Performance Analysis Of MIMO Systems Using Diversity Schemes

BHUSA DEVI  
Student  
Sai Ganapathi Engineering College, Gidiojala(V), Ananda Puram(M), Visakhapatnam

M. BHAGYA SREE  
Assistant Professor  
Sai Ganapathi Engineering College, Gidiojala(V), Ananda Puram(M), Visakhapatnam

Abstract: Multiple-Input-Multiple-Output (MIMO) systems, which use multiple antennas at the transmitter and receiver ends of a wireless communication system. MIMO systems are increasingly being adopted in communication systems for the potential gains in capacity they realize when using multiple antennas. Multiple antennas use the spatial dimension in addition to the time and frequency ones, without changing the bandwidth requirements of the system. The mobile Worldwide Interoperability for Microwave Access (WiMAX) is based on IEEE 802.16 standard and is used for wireless Metropolitan Area Network (MAN). The inclusion of Multiple Input Multiple Output (MIMO) in mobile WiMAX system provides a robust platform for space, time and frequency selective fading conditions and increases both data rate and system performance. The simulation of MIMO-mobile WiMAX model is done by using MATLAB. The performance of mobile MIMO WiMAX system has been carried out using Space Time Block Code for different modulation schemes under different channel conditions like AWGN for different diversity schemes like Alamouti, MRC, OSTBC, Golden code.

Keywords: MIMO Systems; AWGN; WiMAX; MRC; STBC;

I. INTRODUCTION

The first WiMAX system is based on the IEEE 802.16-2004 standard. The features to support mobile applications were added in December, 2005 to introduce 802.16-2005. The resulting standard is referred to as mobile WiMAX. The mobile WiMAX system provides a large number of flexibility in terms of deployment options and potential applications. IEEE 802.16 is a promising technology for ensuring broadband access for the last mile connectivity. It provides a wireless backhaul network that enables high speed Internet access to residential, small and medium business customers, as well as Internet at a cost effective, rapidly deployable solution access for Wi-Fi hot spots and cellular base stations. PHY layer of mobile WiMAX has scalable FFT size from 128 to 2048 point FFT and the range is from 1.6 to 5 Km at 5MHz. Further, MIMO wireless systems help to achieve the goals of the future generation wireless communication system in terms of high data rate, high performance and optimum utilization of the bandwidth. The incorporation of MIMO in mobile WiMAX significantly improves the system coverage, quality of the signal and reliability against fading conditions.

II. SYSTEM IMPLEMENTATION

The MIMO-WiMAX Transmitter and Receiver system is shown in Figure 1. At transmitter side, the information source generates the binary information to be transmitted. The binary information is converted to symbols for digital modulation. The modulated symbols are encoded by (Space time Block Code) STBC encoder and the reverse processes are carried out by different blocks at the receiver.

Figure 1: MIMO-WiMAX Transmitter and Receiver

Transmitter

Transmitter consists of information source, modulator and STBC encoder.

a. Information Source

The Bernoulli binary generator block generates random binary numbers using a Bernoulli distribution. The Bernoulli distribution with parameter p produces zero with probability p and one with probability 1-p. The Bernoulli distribution has mean value 1-p and variance p (1-p). The probability of a zero parameter specifies p, and can be any real number between zero and one.

b. Symbol Modulation

The binary information generated by information source is coo groups of bits to form binary symbols. These symbols are modulated using digital modulation schemes such as BPSK, QPSK, 16-QAM and 64-QAM.
c. STBC Encoder

This block is used for space time diversity coding which is used to reduce the effect of noise and increase the bandwidth by reducing the Bit Error Rate. Alamouti STBC is one of most important technique to achieve diversity using MIMO systems, and secure mean of exchange information. It is usually design under certain assumption and consideration of having knowledge about response of channel i.e. perfect channel state information (CSI) at

1. Transmitter site only
2. Receiver site only
3. The both site

The block then transmits the encoded symbol by a space time block code to spread each of the N-transmit antennas according to the type of coding technique used

Receiver

Receiver mainly consists of STBC decoder and demodulator.

a. STBC Decoder

This block is used for space time diversity decoding which is used to decode encoded data. It is usually design Channel under certain assumption and consideration of having knowledge about response of channel.

b. Demodulation

The received data is demodulated by demodulator to get recovered data. This recovered data is compared with transmitted random data which gives Bit Error Rate (BER).

