Scientific Journal of Impact Factor (SJIF) : 3.134

ISSN (Print): 2348-6406
ISSN (Online): 2348-4470

International Journal of Advance Engineering and Research Development

MIMO PERFORMANCE ON Wi-MAX NETWORKS FOR DIFFERENT MODULATION SCHMES

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Abstract*- A detailed study of the performance of MIMO-OFDM transmission on Wi-MAX physical layer specified in IEEE 802.16-2004 has been carried out using MATLAB Simulink. In order to combat the temporal variations in quality on a multipath fading channel adaptive modulation and coding techniques are used. This technique employs multiple modulation and coding schemes to instantaneously adapt to variations in the channel SNR, thus maximizing the system throughput and improving BER performance. The Wi-MAX system incorporates Reed-Solomon (RS) encoder with Convolution encoder with 1/2 and 2/3 rated codes in FEC channel coding. Orthogonal Frequency Division Multiple (OFDM) accesses use adaptive modulation technique such as BPSK, QPSK and 16-QAM, on the physical layer of Wi-MAX and the concept of cyclic prefix that adds additional bits at the transmitter end. The simulation results of estimated Bit Error Rate (BER) show that the implementation of interleaved RS code (255, 239, 8) with 2/3 rated Convolution code under BPSK modulation technique is found to be highly effective for Wi-MAX communication system. The Implementation of MIMO systems on Wi-MAX networks show that there is an significant improvement in SNR ~3 dB at BER~10^{-3} for BPSK modulation exhibiting a lowest value for SNR ~9 dB.*

Keywords*- Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Phase Shift Keying (PSK), Quadrature Amplitude modulation (QAM), Bit Error Rate (BER), Signal to Noise Ratio (SNR), Additive White Gaussian Noise (AWGN), Line-of-Sight (LoS),Reed-Solomon (RS), Forward Error Correction (FEC), Worldwide interoperability for Microwave Access (Wi-MAX), Subscriber Station (SS), Base Station (BS).*

I. INTRODUCTION

Antenna diversity, also known as space diversity, is one of the several wireless diversity schemes that use two or more antennas to improve the quality and reliability of a wireless link. Often, especially in urban and indoor environments, there is no clear line of sight (LOS) between transmitter and receiver. Instead the signal is reflected along multiple paths before finally being received.

Antenna diversity is especially effective at mitigating these multipath situations. This is because multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Thus, if one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Collectively such a system can provide a robust link.

In radio, Multiple-Input Multiple-Output (MIMO), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, Wi-MAX and HSPA+ [2,8,9,15].

Conventional high-speed broadband solutions are based on wired-access technologies such as Digital Subscriber Line (DSL). This type of solution is difficult to deploy in remote rural areas, and furthermore it lacks support for terminal mobility. Mobile Broadband Wireless Access (BWA) offers a flexible and cost-effective solution to these problems. The IEEE Wi-MAX / 802.16 is a promising technology for broadband wireless metropolitan area networks (WMANs) as it can provide high data rates (up to 100 mbps), extended coverage (up to 50 km) for fixed and mobile users (5-15 km), network scalability, security& support of quality of services. It provides a wireless backhaul network that enables high speed internet access to residential, small and medium business customers, as well as internet access for Wi-Fi hot spots and cellular base stations. It supports both point to multipoint (p2mp) and multipoint-to multipoint (mesh) modes. Hence Wi-MAX will connect rural areas in developing countries as well as underserved metropolitan areas [1,4,5,20].

Mobile Wi-MAX supports full mobility, nomadic and fixed systems. In this paper, we focused on Wi-MAX and physical layer simulation. The basic concept of Wi-MAX including its standards and relationship with other technologies is analyzed. A model for simulating Wi-MAX physical layer using Simulink in MATLAB is presented. Finally, performance of the system implementation with different SNR is tested and BER Vs SNR curves are plotted [6,7].

