Transmit Beamforming for Performance Enhancement of IEEE 802.16e Mobile WiMAX

Ekta Tiwari, Suchita Varade

***Abstract*— This paper aims at performance evaluation of mobile WiMAX system which uses multiple antenna technique such as space time block coding space time trellis coding with and without transmit beamforming for multiple transmit and multiple receive antennas. The mobile WiMAX system has been analyzed for modulation scheme such as mPSK along with different combination of multiple transmit and receive antenna. Computer simulations are done using MATLAB 7.10.The performance of the proposed system has been analyzed in terms of bit error rate (BER). Simulation results shows that the multiple antenna technique in combination with transmit beamforming improves the performance of mobile WiMAX system in terms of BER as number of transmitting antenna increases without increasing the transmit power and bandwidth.**

***Index Terms*—Mobile WiMAX, Multiple Input Multiple Output (MIMO),Space Time Block Code(STBC), Space Time Trellis Code(STTC), Transmit Beamforming.**

I. INTRODUCTION

Some decades ago, analog systems were used. Both the sources and transmission system were on analog format but the advancement of technology made it possible to transmit data in digital form. Along with those, the computer was getting faster to the fastest, the data payload capacity and transmission rate increased from kilobits to Megabits and megabits to gigabits. From wire to wireless concept emerged and after researching and investing so much money, Engineers became successful to invent wireless transmitter to transmit data. Applications like voice, Internet access [1], instant messaging, SMS, paging, file transferring, video conferencing, gaming and entertainment etc became a part of life.

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Cellular phone systems, WLAN, wide-area wireless data systems, ad-hoc wireless networks and satellite system s etc. are wireless communication. All emerged based on wireless technology to provide higher throughput, immense mobility, longer range, robust backbone to thereat. The vision extended a bit more by the Engineers to provide smooth transmission of multimedia anywhere on the globe through variety of applications and devices leading a new concept of wireless communication, which is cheap and flexible to implement, even in odd environment. This is a fact that, Wireless Broadband Access (WBA) via DSL, T1-line or cable infrastructure is not available especially in rural areas. The DSL can covers only up to near about 18,000 feet (3 miles), this means that many urban, suburban, and rural areas may not served [2]. The Wi-Fi standard broadband connection may solve this problem a bit but not possible in everywhere due to coverage limitations. But the Metropolitan-Area Wireless standard which is called WiMAX can solve these limitations. The wireless broadband connection is much easier to deploy, have long range of coverage, easier to access and more performance evaluation of IEEE 802.16e (Mobile WIMAX) in OFDM Physical Layer flexible. This connectivity is really important for developing countries and IEEE 802.16 family helps to solve the last mile connectivity problems with WBA connectivity. IEEE 802.16e can operate in both Line-Of-Sight (LOS) and Non-Line-Of-Sight (NLOS) environments. In NLOS, the PHY specification is extended to 211 GHz frequency band which aim is to fight with fading and multipath propagation [3, 4].

Organization of this paper is as follows: Section II presents WiMAX IEEE 802.16e; Section III presents a MIMO system while OFDM is given in section IV .Section V and Section VI briefs about the diversity techniques and WiMAX physical layer. System model and simulation results are given in Section VII and VIII followed by the conclusions. In this paper the symbols [.]*, [.]T, and, [.]H, are conjugate, transpose and, conjugate transpose operators, respectively.

II. WIMAX IEEE 802.16 E

WiMAX IEEE 802.16e was an amendment of 802.16d standard which finished in 2005 and known as 802.16e-2005. Its main aim is mobility including large range of coverage. Sometimes it is called mobile WIMAX.

This standard is a technical updates of fixed WIMAX which has robust support of mobile broadband. Mobile WIMAX was built on Orthogonal Frequency Division Multiple Access (OFDMA). It mentioned that, both standards (802.16d-2004 and 802.16e-2005) support the 256-FFT size. The OFDMA system divides signals into sub-channels to enlarge resistance to multipath interference. For instance, if a

30 MHz channel is divided into 1000 sub-channels, each user would concede some sub-channels which are based on distance [3].

