Far East Journal of Electronics and Communications

http://www.pphmj.com
http://dx.doi.org/10.17654/EC017061421
Volume 17, Number 6, 2017, Pages 1421-1436 **ISSN: 0973-7006**

ANALYSIS OF WiMAX SYSTEM AUGMENTED WITH SPATIAL MULTIPLEXING AND SPATIAL DIVERSITY

Akanksha Sharma, Lavish Kansal* and Gurjot Singh

School of Electronics and Electrical Engineering
Lovely Professional University
Punjab, India

Abstract

The current vision of wireless services demands proper data, perfect reliability, throughput, etc. with efficient bandwidth utilization. The presence of various receiving wires in a framework implies the existence of various propagation ways. There are two prime families of multiple input multiple output (MIMO) regarding how to transmit information over provided channel. Spatial diversity (SD) will be enhancing the reliability of the framework, by sending same information over the diverse spread ways. Spatial multiplexing (SM) enhances the information rate of the framework, by putting diverse parts of the information on various engendering ways. These MIMO techniques, when combined with Worldwide Interoperability for Microwave Access (WiMAX), will enhance its performance significantly. In this paper, the focus is on comparing spatial diversity, and spatial multiplexing augmented WiMAX with conventional WiMAX for different modulation levels and code rates. Simulation results depict variations in bit error rate for both the scenarios, i.e., spatial diversity and spatial multiplexing.

Received: May 5, 2017; Accepted: August 16, 2017
Keywords and phrases: OFDM, WiMAX, MIMO, SD, SM.
*Corresponding author

1. Introduction

WiMAX (Worldwide Interoperability for Microwave Access) network or BWA-MAN (Broadband Wireless Access Metropolitan Area Network) technology that is occupied by IEEE 802.16 standard, also known as IEEE Wireless MAN, provides the frequency ranges of microwave and millimeter wave through new air interface standard with the purpose of allocating broadband wireless access that can be interoperated coherently by the multiple users present in surroundings using the concept of “one to many points” under Metropolitan Area Network [2]. WiMAX, an exclusive firm, launched in June 2001, to synchronize and prosper the equipment and its components to make it interoperable, compatible and can provide services up to 20 or 30 miles from the base station. In 2007, they got the certification and released the product in 2008 along with mobility and nomadic access. Additionally, improved version for covering NLOS (non-line of sight) environment, flexible channel bandwidth, adaptive modulation and antenna systems, transmit diversity, and robust error control mechanisms make it more powerful.

MIMO systems and their functions are the boon for environment providing numerous antennas on both transmitter and receiver that raise throughput, data rate, spectral efficiency and reliability, by reducing the transmission power requirement, is giving people a better environment in the field of wireless communication [3]. Techniques involving in MIMO such as spatial multiplexing and spatial diversity for betterment in BER vs. SNR graph. To increase the reliability of the message signal by sending two or more antennas with different attributes and to combat fading, co-channel interference, for avoiding burst errors, we go for diversity technique and for multiplexing [4]; we send two or more communication channels with same properties and increase the throughput, capacity and multiplexing gain of the system.

Based on WiMAX physical layer and its functions the simulations have been carried out for both spatial multiplexing and spatial diversity. The remaining paper is catalogued as follows: Section 2 introduces WiMAX physical layer along with its full details of the block diagram. Classification of MIMO systems along with its proper description and definition is contemplated in Section 3. Section 4 focuses on introducing MIMO-WiMAX and along with that MIMO technique in detail. Simulation results are discussed in Section 5. Finally, the paper is concluded based on results in Section 6.

2. WiMAX Physical Layer Model

Here, physical layer setup of OFDM is described through WiMAX which enables data, communication media, video and audio. The main thing is the coding of the channel i.e. collection of three stages: randomization, forward error correction (FEC) and interleaving. FEC can be done with the help of Reed-Solomon (RS) and convolutional code (CC), and after that modulation, FFT and the cyclic prefix are introduced. The reverse process is the same as done before. To support all the above things block diagram of WiMAX physical layer (802.16e standard) is shown in Figure 1.