Channels

Additive White Gaussian Noise (AWGN)

AWGN is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density expressed as watts per hertz of bandwidth and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. In the study of communication systems, the classical (ideal) AWGN channel, with statistically independent Gaussian noise samples corrupting data samples free of inter-symbol interference (ISI), is the usual starting point for understanding basic performance relationships. An AWGN channel adds white Gaussian noise in the signal that passes through it.

SPACE TIME CODES

A. Alamouti Space-Time Code

Space-time block codes (STBC) are a generalized version of Alamouti scheme, but have the same key features. These codes are orthogonal and can achieve full transmit diversity specified by the number of transmit antennas. In other words, space-time block codes are a complex version of Alamouti’s space-time code, where the encoding and decoding schemes are the same as there in the Alamouti space-time code on both the transmitter and receiver sides. The data are constructed as a matrix which has its columns equal to the number of the transmit antennas and its rows equal to the number of the time slots required to transmit the data. At the receiver side, the signals received are first combined and then sent to the maximum likelihood detector where the decision rules are applied.

It is a complex space-time diversity technique that can be used in 2×1 MISO mode or in a 2×2 MIMO mode. The Alamouti block code is the only complex block code that has a data rate of 1 while achieving maximum diversity gain. Such performance is achieved using the following space-time block code:

![Figure 2: Alamouti space-time diversity technique](image)

Briefly, two antennas are used, to send two OFDM symbols and their conjugate, in two time slots, which brings a diversity gain without having to compromise on the data rate. Over the air, the transmitted symbols will suffer from channel fading and at the receiver, their sum will be received. Here is the schematic diagram of an Alamouti wireless system in 2×2 MIMO mode:

![Figure 3: A 2x2 MIMO wireless system using the Alamouti block code](image)

Since the transmission is done over two periods of time, the decoding will also be done over two
periods of time. At the receiver, the received vector $Y$ can be represented by the following equation:

$$\mathbf{Y} = \begin{bmatrix} y_1^1 \\ y_1^2 \\ y_2^1 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_1^2 \\ n_2^1 \\ n_2^2 \end{bmatrix}$$

This is for the first time period. For the second time period, the equation is as follows:

$$\mathbf{Y} = \begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} -x_2^- \\ x_1^- \end{bmatrix} + \begin{bmatrix} n_1^2 \\ n_2^2 \end{bmatrix}$$

where $\begin{bmatrix} y_1^1 \\ y_1^2 \end{bmatrix}$ represents the received OFDM symbol at the first time period, for antennas 1 and 2, respectively, and where $\begin{bmatrix} y_2^1 \\ y_2^2 \end{bmatrix}$ represents the received OFDM symbol at the second time period for antennas 1 and 2, respectively. Both equations can easily be combined and arranged to produce the following result:

$$\mathbf{Y} = \begin{bmatrix} y_1^1 \\ y_1^2 \\ y_2^1 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12} & -h_{11} \\ h_{22} & -h_{21} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_1^2 \\ n_2^1 \\ n_2^2 \end{bmatrix}$$

The next step is to find a way to isolate the transmitted symbols, $x_1$ and $x_2$. One way to reduce the number of unknowns is by using a channel estimator to estimate the channel coefficients. In Nutaq’s OFDM reference design, channel estimation OFDM symbols are sent with each transmitted packet to enable estimating those channel coefficients at the receiver. Given the following matrix:

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12} & -h_{11} \\ h_{22} & -h_{21} \end{bmatrix}$$