II. MIMO SYSTEM

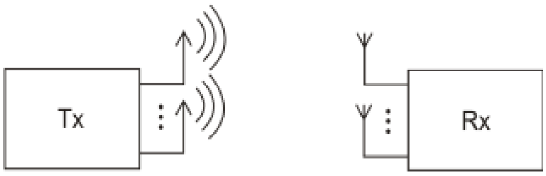

Fig. 1: A MIMO System

Single Input Single Output (SISO), Single Input multiple Output (SIMO) and Single Input Multiple Output (SIMO) system are basically the basis and origin of MIMO. Foschini and others at Bell Labs thought of using multiple antennas at both sides of the basic communication model i.e. the transmitter and the receiver. Successfully they achieved better performance than the diversity at transmitter and receiver. This increased the channel capacity (bits per channel use) and improved the throughput along with the expected rate. The probability that a signal is deep in fade is thus reduced to a certain level. The complexity is though little greater than SISO but the fact that the trade-off is acceptable arises because the complexity is less than the performance achieved in return. MIMO technology constitutes a breakthrough in wireless communication system design. It exploits the multipath phenomenon. Thus a MIMO system offers spectral efficiency as compared to SISO, MISO and SIMO. So within the limited bandwidth and limited power the capacity is increased. QoS (Quality of Signal) becomes better when MIMO is used. MIMO also helps to increase system speed when different data streams are used at different antennas. To characterize a MIMO system; with m transmit antennas and n receive antennas, the channel response or the propagation matrix is given by,

$$H(t) = \begin{pmatrix} h_{1,1}(t) & \cdots & h_{1,m}(t) \\ \vdots & \ddots & \vdots \\ h_{n,1}(t) & \cdots & h_{n,m}(t) \end{pmatrix}$$

Generic Propagation Matrix (H)

In general the overall channel impulse response of a MIMO system can be described by nxm matrix which is known as the propagation matrix, where n is the number of receiving antennas and m is the number of transmitting antennas [2,8,15].

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) has grown to be the most popular communication system in high speed communication in the last decade. In fact, it has been said that OFDM technology is the future of wireless communication. OFDM was first proposed as a way of dealing with multipath. One of the problems with single carrier modulations (SCM) is that in a given environment, the symbol interval becomes much shorter than the delay spread as the symbol rate is increased. With multi-carrier modulation formats the symbol rate is decreased and the number of carriers is increased. The basic idea is that if a signal is sent over multiple low-rate carriers instead of a single high-rate carrier then inter-symbol interference (ISI) is eliminated and multipath effects can be compensated with a much simpler equalizer. As a modulation format, OFDM is very flexible in that it can be easily scaled to meet the needs of a particular application. For applications like VOFDM, the lack of ISI also greatly simplifies the implementation of diversity reception. BWIF (uplink), 802.11A and Hyperlan/II are unique in that the OFDM is pulse modulated. While the specifics of BWIF are proprietary, the impact on WLAN products is the need for special synchronization techniques [16,18].

IV. IEEE 802.16 Wi-MAX PROTOCOL LAYERS

The IEEE 802.16 standard is structured in the form of a protocol stack with well-defined interfaces.

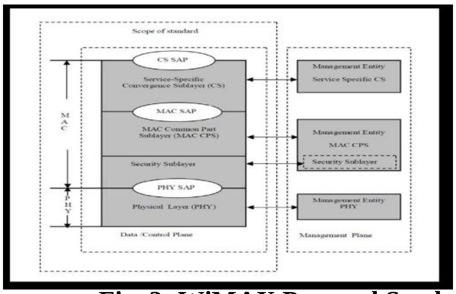

Fig. 2: WiMAX Protocol Stack

MAC LAYER

The Primary work of the MAC layer is to increase the performance by accommodating multiple physical layer specifications and their services, addressing the needs for different environments. It is generally designed to work with point-to-multipoint networks, through a base station that control independently. Access and resource allocation algorithms can be capable to carry hundreds of terminals on a single channel, terminals; that may be shared by multiple users. Therefore, the MAC protocol defines how and when a BS or a subscriber station may enlighten the transmission. At the time of downlink there is only one user, and the MAC protocol is quite simple using TDM to multiplex the data. In uplink, when more than one SS contend for accessing the channel, then MAC layer protocol provide a mechanism that is a TDMA technique, thus providing an efficient use of the bandwidth.

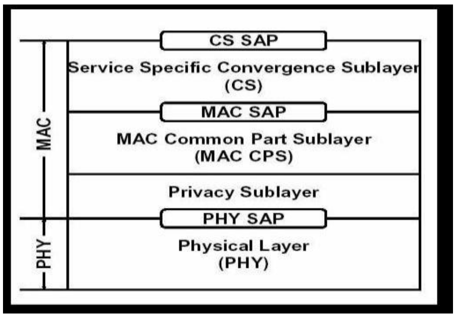

Fig. 3: WiMAX Physical and MAC layer architecture

PHYSICAL (PHY) LAYER

Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. It also defines the type of modulation and demodulation as well as transmission power. Wi-MAX 802.16 PHY-layer considers two types of transmission techniques OFDM and OFDMA. Both of these techniques have frequency band below 11 GHz and use TDD and FDD as its duplexing technology. Wi-MAX physical layer is based on the orthogonal frequency division multiplexing (OFDM). OFDM is a good choice of high speed data transmission, multimedia communication and digital video services. It even can maintain very fast data rate in a non-line of sight condition and multipath environment.