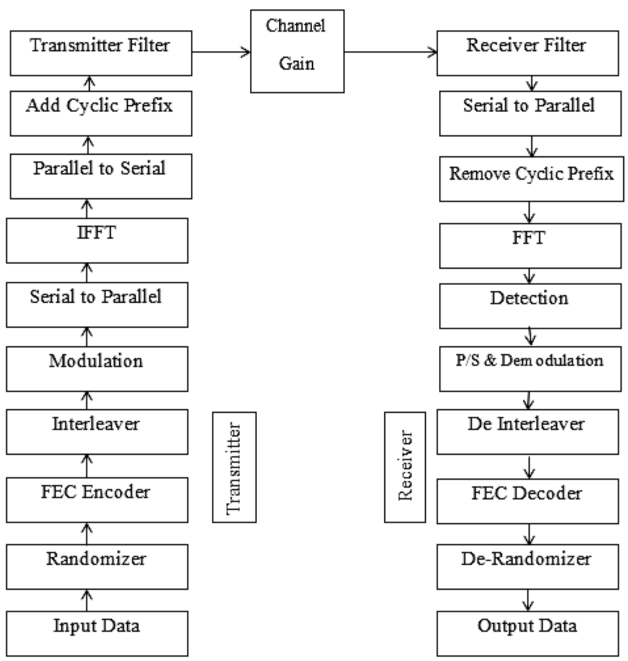


Figure 1. WiMAX physical layer model.

➢ Randomization

For improvement in coding performance, first of all, randomization is done. The purpose is to make ones and nulls in random sequence by operating bit by bit with the help of pseudo random binary sequence (PRBS) generator. Equation (1.1) shows the randomization generator:

$$1 + x^{14} + x^{15} = \text{out.} \tag{1.1}$$

➢ Forward error correction (FEC)

It mainly detects and corrects the error or rebuilds the bits again without any requirement of retransmitting information stream. A digital processing technique improves the reliability of data by putting redundant data before sending information [6]. Coding system includes FEC are RS codes, TURBO codes, convolution codes, etc. for improvement in the capacity of the channel.

• RS codes

An instance of error correcting codes where redundant information bits are added to get the data reliability irrespective of storing data, retrieving it or transmission errors. They depended on Galois field (GF) operations and represented as GF (2^m).

• Convolution codes

Convolutional codes are more popular for their memory to keep the previous bits along with the current bits. It has a property of encoding overall information stream in an individual code word without the need of segmenting. Both data and code words are of infinite length, so called as information and code sequence. Represented as (**N**, **K**, **M**) having code rate of $R = k/n,$ where n is number of output bits, k = input bits (constraint length) and input memory m that should be enormous enough to tackle probabilities of error, with condition $k < n$ as the performance of convolution codes depends on constraint length and code rate [7]. A process called puncturing is performed which means discarding the encoded bits and reducing the transmitted bits which are increasing the code rate automatically.

➢ **Interleaving**

Interleaving contains permutation equations which correct the errors as it spreads the data over distributed carriers in the combination of 192 data carriers of OFDM symbol of total 256 carriers. It disperses code symbols in time before the transmission and broadcast burst errors and totally focuses on the position of the bits thus reducing the errors and increasing the efficiency of FEC [8]. Block interleaver which mainly works for operating one block of the bit at a time and each bit is called as interleaving depth, which informs about the delay introduced on the side from where the signal is sent. Mainly, block interleaver is popular for its operation to write the data column-wise and same can be read in row-wise format and vice versa.

➢ **Modulation**

According to the averaging of the constellation, random values are passed with the help of adaptive modulation schemes. Modulation is done based on the size of the data and different modulation schemes like BPSK, QPSK, 16 QAM and 64 QAM, etc. Particular arrangements are done to adjust a signal, for instance, M-QAM and M-PSK and M is determined as bits according to which the constellation is mapped, and demodulation is performed to restore the transmitted digital data back.

