

## Performance Analysis of MIMO Channel Under Distributed Orthogonal Spaces

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#### ABSTRACT

The main aim of this paper to analyze the performance analysis of the system which uses space-time turbo codes under Distributed Orthogonal Spaces which are combined with adaptive beam forming for multiple transmitter and receiver antennas based on distributed orthogonal frequency division multiplexing (OFDM) system. The performance analysis has been implemented using maximum-likelihood detection and simulation results demonstrate that the proposed system not only provides the good interfacing and also improves the bit-error rate (BER) performance of the system. Experimental results show that an adaptive beamforming gives the optimum performance on relay fading channels and BPSK recovery. In this system we optimize the fading channel and give the comparative analysis of 2\*2, 4\*4 and 16 \*16 BER analysis.

#### **KEY WORDS**

MIMO, OFDM, BER, Q-PSK, WiMAX, QAM Modulation

#### **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.

The WiMAX physical layer model is based on OFDM (Orthogonal Frequency Division Multiplexing) technique. OFDM is the transmission scheme to enable high-speed data, video and multimedia communications which is used by various commercial broadband systems. OFDM is an elegant and efficient scheme for high data rate transmission in a non-line-of-sight radio environment. The physical layer model of WiMAX system is shown in figure 1. The various blocks of this model are explained below

**1.1 Randomization:** It is the first process which is carried out in the WiMAX Physical layer after the data packet is received from the higher layers and each of the burst in Downlink as well as in the Uplink is randomized. It is basically scrambling of data to generate random sequence in order to improve coding performance and data integrity of the input bits.

**1.2 Forward Error Correction (FEC):** It basically deals with the detection and correction of errors due to path loss and fading that leads to distortion in the signal. There are number of coding systems that are involved in the FEC process like RS codes, convolution codes, Turbo codes, etc. Basically we will be focusing upon the RS as well as the convolution codes.

#### 1.2.1 RS code:

These are non-binary cyclic codes that add redundancy to the data. This redundancy is basically addition of parity bits into the input bit stream that improves the block errors.

#### 1.2.2 Convolution codes (CC):

These CC codes introduce redundant bits in the data stream with the use of linear shift registers (m). The information bits are applied as input to shift register and the output encoded bits are obtained with the use of modulo-2 addition of the input information bits. The contents of the shift register in 802.11a physical layer



uses Convolution code as the mandatory FEC.

interleaving mainly operates on one of the block of bits at a time.





These convolution codes are used to correct the random errors and are easy to implement than RS codes. Coding rate is defined as the ratio of the input bits to the output bits. Higher rates like 2/3 and 3/4, are derived from it by employing "puncturing." Puncturing is a procedure that involves omitting of some of the encoded bits in the transmitter thus reducing the number of transmitted bits and hence increasing the coding rate of the CC code and inserting a dummy "zero" metric into the convolution Viterbi decoder on the receive side of WiMAX Physical layer in place of the omitted bits. Code rate of convolution encoder is given as:-



Fig.2 Convolution Encoder; code rate=1/2, m=2

For Decoding the Viterbi algorithm is used at the receiver side of the PHY layer. To describe a convolution code, one need to characterize the encoding function (m), so that given an input sequence m, one can readily compute the output sequence U.

#### **1.3 Interleaving:**

It aims at distributing transmitted bits in time or frequency domain or both to achieve desirable bit error distribution after the demodulation process. In interleaving, data is mapped onto non-adjacent subcarriers to overcome the effects of multipath distortion and burst errors. Block The number of bits in each block is known as interleaving depth, which defines the delay introduced by interleaving process at the transmitter side. A block interleaving can be described as a matrix to which data is written in column format and data is read in row wise format, or vice versa.

#### **1.4 Modulation:**

This process involves mapping of digital information onto analog form such that it can be transmitted over the channel. A modulator is involved in every digital communication system that performs the task of modulation. Modulation can be done by changing the amplitude, phase, as well as the frequency of a sinusoidal carrier. In this paper we are concerned with the digital modulation techniques. Various digital modulation techniques can be used for data transmission, such as M-PSK and M-QAM, where M is the number of constellation points in the constellation diagram. Inverse process of modulation called demodulation is done at the receiver side to recover the original transmitted digital information.

#### **1.5 Pilot Insertion:**

Used for channel estimation & synchronization purpose. In this step, pilot carriers are inserted whose magnitude and phase is known to the receiver

#### **1.6 Inverse Fast Fourier Transform (IFFT):**

An Inverse Fast Fourier transform converts the input data stream from frequency domain to time domain representing OFDM Subcarrier as the channel is basically in time domain. IFFT is useful for OFDM system as it generates samples of a waveform with frequency components satisfying the orthogonally condition such that no interference occurs in the subcarriers.