III. MIMO System

A. *Space – Time Codes*

Space-Time Codes (STC) provide transmits diversity for the Multi-Input Multi-Output fading channel. There are two main types of STC's namely Space-Time Block Codes (STBC) and Space-Time Trellis Codes (STTC). Space time block codes operate on a block of input symbols, producing a matrix output whose columns represent time and rows represent antennas. Their main feature is the provision of full diversity with a very simple decoding scheme. On the other hand, Space-time trellis codes operate on one symbol at a time, producing a sequence of vector symbols whose length represents antennas. Space-time block codes can achieve a maximum possible diversity advantage with a simple decoding algorithm. It is very attractive because of its simplicity. However, no coding gain can be provided by space-time block codes.

The basic two main types of space-time code

Space-Time Block Codes (STBC)

The Almouti Scheme achieves the full diversity with a very maximum likelihood decoding algorithm. The key feature of the scheme was generalized to an arbitrary number of transmit antennas by applying the theory of orthogonal designs. The generalized schemes are referred to as Space Time Block Codes (STBCs) [13]. The space-time block codes can achieve the full transmit diversity specified by the number of the transmit antennas nT, while allowing a simple maximum likelihood decoding algorithm, based only on linear processing of the received signals.

Space –Time Block Encoder

Fig.1 shows an encoder structure for space-time block codes. In general, a space-time block code is defined by an nT x P transmission matrix X. Here nT represents the number of transmit antennas and p represents the number of time periods for transmission of one block of coded symbols.

Let us assume that the signal constellation consists of 2m points. At each encoding operation, a block of km information bits are mapped into the signal constellation to select modulated signals x1, x2…. Xl, where each group of m bits selects a constellation signal. The modulated signals are encoded by a space-time block encoder to generate nT parallel signal sequences of length p according to the transmission matrix x. These sequences are transmitted through nT transmit antennas simultaneously in p time periods.

In the space-time block code, the number of symbols the encoder take as its input in each encoding operations is k. The number of transmission periods required to transmit the space-time coded symbols through the multiple transmit antennas is p. In other words, there is p space-time symbols transmitted from each antennas for each block of k input symbols. The rate of a space-time block code is defined as the ratio between the number of symbols the encoder takes as its input and the number of space of symbols the encoder takes as its input and the number space-time coded symbols transmitted from each antenna. It is given by.

R = k/p

The spectral efficiency of the space-time block code is given by

$$n= \frac{r_b}{B} = \frac{r_s mR}{r_s} = \frac{km}{p} \text{bits/s/Hz} \quad (1)$$

Where, rb and rs are the bit and symbol rate, respectively and b is the bandwidth.

The entries of the transmission matrix x are linear combinations of the k modulated symbols x1, x2,….xk and their conjugates x1, x2, ….. xk in order to achieve the full transmit diversity of nT, the transmission matrix x is constructed based on orthogonal designs such that [13].

$$X, XH = c(|x_1|^2 + |x_2|^2 + \cdots + |xk|^2)In_T \quad (2)$$

Where, c is a constant, xH is the Hermitian of x and InT is an nT x nT identity matrix. The ith row of x represents the symbols transmitted from the ith transmit antenna consecutively in p transmission periods, while the jth column of x represents the symbols transmitted simultaneously through nT transmit antennas at time j. The jth column of x is regarded space-time symbol transmitted at time j. The element of x in the ith row and jth column xi, i=1,2… p, represents the signal transmitted from the antenna I at time j.

It has been shown that the rate of a space-time block with full transmit diversity is less than or equal to one, R< 1[13]. The code with a full rate R=1 requires no bandwidth expansion. While the code with rate R < 1 requires a bandwidth expansion of 1/R. for space-time block codes with nT transmit antennas, the transmission matrix is denoted by xnT The code is called the space-time block code with size nT.