➢ **Inverse FFT**

The function of IFFT is to obtain the signal in time domain, and after modulation, the produced symbols obtained can be taken as the sinusoidal amplitudes over a particular range. Before employing the IFFT algorithm, each of the discrete samples correlates to a single subcarrier. Rather keeping the fact that OFDM subcarriers are orthogonal, the IFFT is a prompt way to laterally modulate these subcarriers, through which the usage of numerous modulators and demodulators, operation, is avoided.

➢ **Cyclic prefix**

It copies the end symbol that is added at the starting of every symbol of OFDM. So, to mitigate the issue of inter-symbol interference happened due to multipath propagation and to reduce delay. These delays disturb the beginning of next symbol and make noise that is why the second symbol is placed away from the first symbol, and the cyclic prefix is detached at the receiver side to get the original signal [9].

➢ **Receiver**

The reverse operation is performed as done by the transmitter. After the cyclic prefix is removed, then, the signal which is received is needed to be reformed into the frequency domain with the help of FFT and convolution operation is altered into multiplication. Then, de-interleaving, de-mapping, decoding followed by de-randomization are done.

3. MIMO Systems

A technology containing radio antenna which transfers more data at the same time with the help of multiple antennas i.e. multiple transmitters and multiple receivers is a function of MIMO. Taking the asset of radio wave paradox, called ‘multipath’ and improving by using spatial dimensions, directly increase the performance and scope of the system. Here from Figure 2, we can see that multiple transmitters are sending unique data to receivers, categorized broadly into three categories [10]. Firstly, beamforming in which the signal is only sent at desired and needed direction. For proper gain and reliability, different antennas having different information are sent, i.e., diversity is used. For the throughput and increased data rate where different antennas have same information are sent called as spatial multiplexing.

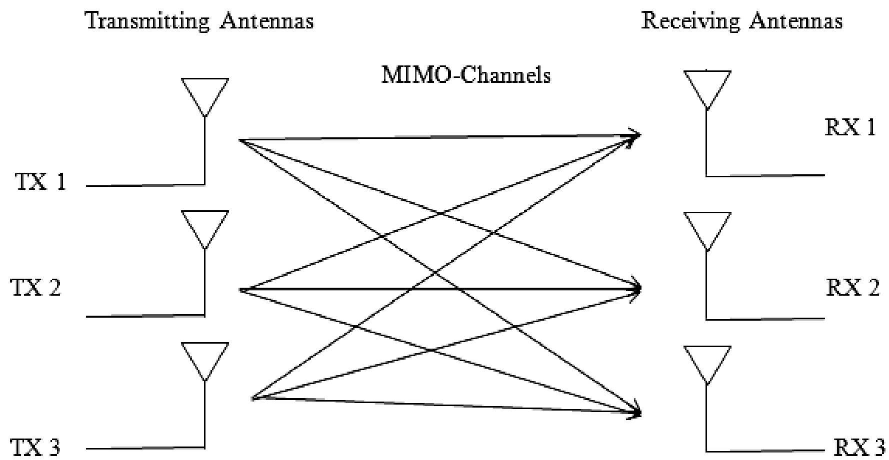


Figure 2. Block diagram of MIMO systems.

(A) Spatial diversity (SD)

Techniques to upgrade signal-to-noise ratio (SNR) and mitigate multipath fading, in which dependent information is sent through different paths and at the receiver end we get multiple independent faded replicas of signal called as spatial diversity or transmit/receive diversity [3]. It alleviates fading and significantly improves link quality. In this, maximum diversity gain $d_{\max}$ is achieved that is a sum of autonomous striking routes between transmitter and receiver side. Higher will be the diversity gain; lower will be the probability of error (P_e). Considering an (M_R, M_T) scheme, overall signal paths can be written as $M_R M_T$ [11]. For Alamouti code number of independent symbols sent in a symbol period is only one as can be seen from Figure 3.