Similarly FFT converts the time domain to frequency domain as basically we have to work in frequency domain. By calculating the outputs simultaneously and taking advantage of the cyclic properties of the multipliers FFT techniques reduce the number of computations to the order of N log N. The FFT is most efficient when N is a power of two.

#### **Cyclic Prefix**

One way to prevent ISI is basically to create a cyclically extended guard interval in between the data bits, where each of the OFDM symbol is preceded by a periodic extension of the signal itself which is known as the Cyclic Prefix as shown in fig. 3. When the guard interval is longer than the channel impulse response, or the multipath delay, the IS1 can be eliminated.



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Fig 3 Cyclic Prefix

#### **Communication channels:**

Communication channels are kind of medium of communication between transmitter and receiver. These channels are mainly divided into fast and slow fading channels. A channel is known as fast fading if the impulse response of the channel changes approximately at the symbol rate of the communication system, whereas in slow fading channel, impulse response stays unchanged for several symbols

#### **1.7 WIMAX-MIMO SYSTEMS**

MIMO systems 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. Main aim of combining both WiMAX and Spatial multiplexing MIMO technique is to achieve higher data rates by lowering the BER and improving the SNR of the whole system. The proposed block diagram of WiMAX-MIMO systems is given in figure 4.



Fig. 4 WIMAX-MIMO SYSTEM



#### Fig. 5 MIMO-mobile WiMAX mode

The use of WiMAX technology with the MIMO technology provides an attractive solution for future broadband wireless systems that require reliable, efficient and high-rate data transmission. Employing MIMO systems in WiMAX [18] yields better BER performance compared to simple WiMAX protocol. Spatial multiplexing technique of MIMO systems provides spatial multiplexing gain that has a major impact on the introduction of MIMO technology in wireless systems thus improving the capacity of the system.

Combining of both the systems involves employing STBC encoder and decoder at the transmitter and receiver side of WiMAX Physical Layer respectively.

#### 1.8 Channel

#### 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.

#### **1.9 SPACE TIME CODES:**

#### 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.

Space-time block codes were designed to achieve the maximum diversity order for the given number of transmit and receive antennas subject to the constraint of having a simple linear decoding algorithm. This has made space-time block codes a very popular and most widely used scheme. Training-based methods [4] seem to give very good results on the performance of channel estimation at the receiver. Pure training-based schemes can be considered as an advantage when an accurate and reliable MIMO channel needs to be obtained. However, this could also be a disadvantage when bandwidth efficiency is required. This is because pure training-based schemes reduce the bandwidth efficiency considerably due to the use of a long training sequence which is necessarily



needed in order to obtain a reliable MIMO channel estimate. Because of the computation complexity of blind and semiblind methods, many wireless communication systems still use pilot sequences to estimate the channel parameters at the receiver side.

It is a complex space-time diversity technique that can be used in  $2 \times 1$  MISO mode or in a  $2 \times 2$  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:



Alamouti Space-time diversity Fig 6: Alamouti space-time diversity technique

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  $2\times 2$  MIMO mode



Fig 7: A 2×2 MIMO Wireless System Using the Alamouti Block Code

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:

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

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

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

$$\begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix}$$

 $y_1^2$ 

where  $U^{\prime}2 J$  represents the received OFDM symbol at the first time period, for antennas 1 and 2, respectively,

and where  $y_2^2$  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:

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

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:



$$m{H} = egin{bmatrix} h_{11} & h_{12} \ h_{21} & h_{22} \ h_{12}^* & -h_{11}^* \ h_{22}^* & -h_{21}^* \end{bmatrix}$$

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

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

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

$$\begin{bmatrix} \widehat{x_1} \\ x_2 \end{bmatrix} = (H^H H)^{-1} H^H \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix}$$

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:

#### **Proposed Method**

#### Orthogonal space-time codes

The Alamouti space-time code supports maximum-likelihood (ML) detection with linear processing at the receiver. The simple structure and linear detection of that code makes it very attractive; it has been adopted for both the W-CDMA and CDMA-2000 standards. That scheme was later generalized in to an arbitrary number of antennas. Here, they will brief review the basics of STBCs. Figure 3.3 shows the baseband representation for Alamouti STBC with two antennas at the transmitter. The input symbols to the space-time block encoder are divided into groups of two symbols each. At a given symbol period, the two symbols in each group  $\{c_1,c_2\}$  are transmitted simultaneously from the two antennas. The signal transmitted from Antenna 1 is  $c_1$  and the signal transmitted from Antenna 2 is  $c_2$ . In the next symbol period, the signal  $-c_2^*$  is transmitted from Antenna 1 and the signal  $c_1^*$  is transmitted from Antenna 2. They assume a single-antenna receiver, and denote with h1 and h2 be the channels from the and second transmit antennas to the receive antenna, (Figure 3.4) respectively. The channel gains are constant over two consecutive symbol periods. The received signals can be expressed as