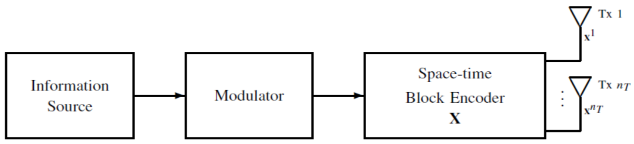


Fig. 1 Encoder for STBC

The orthogonal designs are applied to construct space space-time block codes. The rows of the transmission matrix xnT are orthogonal to each other. This means that in each block, the signal sequences from any two transmit antennas are orthogonal. For example, if we assume that, xi = (xi,1, xi,2… xi,p) is the transmitted sequence from the ith antenna, i=1,2… nT, we have.

$$xi,xj = \sum_{t=1}^{p} x_{i,t}, x_{i,t} = 0, i \neq j, i,j \in \{1,2,\ldots,n_T\} \quad (3)$$

Where, xt,xj denotes the inner product of the sequences xi and xj. The orthogonality enables to achieve the full transmit diversity for a given number of transmit antennas. In addition, it allows the receiver to decouple the signals transmitted from different antennas and consequently, a simple maximum likelihood decoding, based only on linear processing of the received signals.

Space-Time Trellis Codes

Space-time block codes can achieve a maximum possible diversity advantage with a simple decoding algorithm. It is very attractive because of its simplicity. However, no coding gain can be provided by space-time block codes, while non-full rate space-time block codes can introduce bandwidth expansion [15]. STTC was first introduces by Tarokh, Seshadri and Calderbank [1]. It was widely discussed and explored in the literature as STTC can simultaneously offer a substantial coding gain, spectral efficiency and diversity improvement on flat fading channels.

By applying the space-time code design criteria, optimum space-time trellis coded M-PSK schemes for various numbers of transmit antennas and spectral efficiencies are constructed for slow and fast fading channels [14]. The code performance is evaluated by simulations and compared against the capacity limit. The effects of imperfect channel estimation and correlated antenna elements on the code performance are also presented.

Encoder Structure for STTC

For space-time trellis codes, the encoder maps, binary data to modulation symbols, where the mapping function is described by a trellis diagram [1].

Let us consider, an encoder of space-time trellis codes M-PSK modulation with nT transmit antennas as shown in Fig.2 The input message stream, denoted by c, is given by ,

$$c=(c0,c1,c2\ldots ct\ldots) \quad (4)$$

Where, ct is a group of m=log2 M information bits at time t and given by,

$$ct=(c_t^1,c_t^2\ldots.c_t^m) \quad (5)$$

The encoder map the input sequence into an M-PSK modulated signal sequence, which is given by,

$$x=(x0,x1,x2\ldots xt\ldots) \quad (6)$$

Where, xt is a space-time symbol at time t and given by,

$$xt=(x_t^1,x_t^2\ldots.x_t^m)T \quad (7)$$

The modulated signals, $x_t^1 x_t^2$,…. x_t^{nT} , are transmitted simultaneously through nT transmit antennas.

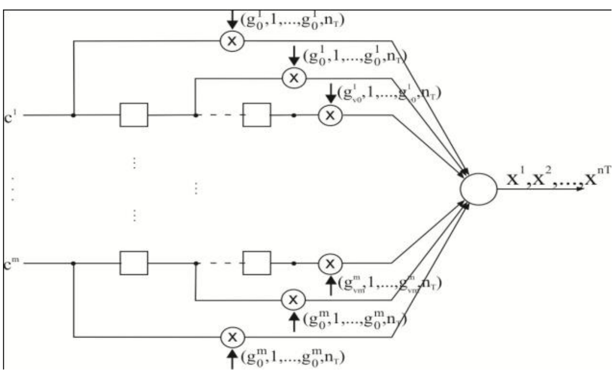


Fig. 2 Encoder for STTC

B. Transmit Beamforming

Transmit beamforming is not a new idea in wireless communications. However, although it also applies multiple antennas, its idea quite differs from idea of spatial diversity. In this case, the assumption is that antennas are close enough to transmit over highly correlated channels. One of advantages of this approach is that beamforming reduces Multiple Access Interference in multi access systems [1]. Prefiltering at base station can also be performed when multiple antennas are available [2].

