, the SNR ratio should be approximately 22dB when the Doppler frequency is 100Hz, the SNR should be 21.5dB when the Doppler frequency is 50 Hz, and it should be 19dB when the Doppler frequency is 5 Hz.

REFERENCES