#### Fig 8: Transmitter Diversity With Orthogonal Space-Time Block Coding



#### Fig 9: Receiver For Orthogonal Space-Time Blocks Coding

$$r_{1} = h_{1}c_{1} + h_{1}c_{2} + n_{1}$$
$$r_{2} = h_{1}c_{2}^{*} + h_{2}c_{1}^{*} + n_{1}$$

where r1 and r2 are the received signals over two consecutive symbol periods and n1 and n2 represent the receiver noise and are modeled as complex Gaussian random variables with zero mean and potheyr spectral density No=2 per dimension. They

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define the received signal vector  $= [r_1 r_2^*]^r$  the code symbol vector  $c = [c_1 c_2]^r$ , and the noise

vector  $n = [n_1 n_2^*]^r$ . The above Equations can be rewritten in a matrix form as

$$\mathbf{r} = \mathbf{H}\mathbf{c} + \mathbf{n}$$
$$H = \begin{pmatrix} h_1 & h_2 \\ h_2 & -h_2 \end{pmatrix}$$

The matrix H represents a concatenation of the channel vector (h1 h 2) t and the Alamouti code. The vector n is a complex Gaussian random vector with zero mean and covariance No = 2. Let us define C as the set of all possible symbol pairs  $c = \{c_1, c_2\}$ . Diversity order provided by that scheme is 2Lr. Figure 3.4 shows a simplified block diagram for the receiver with two receive antennas. Note that the decision rule in (2.12) and (2.14) amounts to performing a hard decision

 $r and r_{dd} = \sum_{m=1}^{L} H_m^* r_m$  respectively. Therefore, as on shown in Figure 5, the received vector after linear combining, RM, can be considered as a soft decision for  $c_1$  and  $c_2$ , which can be utilized by any outer channel codes used in the system. Note also that for the above 4×4 STBC, the transmission rate is one symbol/transmission, and it achieves the maximum diversity order of 4 that is possible with a  $16 \times 16$ system. The method of Alamouti can be generalized to more than two transmit antennas. The resulting orthogonal codes are still optimally decoded with a linear receiver. Unfortunately, only a few codes with a rate of one symbol/ transmission are available, and for the case of general complex-valued signals, there is no orthogonal rate-1 code beyond the Alamouti code. However, it is possible to design orthogonal codes by relaxing the rate requirement below one symbol/ transmission. For example, for  $L_t=4$ , a rate 1/2 STBC is given by

$$C = \begin{pmatrix} c_1 & -c_2 & -c_3 & -c_4 & c_1^* & -c_2^* & -c_3^* & -c_4^* \\ c_2 & c_1 & c_4 & -c_3 & c_2^* & c_1^* & c_4^* & -c_3^* \\ c_3 & -c_4 & c_1 & c_2 & c_3^* & -c_4^* & c_1^* & c_2^* \\ c_4 & c_3 & -c_2 & c_1 & c_4^* & c_3^* & -c_2^* & c_1^* \end{pmatrix}$$

#### PROPOSED RESULTS



Fig 10: BER of Alamouti Codes Based on QAM Modulation



Fig 11: BER of Alamouti And MRC With 2×1 And 1×2



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Fig 13: BER of Alamouti, OSTBC and MRC with 2x2,4x1 and 1x4

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

# Table 1: BER performance Proposed and Existing Methods at SNR = 8db

Method	Bit-Error Rate
No-Diversity	0. 1159
MRC	0. 2218
OSTBC (4×1)	0. 0037
OSTBC (2×2)	0. 0004

The MIMO-WiMAX model is simulated for different digital modulation schemes (BPSK, QPSK, QAM) with the consideration of <sup>1</sup>/<sub>2</sub>, <sup>3</sup>/<sub>4</sub> code rates of convolutional codes under AWGN, Rayleigh and Rician channels with the help of MATLAB package. The performance parameter in terms of BER of MIMO-WIMAX systems is determined and compared for adaptive modulation and various constant modulations. The simulation is carried out at 5 MHz channel bandwidth for the physical layer of MIMO-WIMAX at both the transmitter and the receiver. The simulation parameters used for simulation is given in Table 2.