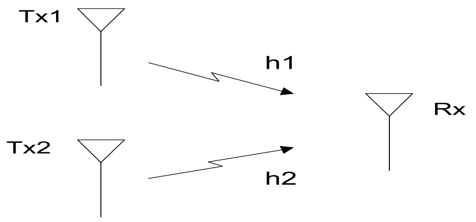
User specific beamforming weights per antenna, assuming that desired user come from the broadside direction, are

$$wk = \frac{\sqrt{P_0}}{\sqrt{N_a}} sk \quad (8)$$

Where, P0 is symbol's transmitted power. This normalization factor is included to take into account equal power distribution per antenna.

$$sk = [\begin{matrix} e^{j0\frac{2\pi d}{\lambda}\sin\theta_k} \\ e^{j1\frac{2\pi d}{\lambda}\sin\theta_k} \\ e^{j2\frac{2\pi d}{\lambda}\sin\theta_k} \\ \vdots \\ e^{j(N_a-1)\frac{2\pi d}{\lambda}\sin\theta_k} \end{matrix}] \quad (9)$$

The gain of antenna array appointing to the desired direction is, $gp(\theta_k)$=wpHSk (10)



(3.5)

Fig. 3 Multiple Input Multiple Output using Two transmit and One receive antenna

For example consider 2 transmit and 1receive antenna. From Fig. 3, on the received antenna, the received signal is,

$$y = [h1\ h2]\begin{bmatrix} e^{-j\theta_1} \\ e^{-j\theta_2} \end{bmatrix} + n \quad (3.7)\ (3.8) \quad (11)$$

Where,
y is the received symbol,
hi is the channel on the i th transmit antenna,
x is the transmitted symbol and
n is the noise on the receive antenna.

When transmit beamforming is applied, the symbol from each transmit antenna is multiplied with a complex number corresponding to the inverse of the phase of the channel so as to ensure that the signals add constructively at the receiver. In this scenario, the received signal is,

$$y = (|h_1| + |h_2|)x + n \quad (12)$$

Where,

$$h1 = |h_1|e^{-j\theta_1}$$
$$h2 = |h_2|e^{-j\theta_2} \quad (13)$$

In this case, the signal at the receiver is,

$$y = [h1\ h2]\begin{bmatrix} x \\ x \end{bmatrix} + n = (h1 + h2)x + n \quad (14)$$