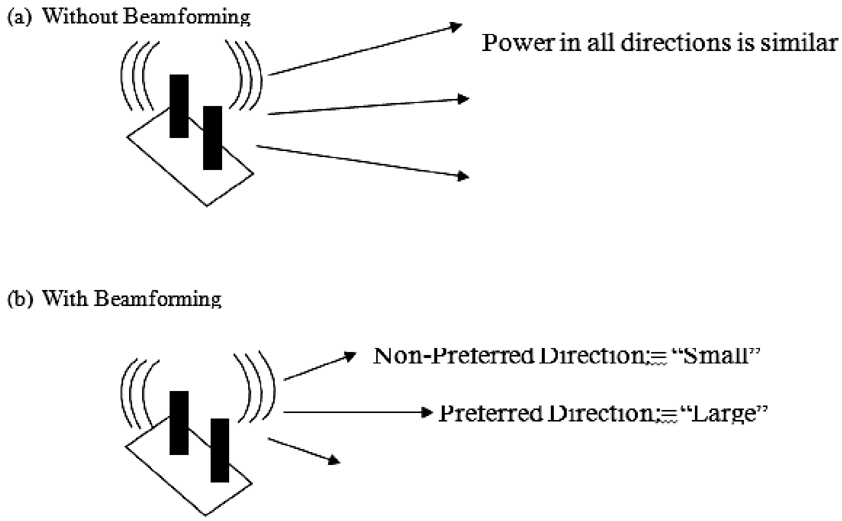


Figure 3. Beamforming concept.

(B) Spatial multiplexing (SM)

In spatial multiplexing, several collective autonomous connections (on the equivalent channel) are sent from transmitter to receiver to disseminate at bigger information rates forming the cross paths between antenna. Every transmit antenna sends its signal at divergent streams of data. It can be the possibility that each receiver antenna may receive all the data sent from the transmitter. Transmitting independent links gives us the advantage of getting higher data rates and throughput [12]. If broadcasting is prosperous enough (channel H), different spatial data streams are created within the same bandwidth. Its main asset is that they come with no extra power and bandwidth and provide additional data capacity. This technique involves V-BLAST technology which is mainly used to improve the spectral efficiency of the system [15]. It organizes channel limit at high SNR and involves complexity and costs at both transmitter and receiver side.

(C) Beamforming

Beamforming is a marked processing generation that is used to make the reception or transmission specific on a particular angular direction in which we want to. Beamforming mainly focuses on one side of the array to get desired particular signal and tries to avoid other directions as shown in Figure 3. Beamforming, along with smart antennas and MIMO is one of few technologies, which lifts up the coverage and quantity of WiMAX by providing an improved signal-to-noise ratio (SNR). Beamforming permits higher data rates and cuts down the number of retries, which increases the overall capacity of the system, which leads to making use of spectrum more efficiently.

4. MIMO-WiMAX

The ongoing demand for high data rate, reliability and channel capacity, many radio standards like WiMAX, 3GPP HSPA, LTE and WLAN are implementing MIMO technology. Using both transmitter and receiver antennas simultaneously, it gives advantage and a better chance to MIMO to hike the transmission quality of the signal as well as the data rate. By taking the advantage of multipath propagation by this technology and appears in a radio channel, that was remarked as interference in previous radio standards. In MIMO, every step of increasing lanes between the transmitter and the receiver upgrades the signal-to-noise ratio (SNR). Most of the MIMO techniques are defined in two, three or four antenna systems by different communication standards. WIMAX includes Matrix-A and Matrix-B MIMO.

1. MATRIX-A (increased coverage area)

- Improved SNR at the receiver side.
- Increases capacity at cell edges.
- Improved signal quality.
- Enhanced throughput.

2. MATRIX-B (increased data rate)

- Improves bandwidth efficiency.
- Ideal signal conditions.
- Use of cyclic delay diversity.

In the IEEE standard, 802.16e-2005 MIMO is defined for 2 or 4 antenna systems, whereas first applications focus on 2 antennas only as shown in Figure 4. WiMAX uses transmit diversity/STBC (Matrix-A) and spatial multiplexing (Matrix-B). Both Matrix-A and Matrix-B type of modulation are required to improve information rate and spectral efficiency. Main desire to combine both WiMAX and MIMO technique is to carry out higher data rates by decreasing the BER and improving the SNR of the whole system. MIMO-WIMAX provides many directions in which independent result can occur and to use them exclusively to find maximum diversity from the channel [9].