We can isolate $x_1$ and $x_2$ by simply multiplying the matrix $\mathbf{Y}$ by the inverse of $\mathbf{H}$. However, since this matrix is not square, we need to use the Moore-Penrose pseudo-inverse $\mathbf{H}^+$ to solve our equations:

$$\mathbf{H}^+ = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H$$

Using this inverse matrix expression, the noisy estimated transmitted symbols can be found using the following expression:

$$\mathbf{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -1 \\ 1 & 1 \\ 0 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} y_1^1 \\ y_1^2 \\ y_2^1 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} x_1^- \\ x_2^- \end{bmatrix}$$

The last step would be to make a final decision on the transmitted symbols. In Nutaq’s OFDM reference design, the decision is made based on the minimum squared Euclidian distance criterion. In the next figure, we can see that the addition of diversity to the system brings a significant performance gain in terms of BER in simulation:

### B. Golden Code

Golden Code is a 2×2 algebraic perfect space-time code with unprecedented performance based on the Golden number (1+√5)/2. It is a full-rate, full-diversity Space-Time code for 2 transmits and 2 receive antennas, for the coherent MIMO channel. In this paper, we discuss Golden code for 2transmitters-1receiver system (2x1) and 2transmitters-2receivers system (2x2).

#### Encoding

The codeword’s $\mathbf{X}$ of the Golden Code are 2x2 complex matrices of the following form:

$$\mathbf{X} = \begin{bmatrix} 1 & 1+\sqrt{5} \\ 1 & 1-\sqrt{5} \end{bmatrix}$$

We stack $\mathbf{X}$ matric columns row to get a 4x2 matrix.

$$\mathbf{X} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1+\sqrt{5} \\ 1 & 1-\sqrt{5} \\ 0 & 0 \\ 1 & 1\end{bmatrix}$$

In the above matrix the real and imaginary parts are separated out to get an I/Q matrix shown below:

$$\mathbf{X} = \begin{bmatrix} 1 & 1+\sqrt{5} \\ 1 & 1-\sqrt{5} \\ 0 & 0 \\ 1 & 1\end{bmatrix}$$

The above I/Q matrix can be described as follows:

$$\mathbf{X} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1+\sqrt{5} \\ 1 & 1-\sqrt{5} \\ 0 & 0 \\ 1 & 1\end{bmatrix}$$

The codeword’s $\mathbf{X}$ of the Golden Code are 2x2 complex matrices of the following form:
III. SIMULATION RESULTS

![Plot of Symbol Error Rate for Golden Code 2x1 4-QAM](image1)

**Figure 4:** SER for 2x1 for Golden Code using 4-QAM

![Plot of Symbol Error Rate for Alamouti Code 2x1 4-QAM](image2)

**Figure 5:** SER for 2x1 Golden Code using 4-QAM

![Plot of Symbol Error Rate for Alamouti Code 2x1 16-QAM](image3)

**Figure 6:** SER for 2x1 Alamouti Code using 16-QAM

![Plot of Symbol Error Rate for Alamouti Code 2x2 16-QAM](image4)

**Figure 7:** SER for 2x2 Alamouti Code using 16-QAM

From the above experimental results, we can say that our proposed schemes better performance in terms of BER compared to existing methods.

IV. CONCLUSION

Broadband Wireless Access (BWA) has emerged as a promising solution for providing last mile internet access technology to provide high speed internet access to the users in the residential as well as in the small and medium sized enterprise sectors. IEEE 802.16e is one of the most promising and attractive candidate among the emerging technologies for broadband wireless access. The emergence of WIMAX protocol has attracted various interests from almost all the fields of wireless communications. MIMO systems which are created according to the IEEE 802.16-2005 standard (WIMAX) under different fading channels can be implemented to get the benefits of both the MIMO and WIMAX technologies. In this paper, the MIMO-mobile WiMAX system is simulated for different modulation schemes (QPSK, BPSK, 16-QAM, 4-QAM) to analyze BER performance under AWGN channel with the help of MATLAB. Simulation results have shown that MIMO-mobile WiMAX system with different modulation schemes give better BER performance at different values of SNR under different channels. Lower modulation schemes give better BER/SER performance as compared to higher modulation schemes. As SNR value increases, higher modulation schemes give better BER/SER performance.
V. REFERENCES