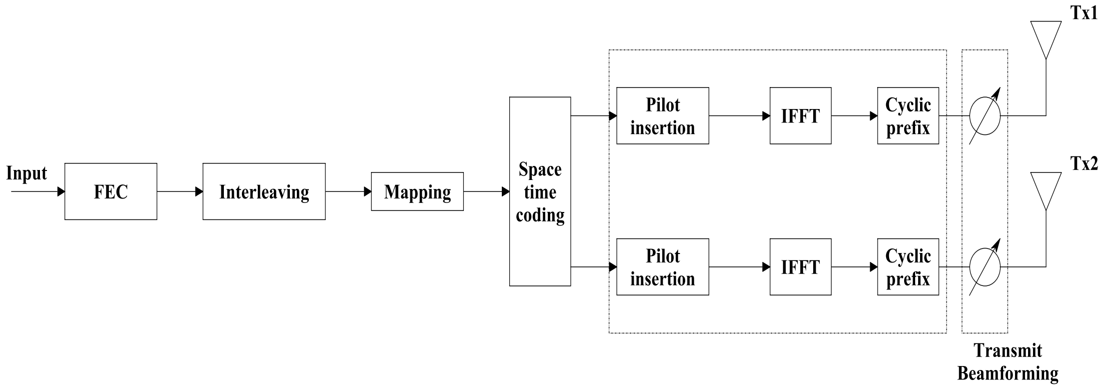


Fig. 4 Transmitter of WiMAX System with STC and Transmit Beamforming

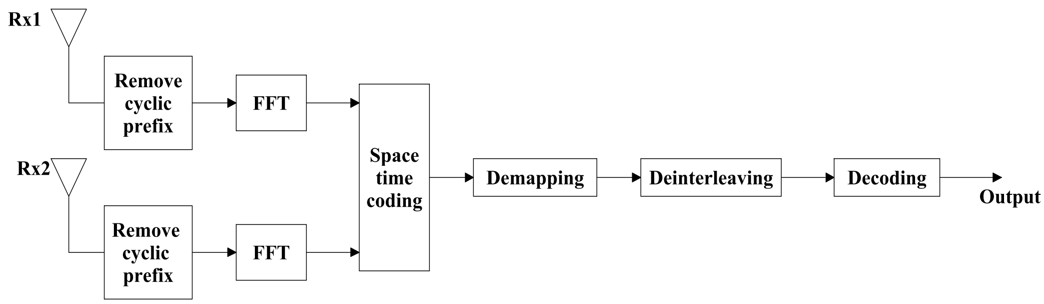


Fig. 5 Receiver of WiMAX System with STC

IV. WIMAX PHYSICAL LAYER

The functional block diagram used in the transmitter and receiver is shown in Figure.4 and figure.5 respectively. The role of the PHY layer is to encode the binary digits that represent MAC frames into signals and to transmit and receive these signals across the communication media. The WiMAX PHY layer is based on OFDM; which is used to enable high speed data, video, and multimedia communications and is used by a variety of commercial broadband systems. The PHY layer; shown in Figure.4, in WiMAX includes various functional stages: (i) Forward Error Correction (FEC), interleaving, and symbol mapping; (ii) OFDM symbol in frequency domain, and (iii) conversion of the OFDM symbol from the frequency domain to the time domain using IFFT .

A. Convolutional Encoder (CC)

Data bits are encoded by a binary Convolution Encoder, which has a native rate of 1/2 and a constraint length of 7.The generator polynomials used to derive its two output code bits, denoted X and Y, are specified in the following expressions: G1 = 171 OCT for X, and G2 = 133 OCT for Y.

B. Interleaver

Data interleaving is generally used to scatter error bursts and thus, reduce error concentration to be corrected with the purpose of increasing efficiency of FEC by spreading burst errors introduced by the transmission channel over a longer time.

C. Mapping

It refers to the baseband modulation that consists on the mapping of the input bits to complex symbols, according to the considered constellation. All the digital modulations proposed by the standard (QPSK, 16QAM, 64 QAM) may be simulated. The output of this block consists of complex valued modulation symbols.

D. OFDM Modulation

OFDM is a multicarrier modulation technique, which provides high bandwidth efficiency because the carriers are orthogonal to each other and multiple carriers share the data among themselves. The main advantage of this transmission technique is their robustness to channel fading .The OFDM transmitter basic building blocks are shown in Figure.4. The serial to parallel converter receive the M serial bits to be transmitted, and those bits are divided into N sub blocks of mn bits each sub block. Those N sub blocks will be mapped by the constellation modulator using Gray codification, this way an + jbn values are obtained in the constellation of the modulator. The modulation scheme converts input data into complex valued constellation points, according to a given constellation, BPSK, QPSK, 8-PSK, 16-QAM and 64-QAM.

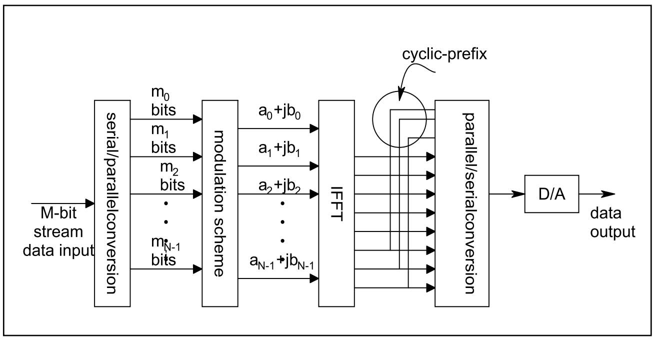


Fig. 6 OFDM transmitter

E. IFFT

The Inverse Fast Fourier Transform (IFFT) transforms the signals from the frequency domain to the time domain.

F. Cyclic Prefix

The cyclic prefix (CP) is a copy of the last N samples from the IFFT, which are placed at the beginning of the OFDM frame; usually used to combat the inter-symbol interference (ISI) and inter-channel-interference (ICI) introduced by the multipath channel through which the signal is propagated. Four different duration of cyclic prefix are available in the standard. Being G the ratio of CP time to OFDM symbol time, this ratio can be equal to 1/32, 1/6, 1/8 and ¼.

G. Channel

The Flat and frequency selective Rayleigh fading channel adds a noise of a certain variance to the useful signal.