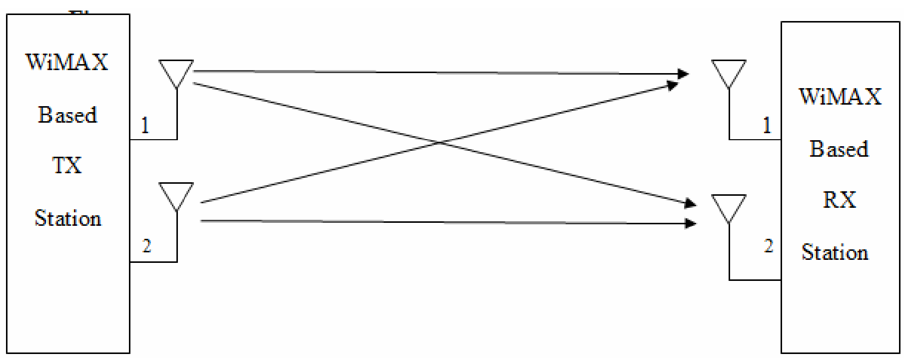


Figure 4. MIMO-WiMAX system communication.

By estimating the performance of WiMAX systems through adaptive modulation then it provides the opportunity for BER to improve. Using both spatial multiplexing and spatial diversity and making their comparison on WiMAX will provide a bigger and major impact on MIMO systems and thus will improve the coverage, diversity gain and throughput of the systems.

In this paper, the performance of MIMO-WiMAX systems is analyzed by using two most important and essential parts of MIMO that are spatial diversity (STBC or transmit/receive diversity) and spatial multiplexing (V-BLAST).

5. Simulation Results

In this paper, performance of the MIMO-WiMAX system for diverse modulation techniques and different convolutional code rates are presented, and the consequences on the BER performance by increasing the order of the modulation are conferred. The pattern of SNR vs. BER is followed to show the different improvements in the every graph on changing the values every time. Two MIMO techniques as discussed above i.e. spatial multiplexing and spatial diversity are appended with WiMAX, and their performance is compared with conventional WiMAX. In the case of spatial multiplexing, the increase in the throughput and data rate is there, when we are sending different data over different antennas and in the case of spatial diversity, capacity and diversity gain, improved signal quality by sending different data over same antennas to have a better possibility of results.

5.1. Spatial multiplexing-WiMAX vs. conventional WiMAX

Performance analysis of spatial multiplexing augmented WiMAX, and conventional WiMAX has been shown in Figure 5. In these simulations, various modulation rates i.e. BPSK1/2, QPSK1/2, QPSK1/4, 16-QAM1/2 and different cyclic prefix values i.e. 1/4, 1/8, 1/16 are taken into consideration. The results are simulated in Rayleigh environment. For the spatial multiplexing, two transmit and two receiving antennas i.e. Ntx = Nrx = 2 are considered. Overall results depict that BER is increasing in case of spatial multiplexing augmented WiMAX in comparison to conventional WiMAX. But, this increase in BER is at the expense of increased capacity by twice as compared to conventional WiMAX. In the case of spatial multiplexing augmented WiMAX, to achieve the same BER approximately 20 dB, more SNR is required in comparison to conventional WiMAX. But, this elevated SNR requirement is decreasing on increasing the modulation levels as depicted in the simulation results.

