Spectral Efficiency Performance of MIMO with Orthogonal Space Time Block Code using FEC and various Modulation Techniques

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Abstract— The WiMAX (Worldwide Interoperability for Microwaves Access) is a broadband wireless data communication technology based around the IEEE 802.16 standard providing high-speed data communication over a wide area along with cost effective access. MIMO-OFDM technology is a combination of multiple-input multiple-output (MIMO) wireless technology with orthogonal frequency division multiplexing (OFDM) that has been recognized as one of the most promising techniques to support high data rate and high performance in different channel conditions. Alamouti's space time block coding scheme for MIMO system has drawn much attention in wireless technologies just because of its decoding simplicity.

Key words: WiMAX, MIMO, OFDM, OSTBC, FEC, Modulation Techniques, BPSK, QPSK, QAM, MLSE

I. INTRODUCTION

Digital communication using Multiple-Input Multiple-Output (MIMO) systems is one of the most significant technical breakthroughs in modem communication. MIMO systems are simply defined as the systems containing multiple transmitter antenna and multiple receiver antennas. The communication theories show that MIMO systems can provide a potentially very high capacity, in many cases, of grows approximately linear with the number of antennas. Recently, MIMO systems have already been implemented in wireless communication systems, especially in wireless LANs (Local Area Networks). The core idea under the MIMO systems is the ability to turn multi-path propagation.

The main feature of MIMO systems is space-time processing. Space-Time Codes (STCs) are the codes designed for the use in MIMO systems. STCs, signals are coded in both temporal and spatial domains. It is among different types of STCs, orthogonal Space-Time Block Codes (OSTBCs) possess a number of advantages over other types of STCs.

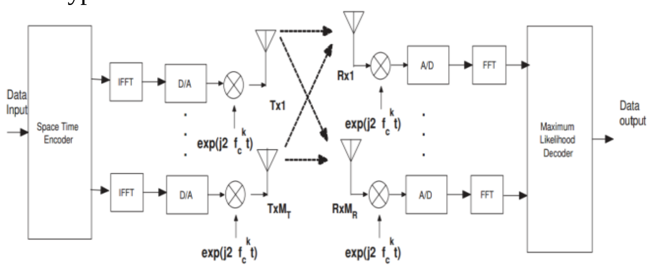

Fig. 1: MIMO-OFDM System

MIMO-OFDM technology is a combination of multiple-input multiple-output (MIMO) wireless technology with orthogonal frequency division multiplexing (OFDM) that has been recognized as one of the most promising techniques to support high data rate and high performance in different channel conditions. Again, space time block coding scheme for MIMO system has drawn much attention in wireless technologies just because of its decoding simplicity

A. Worldwide Interoperability for Microwaves Access (WiMAX)

Broadband Wireless Access (BWA) has emerged as a promising solution for last mile access technology to provide high speed internet access in the residential as well as small and medium sized enterprise sectors. As discussed above section, cable and digital subscriber line (DSL) technologies are providing broadband service. But due to the practical difficulties many urban and suburban locations may not be served by DSL connectivity as it can only reach about three miles from the central office switch. On Broadband wireless Access, because of wireless nature, it can be faster to deploy, easier to scale and more flexible, thereby giving it the potential to serve customers not served or not satisfied by their wired broadband alternatives. IEEE 802.16 standard for Broadband wireless Access (BWA) and its associated industry consortium, WiMAX (Worldwide Interoperability for Microwave Access) forum promise to offer high data rate over large areas to a large number of users where broadband is unavailable

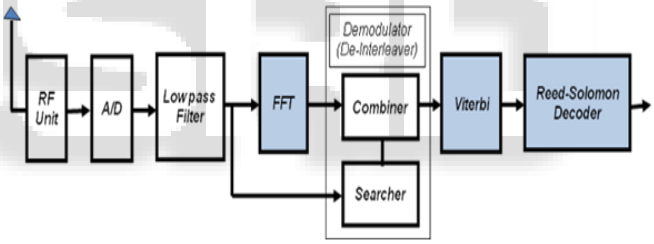

Fig. 2: WiMax System

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM is similar to FDM but much more spectrally efficient by spacing the sub channel much more spectrally efficient by spacing much closer together [1]. This is done by finding frequencies that are orthogonal, which means that are perpendicular in a mathematical sense, an allowing the spectrum of each sub-channel to overlap another without Interfering with it. In the effect of this is seen as the required bandwidth is greatly reduced by removing guard bands and allowing signals to overlap .In order to demodulate the signal, a discrete Fourier transform (DFT) is needed. Fast Fourier transform (FFT) chips are commercially available making this a relatively easy operation.