H. Receiver

The complementary blocks are implemented in the receiver: the CP is removed, subcarriers are demodulated via the FFT transform, and then subcarrier de-mapping is performed. The blocks of the OFDM receiver are shown in the Figure.3. The receiver blocks are basically the inverse of the transmitter blocks. When communicating over a wireless radio channel the received signal cannot be simply modeled as a copy of the transmitted signal corrupted by noise. At the receiving side, a reverse process (including de-interleaving and decoding) is executed to obtain the original data bits. As the de-interleaving process only changes the order of received data, the error probability is intact. When passing through the CC decoder some errors may be corrected, this results in lower error rates.

V. SIMULATION AND DISCUSSION

Finally, simulation performed on MIMO system by using Alamouti scheme by considering different antenna arrangement for MIMO as 2x1, 3x1 and 4x1 Alamouti space time block code diversity schemes along with the modulation schemes like BPSK and QPSK are implemented. All the necessary conditions were implemented in the simulation according to the 802.16e OFDMA-PHY specification using Matlab 7.10 coding. The mathematical values are assumed in order to get BER performance. Eb/No ratio range is defined, it is taken from 0 to 20 if taken larger, and it takes more time to produce result.

The goal is to evaluate the performance of the WiMAX system using multiple antenna techniques in terms of bit error rate and coding gain. The curves show the BER as a function of the Bit Energy to Noise rate (Eb/N0), which is a measure of the energy efficiency.

Figure 7 and 8 are the final output of the system. The source symbols were transmitted in frame length 600, and the viterbi algorithm sequence detection used to decode the received signals. Fig. 7 shows Bit Error Rate curves of a 2 transmit antenna and 1 receive antenna and Figure 8 shows bit error rate curves of a 2 transmit and 2 receive antenna system with QPSK modulation scheme. Signal to Noise Ratio (SNR) is permissible upto 20 dBs. At low SNR, the error performance curves are close to each other and they behave according to the expectations at medium and high SNR. This phenomenon can be explained as the definition of coding gain advantage.

A. Simulation Parameters

Simulation Parameter	**Value**
Frame Length	600
Number of Packets	10
Number of transmitting Antenna	2
Number of receiving Antenna	1,2
Channel Model	Rayleigh
Channel estimation	Perfect
Modulation	QPSK
SNR	upto 20dB

Table 1 : Simulation Parameters

B. Simulation results for 2x1 system

2X1	SNR			
BER	STBC+TBRF	STBC	STTC+TBRF	STTC
10^{-2}	5 dB	6dB	11.5dB	13dB

Table 2:SNR versus BER for 2x1 system.

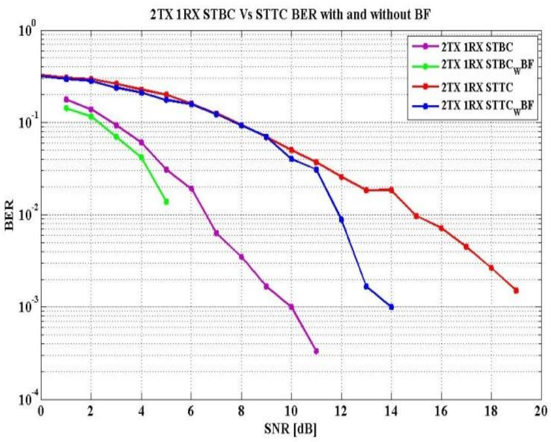


Fig. 7 Output of WiMAX System with STBC versus STTC with and without Transmit Beamforming for 2x1 system .

STBC system in Rayleigh environment has Bit error rate (BER) of 10^{-2} at the SNR level 6 dB, and the STBC-transmit beamforming system has same BER at an SNR level of 5 dB, then the coding gain = 6dB-5dB= 1dB. In 2x1 STTC system in Rayleigh environment has Bit error rate (BER) of 10^{-2} at the SNR level 13 dB, and the STTC-transmit beamforming system has same BER at an SNR level of 11.5 dB, then the coding gain = 13dB-11.5dB= 1.5dB.