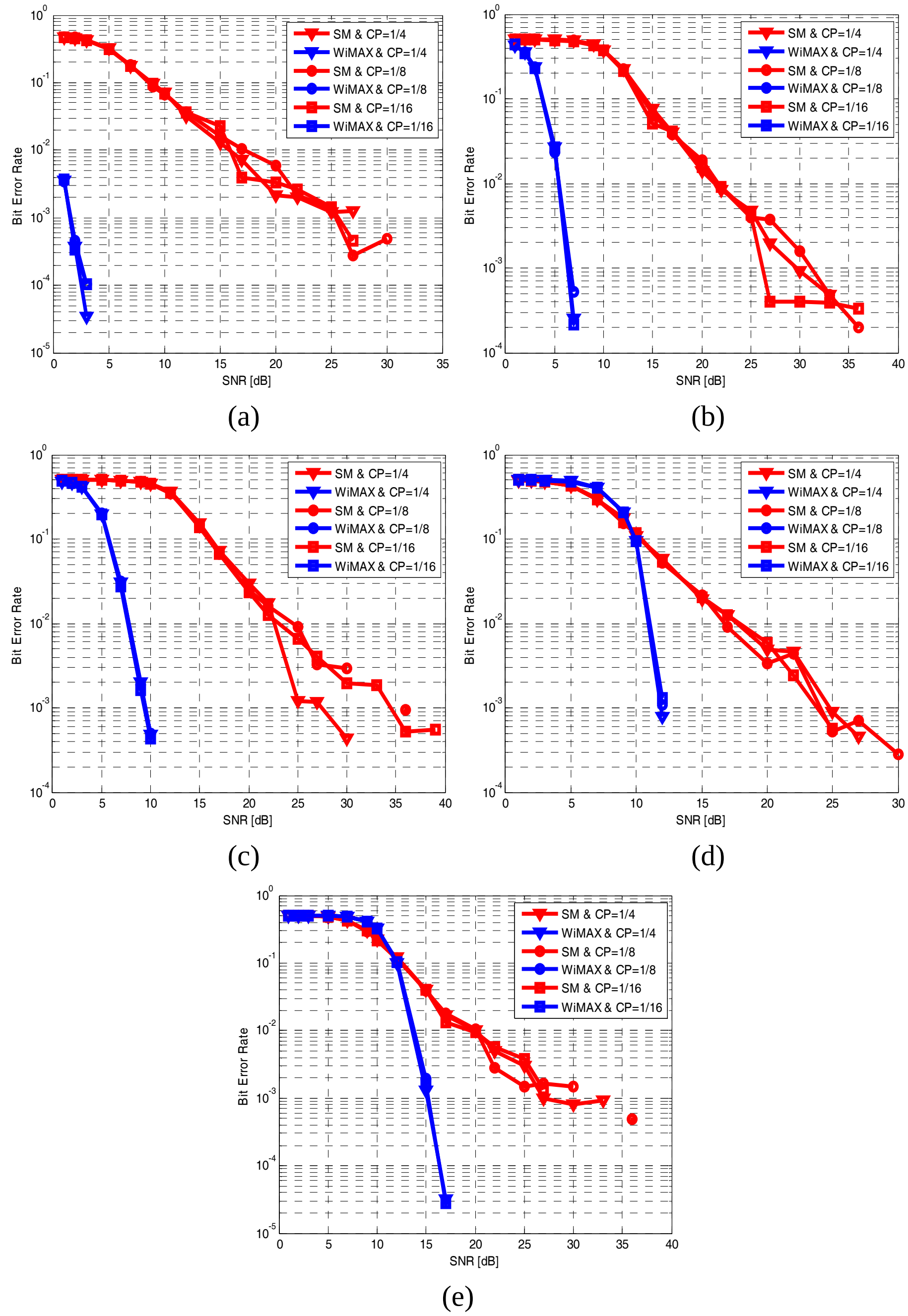
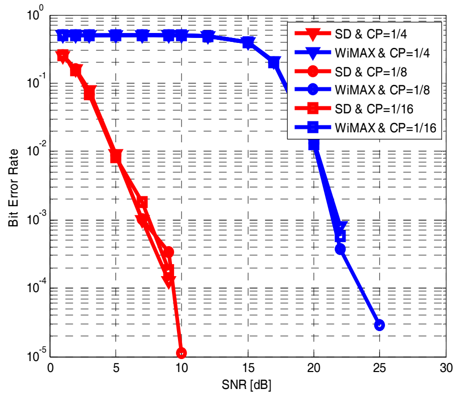
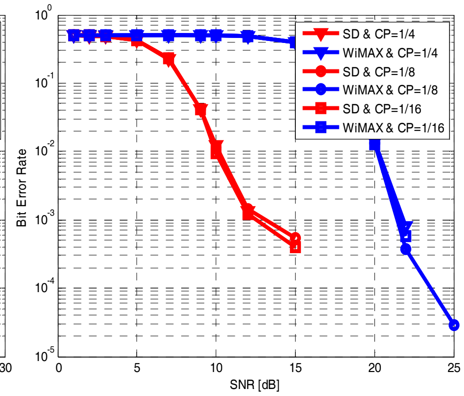


Figure 5. BER vs. SNR of spatial multiplexing vs. conventional WiMAX for (a) BPSK1/2, (b) QPSK1/2, (c) QPSK1/4, (d) 16-QAM1/2, (e) 16-QAM3/4.