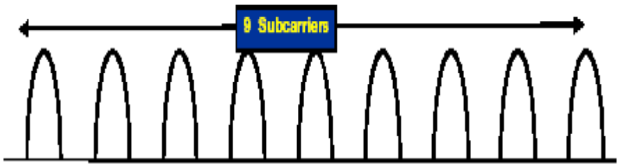

Fig. 3: Frequency Division Modulations

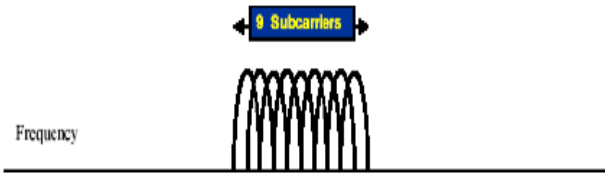

Fig. 4: OFDM

A. *Convolution Encoder (FEC)*

In the prescribed implementation, for the purpose of forward error correction convolution encoder has been used providing the simplest structure and much better results from the point of view of reliability of transmission. Convolution encoder has a code rate of ½.

B. *Space Time Block Code*

A complex orthogonal space-time block code for two transmit antennas was developed by Alamouti [2]. In the Alamouti encoder, two consecutive symbols x_1 and x_2 are encoded with the following space-time codeword matrix as follows:

$$X = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix} \quad (1)$$

Alamouti encoded signal is transmitted from the two transmit antennas over two symbol periods. During the first symbol period at t+T, two symbols x_1 and x_2 are simultaneously transmitted from the two transmit antennas. During the second symbol period t= 2T, in these symbols are transmitted again, where $-x_2^*$is transmitted from the first transmit antenna and x_1^* transmitted from the second transmit antenna system. For Maximum Likelihood signal detection of Alamouti's space-time coding communication, we assume that two channels gains h1(t) and h2(t) remain constant over two consecutive symbol periods such that

$$h1(t) = h1(t+T) = h1 = |h1|e^{j\theta 1} \quad (2)$$

$$h1(t) = h2(t+T) = h2 = |h2|e^{j\theta 2} \quad (3)$$

Where |h1|and $e^{j\theta 1}$ denote the amplitude gain and phase rotation over the two symbol periods. At the receiver the received signals y1 and y2 at time t and t+Ts can be given as

$$y_1=h_1x_1+h_2x_2+z_1 \quad (4)$$

$$y_2=h_1x_2^* + h_2x_1^* +z_2 \quad (5)$$

Where z1 and z2 are the additive noise at time t and t+Ts respectively. This paper we have proposed Alamouti's space time block code for two transmit antenna and more than one receive antenna case.

III. MODULATION TECHNIQUES

WiMAX uses a special type of modulation technique which is a mixture of ASK and PSK with a new name called Quadrature Amplitude Modulation (QAM). In QAM, amplitude and phase changes at the same time. In the different types of QAM are available for WiMAX networks depending on throughput and range. 64 QAM has higher throughput but lower range whereas 16 QAM has lower throughput but higher range to cover from the BS. The WiMAX has the freedom to select Quadrature Phase Shift Keying (QPSK) and QAM as its modulation techniques depending on the situation.

A. *Binary Phase Shift Keying (BPSK)*

This is also known as two-level PSK as it uses two phases separated by 180º to represent binary digits (0, 1). This kind of phase modulation is very effective and robust against noises especially in low data rate applications as it can modulate only one bits/symbol. The principle equation 3 is.

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{for binary 1} \\ A\cos(2\pi f_c t + \pi) & \text{for binary 0} \\ A\cos(2\pi f_c t) & \text{for binary 1} \\ -A\cos(2\pi f_c t) & \text{for binary 0} \end{cases} \quad (6)$$

B. *Quadrature Amplitude Modulation (QAM)*

The QAM is popular modulation technique used in various wireless standards. The combined with ASK and PSK which has two different signals sent concurrently on the same carrier frequency but one should be shifted by 90º with respect to the other signal. The principle equation 4 is.

$$s(t) = d_1(t)\cos 2\pi f_c t + d_2(t)\sin 2\pi f_c t \quad (7)$$

C. *Quadrature Phase Shift Keying (QPSK)*

This is also known as four-level PSK where each element represents more than one bits. Each symbol contains two bits and it uses the phase shift of π/2, for means 90º instead of shifting the phase 180º. The principle equation 5 is.

$$s(t) = \begin{cases} A\cos\left(2\pi f_c t + \frac{\pi}{4}\right) & \text{for binary 11} \\ A\cos\left(2\pi f_c t + \frac{3\pi}{4}\right) & \text{for binary 01} \\ A\cos\left(2\pi f_c t - \frac{3\pi}{4}\right) & \text{for binary 00} \\ A\cos\left(2\pi f_c t - \frac{\pi}{4}\right) & \text{for binary 10} \end{cases} \quad (8)$$

In this mechanism, the constellation consists of four points but the decision is always made in two bits. In this mechanism can ensure the efficient use of bandwidth and higher spectral efficiency.