C. Simulation results for 2x2 system

Table 3 : SNR versus BER for 2X2 system

2X2	SNR			
BER	STBC+TBRF	STBC	STTC+TBRF	STTC
10^{-2}	5 dB	6.5dB	7.5dB	9.5 dB

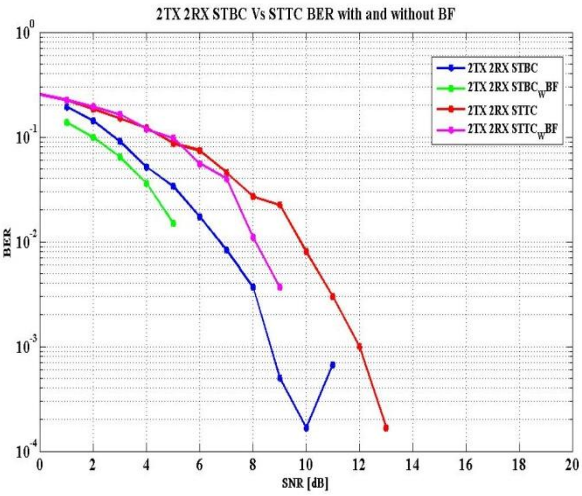


Fig. 8 Output of WiMAX System with STBC versus STTC with and without Transmit Beamforming for 2x2 system .

Table 4 shows the comparison between SNR and BER for 2x1 and 2x2 system different SNR values. From which, it is observed that BER performance of STBC+BF is better than all other techniques at lowest SNR with given simulation parameters. Here, the graph depicts that in both the system as we goes on increasing the number of Transmitting and Receiving antennas, the BER keeps on decreasing due to space diversity and the 2x2 system provide better BER and coding gain performance as compared to the 2x1 system.

VI. CONCLUSION

The WiMAX system is simulated using MATLAB and simulation parameters are assumed. Simulation shows bit error rate (BER) performance with respect to energy per bit to the spectral noise density (Eb/No) of the WiMAX system for STBC versus STTC with and without transmits beamforming under Rayleigh fading channel. The ability to transmit and receive through multiple antennas enables us, while applying spatial diversity, to combat fading and ultimately have substantially improved reliability and increased capacity. The increased capacity, under proper coding, eventually translates into increased throughput. Specifically, the concepts of Space-Time Coding (STC) and transmit beamforming were introduced. The WiMAX system is simulated up to two transmit and/or receive antennas.

Simulation results showed that the degree of diversity achieved, and hence the increase in throughput, is proportional to the number of antennas with which the communication system is equipped.

It is observed that as SNR increases the effect of the distortions introduced by the channel also goes on decreasing, as a result of this the BER will also decreases.

Furthermore, coding gain of 1.5 dB is obtained between STBC with and without transmit beamforming and coding gain of 2 dB is obtained between STTC with and without beamforming at the bit error rate of 10-2 when two transmit-receive antennas are used.

From the simulation results it is observed that: BER performance of STBC+BF > BER performance of STBC > BER performance of STTC+BF> BER performance of STTC for both the systems. But BER and coding gain performance is improved in two transmit and two receive antenna system than two transmit and one receive antenna system. So it can be concluded that system performance improves as number of receiving antenna increases without increasing transmit power and bandwidth.

Multiple inputs and multiple output system for WiMAX system are already a very active area of research and promise great benefits for broadband wireless channel. We can implement our system by using 2×4 and 4×4 MIMO i.e. number of transmitting antenna 2, 4 and number of receiving antenna 4. As it offers significant increase in data throughput and range without additional bandwidth or transmitting power, it also reduces fading.

Transmit beamforming in addition to receive beamforming could be another area to explore. In future WiMAX system can be implemented using receive beamforming at receiver side, which avoid computational complex detectors. Different beamforming algorithms can be used instead of transmit beamforming

Table 4: shows the comparison between SNR and BER for 2x1 and 2x2 system different SNR values.

	SNR(dB)	4	6	8	10	12	14	16	18
BER	2x1								
	STBC+BF	0.0415	0.01383	0	0	0	0	0	0
	STBC	0.0607	0.01917	0.0035	0.001	0	0	0	0
	STTC+BF	0.2102	0.157	0.09267	0.04017	0.0088	0.001	0	0
	STTC	0.2258	0.157	0.09267	0.050	0.02567	0.0185	0.007167	0.002667
	2x2								
	STBC+BF	0.036	0	0	0	0	0	0	0
	STBC	0.0515	0.01717	0.03667	0.0001667	0	0	0	0
	STTC+BF	0.1183	0.05517	0.011	0	0	0	0	0
	STTC	0.1183	0.074	0.02683	0.008	0.001	0	0	0

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