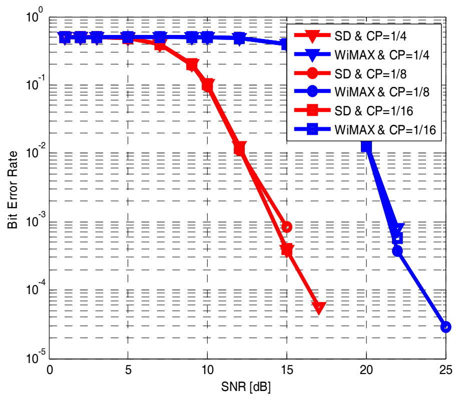
5.2. Spatial diversity-WiMAX vs. conventional WiMAX

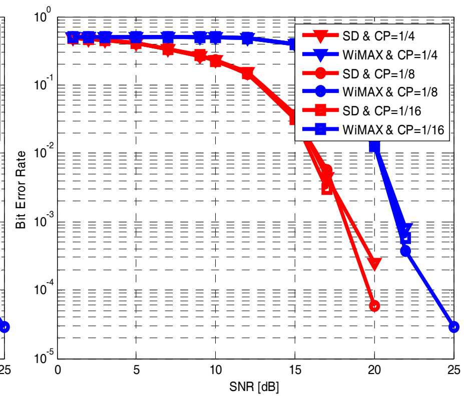
Performance analysis of spatial diversity augmented WiMAX, and conventional WiMAX has been shown in Figure 6. In these simulations, various modulation rates i.e. BPSK1/2, QPSK1/2, QPSK1/4, 16-QAM1/2 and different cyclic prefix values i.e. 1/4, 1/8, 1/16 are taken into consideration. The results are simulated in Rayleigh environment. For the spatial diversity Alamouti scheme with two transmit antennas and two receiving antennas i.e. Ntx = Nrx = 2 is considered. Overall results showed that BER is decreasing in the case of spatial diversity augmented WiMAX in comparison to conventional WiMAX. But, this decrease in BER is at the expense of increased system complexity due to the use of 2 antennas for transmitting the same information as compared to conventional WiMAX where only 1 antenna is used at both transmitter and receiver side. In the case of spatial diversity augmented WiMAX, to achieve the same BER approximately 15 dB less SNR is required in comparison to conventional WiMAX.



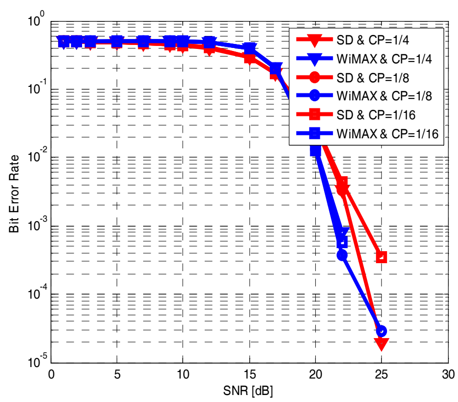


(a) (b)





(c) (d)



(e)

Figure 6. BER vs. SNR of spatial diversity vs. conventional WiMAX for (a) BPSK1/2, (b) QPSK1/2, (c) QPSK1/4, (d) 16-QAM1/2, (e) 16-QAM3/4.

6. Conclusion

This paper demonstrates that the overall performance of WiMAX can be improved if MIMO techniques are used along with it. Results are highlighted in BER vs. SNR format using different convolution code rates and different modulation techniques under the Rayleigh channel model with spatial diversity and spatial multiplexing augmented WiMAX compared with conventional WiMAX technique. It can be seen from the simulation results that in the case of spatial diversity, it offers high diversity gain and reliability i.e. less BER as compared with WiMAX and more throughput in case of spatial multiplexing having high BER when compared with WiMAX. Any one of the above-mentioned techniques i.e. spatial multiplexing or spatial diversity will be appended with WiMAX to enhance its performance in terms of capacity or reliability.