 Table 2 Simulations Parameters for different channels

STANDARD	802.16e
CHANNEL MODEL	AWGN, Rayleigh,
	Rician
MODULATION SCHEME	BPSK, QPSK, 16 & 64
	QAM
CONVOLUTION CODE	1/2, 3/4
RATE	,
CYCLIC PREFIX	1/8
BANDWIDTH	5 MHz
LENGTH OF FFT	512
SNR	0-25



Fig 14 BER of MIMO-WiMAX system for different modulation in AWGN channel

Fig. 14 shows BER vs. SNR performance analysis of BPSK, QPSK and 64-QAM modulation technique over Additive White Gaussian Noise channel. BPSK has lower BER than QPSK and 64 QAM. For ex. at SNR=6, BER in BPSK is 0.0025 where QPSK is 0.020 & 64QAM is around 0.4. At SNR=15 BPSK BER=10<sup>-6</sup> but QPSK BER 10<sup>-4</sup> and 64 QAM-BER 10<sup>-3</sup>.

# Table 3 Comparison of SNR BPSK(BER) of16QAM for 6 and 15 Rounds



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e-ISSN: 2348-6848 p-ISSN: 2348-795X Volume 05 Issue 12 April 2018

SNR(db)	BPSK(BER)	QPSK(BER)	16QAM(BER)
6	0.025	0.034	0.04
15	10.6	10.4	10.;



# Fig 15 BER of MIMO-WiMAX system for different modulation with in Rayleigh Fading channel

Fig 15 shows performance analysis of BPSK, QPSK and 64-QAM modulation technique over Rayleigh fading Channel. In graph as the value of SNR is increases, BER is a decrease in all three-modulation technique. BER performance of BPSK is much better than QPSK and 64 QAM. Also, QPSK is better than 64-QAM for higher SNR values.

## Table 4 Comparison of SNR QPSK(BER) of 16QAM for 6 ,15 ,21 and 25 Rounds

SNR(o	ib)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
6		0.034	0.25	0.35
15		0.0025	0.035	0.050
21		0.00001	0.0001	0.0010
25		10.4	10.4	10.;



# Fig 16 BER of MIMO-WiMAX system for different modulation with in Rician channel

Fig. 16 shows performance analysis of BPSK, QPSK and 64-QAM modulation technique over Rician fading channel. In graph as the value of SNR is increases, BER is decreases in all three-modulation technique is shown in Table 4.5, that mean for better performance BPSK may preferred. There is a little difference exists in BER performance of MIMO WiMAX system between QPSK and BPSK modulation schemes.

Table	5.	Comparison	of	different	modulation	in
Rician	ch	annel				

SNR(dB)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
6	0.025	0.075	0.25
15	0.004	0.007	0.015
21	0.0002	0.0006	0.0015
25	10-s	<b>√10</b> -4	10.;





Fig 17 BER of MIMO-WiMAX system for different modulation with in Rician channel

Table 6. Comparison of Adaptive modulation in
different channel.

SNR(dB)	AWGN(BER)	Rician(BER)	Rayleigh(BER)
6	0.04	0.11	025
15	10.4	10.;	10.
21	104	10.;	10.

Fig 17 shows under AWGN channel, the BER has a value near  $10^{-6}$  at Eb/No of 21dB. While in Rician 5. channel, the MIMO-WiMAX model achieves BER performance of about  $10^{-3}$  at Eb/No of 21dB. This BER is worse in Rayleigh channel when compared to AWGN and Rician channels because of non-line of sight condition. For Rayleigh channel, the BER has value about  $10^{-2}$  at Eb/No of 21 dB.

#### CONCLUSION

Orthogonal Space-time block codes with lower modulation order always gives low bit-error rate when compared with space-time block codes that employ higher order modulation methods.

The result shows that Bit Error Rate (BER) of OSTBC with 256-QAM is less for high SNR and BER with BPSK is less for low SNR. While the throughput of OSTBC with 256-QAM is more when compared to OSTBC with BPSK at higher SNR value. Thus, OSTBC with BPSK is more powerful and efficient which need less bandwidth when near to Base Station. OSTBC with higher modulation has higher bandwidth and more power consumption. Thus, Orthogonal Space Time Block Code with digital modulation can be employed in multi antenna system to increase the reliability and throughput.

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e-ISSN: 2348-6848 p-ISSN: 2348-795X Volume 05 Issue 12 April 2018

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