IV. SPECTRAL EFFICIENCY

It is defined as a measure of the maximum good-put, retransmissions due to co-channel interference and collisions are excluded. Higher-layer protocol overhead (above the media access control sub-layer) is normally neglected. Formula for spectral efficiency is as follows [8].

Spectral eff. = (1-ber)* log2(M) * code rate

Where M = no. of symbol, BER = bit error rate and code rate = 1/2

V. SIMULATION AND RESULTS

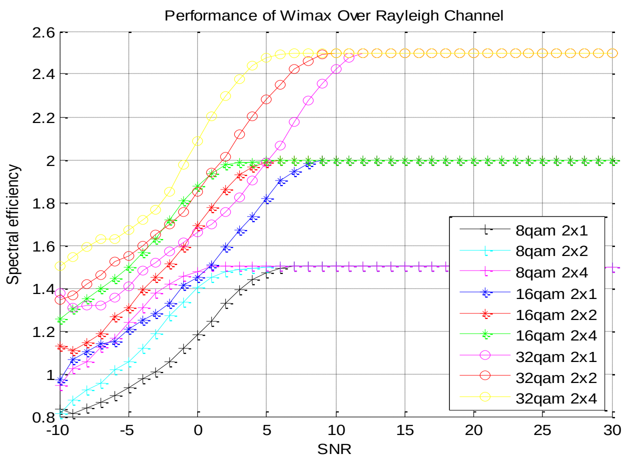

Fig. 5: Spectral Efficiency Performance of QAM Modulations

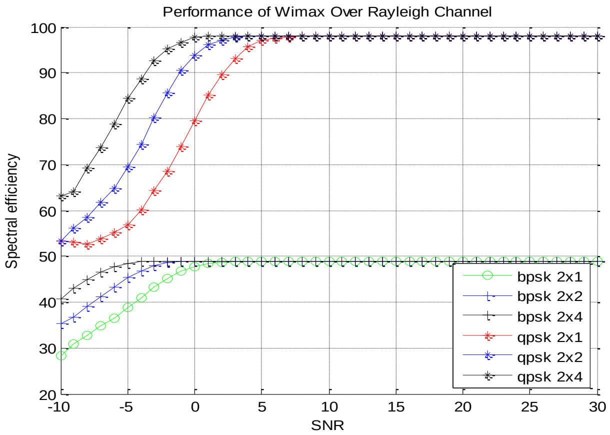

Fig. 6: Spectral Efficiency Performance of PSK Modulations

VI. Scope of the Results

This paper is basically aimed at reducing the bit error rate and enhancing the spectral efficiency and the work done for it is so successful. In case of spectral efficiency, it is much improved for BPSK, QPSK and higher order QAM techniques. For the case of BPSK bit error rate is very less even at the SNR is in negative range which is much better as compared to other systems. We can also observe that all these results are improved much for higher order diversity techniques.

VII. Conclusion and Future Work

MIMO-OFDM System model is designed with the incorporation of Orthogonal STBC scheme for the evaluation of performance gain in a frequency selective fading environment. The simulation result shows that tremendous diversity gain can be achieved with 2 Tx antenna and 4 Rx antenna. The OSTBC MIMO encoding has been used to remove the Inter-symbol interference and to overcome the decoding complexity. Due to 2 antennas used for the transmission double the data rate is achieved over the single channel. The simulation describes various modulation techniques like BPSK, QPSK and QAM which shows improvement in Bit Error Rate and when used with OSTBC. Specially, with 32 QAM, such a combination provides 25%-87% improvements in BER values for SNR ranges of -10 db to 12 db. Results obtained thus prove that spatial diversity significantly improves the performance in terms of BER and Spectral Efficiency in wireless fading channels. For frequency selective fading channels, the information rates increase due to the additional multipath diversity. The information rate increase linearly with the number of antennas, even at very low signal to noise ratios. Hence, there is tremendous increase with the use of MIMO transmission without requiring additional bandwidth or power for frequency selective MIMO channels. This simulation includes the convolution code as a forward error correction but the work can be extended to include turbo code, LDPC and Zig-Zag code with severely faded channels as well and additional components like source coding.

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