References

[1] P. Banelli and S. Cacopardi, Theoretical analysis and performance of OFDM signal in nonlinear AWGN channels, IEEE Trans. Commun. 48 (2000), 430-441.

[2] B. Chen and H. Wang, Maximum likelihood estimation of OFDM carrier frequency offset, IEEE International Conference on Communications, California, 2002, pp. 49-53.

[3] E. Bighieri, A. Goldsmith, B. Muquet and H. Sari, Diversity, interference cancellation and spatial multiplexing in MIMO mobile WiMAX systems, IEEE Mobile WiMAX Symposium, 2007, pp. 74-79.

[4] Q. Li, X. E. Lin and J. Zhang, MIMO precoding in 802.16e WiMAX, J. Commun. Networks 9 (2007), 141-149.

[5] K. P. Maré and B. T. Maharaj, Performance analysis of modern space-time codes on a MIMO-WiMAX platform, IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, France, 2008, pp. 139-144.

[6] S. P. Alex and L. M. A. Jalloul, Performance evaluation of MIMO in IEEE802.16e/WiMAX, IEEE J. Selected Topics in Signal Processing 2 (2008), 181-190.

[7] S. Sezginer, H. Sari and E. Biglieri, A comparison of full-rate full-diversity 2x2 space-time codes for WiMAX systems, IEEE 10th International Symposium on Spread Spectrum Techniques and Applications, 2008, pp. 97-102.

[8] R. Kobeissi, S. Sezginer and F. Buda, Downlink performance analysis of full-rate STCs in 2x2 MIMO WiMAX systems, IEEE 69th Vehicular Technology Conference, 2009, pp. 1-5.

[9] C. Mehlführer, S. Caban, J. A. García-Naya and M. Rupp, Throughput and capacity of MIMO WiMAX, Conference Record of the Forty-third Asilomar Conference on Signals, Systems and Computers, 2009, pp. 1426-1430.

[10] K. Tan, J. H. Andrian, H. Zhu, F. M. Candocia and C. Zhou, A novel spectrum encoding MIMO communication system, Wireless Personal Communications 52(1) (2010), 147-163.

[11] M. S. Murty, D. Veeraiah and A. S. Rao, Performance evaluation of Wi-Fi comparison with WiMAX networks, Inter. J. Distributed and Parallel Systems 3(1) (2012), 321-328.

[12] V. Tilwari and A. S. Kushwah, Performance analysis of Wimax 802.16e physical layer using digital modulation techniques and code rates, Inter. J. Eng. Res. Appl. (IJERA) 3(4) (2013), 1449-1454.

[13] M. Hemalatha, V. Prithviraj, S. Jayalalitha and K. Thenmozhi, Space diversity knotted with WiMAX-a way for undistorted and anti-corruptive channel, Wireless Personal Communications 71(4) (2013), 3023-3032.

[14] H. Zerrouki and M. Feham, A physical layer simulation for WiMAX MIMO-OFDM system: throughput comparison between 2×2 STBC and 2×2 V-BLAST in Rayleigh fading channel, International Conference on Multimedia Computing and Systems, Morocco, 2014, pp. 757-764.

[15] S. Divya, H. A. Kumar and A. Vishalakshi, An improved spectral efficiency of WiMAX using 802.16G based technology, International Conference on Advanced Computing and Communication Systems, Coimbatore, 2015, pp. 1-4.

[16] K. Yang, N. Yang, C. Xing, J. Wu and J. An, Space-time network coding with antenna selection, IEEE Trans. Vehicular Tech. 65(7) (2016), 5264-5274.

[17] C. L. Wang and K. Y. Chu, An improved transceiver design for two-relay SFBC-OFDM cooperative relay systems, IEEE 83rd Vehicular Technology Conference (VTC Spring), Nanjing, 2016, pp. 1-5.