V. MIMO-OFDM IMPLEMENTATION ON Wi-MAX PHY LAYER

The Model of the WiMAX physical layer is built from the IEEE standard documentation. The model is built under the defined parameters. The modeling is created on Matlab 7.9.0 (R2009b), Simulink 9 in Windows XP SP2/Windows 7 operating system. Matlab 7.9.0 (R2009b) Simulink consist all the mandatory source blocks as from the standard documents. The Model includes three main components namely transmitter, channel and receiver. Transmitter consists of channel coding, modulation and sub-components whereas channel is modulated on AWGN and Multipath Rayleigh Fading channel [4,12,13,21].

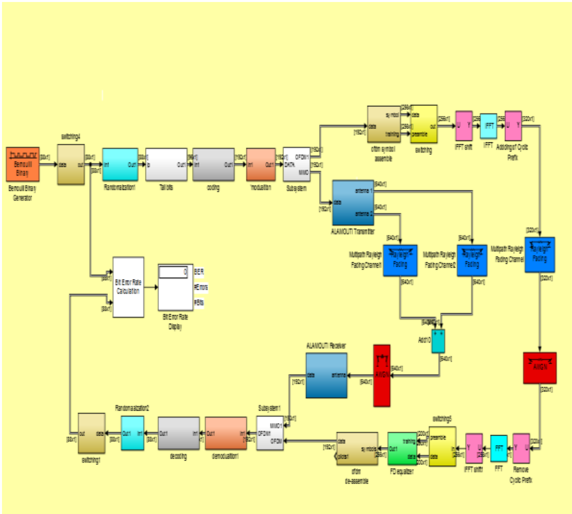

Fig. 4: Simulink Implementation

TRANSMITTER

This section contains the different steps of the transmitter which should be performed before transmitting the data. The blocks representations of the Wi-MAX transmitter simulator are as shown in figure 5.

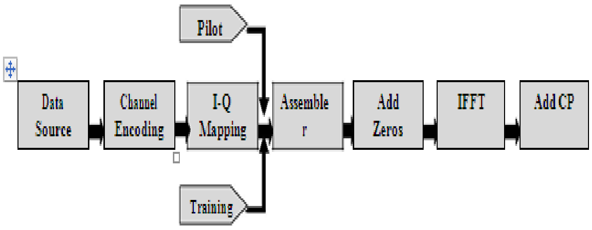

Fig.5: Transmitter of the Wi-MAX system

The data source is generated from the source is randomized, coded and mapped into QAM symbols. The PHY layer uses OFDM with 256 subcarriers. Each OFDM symbol is composed of 192 data subcarriers, one DC subcarrier, eight pilot subcarriers, and fifty five guard carriers. So, the procedure of collecting the zero DC subcarrier, data, and pilots is needed to build the symbols. Moreover, preambles consist of training sequences that would be appended at the starting on each burst. These training sequences are used for analyzing the channel estimation.

RANDOMIZER

The Randomizer performs randomization of input data on each burst on each allocation to avoid long sequence of continuous ones and zeros. This is implemented with a Pseudo Random Binary Sequence (PRBS) generator which uses a 15stage shift register with a generator polynomial with XOR gates in feedback configuration as shown in Fig. 6.

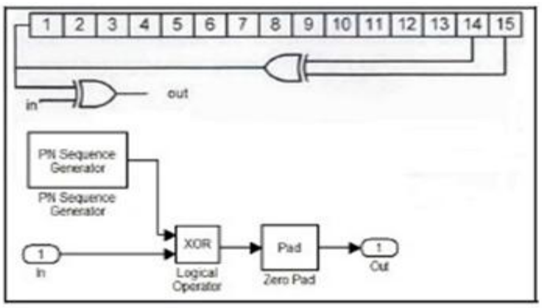

Fig. 6: Randomizer

REED-SOLOMON ENCODER

The encoding process for RS encoder is based on Galois Field Computations to do the calculations of the redundant bits. Galois Field is widely used to represent data in error control coding and is denoted by GF .WIMAX uses a fixed RS Encoding technique based on GF(28) which is denoted as RS(N = 255, K = 239, T = 8)

Where: N = Number of Byte, T = Number of bytes corrected

Eight tail bits are added to the data just before it is presented to the Reed Solomon Encoder stage. This stage requires two polynomials for its operation called code generator polynomial g(x) and field generator polynomial p(x). The code generator polynomial is used for generating the Galois Field Array whereas the field generator polynomial is used to calculate the redundant information bits which are appended at the start of the output data. These polynomials are defined by the standard as below:

Code Generator Polynomial:

p(x)=x8+x4+x3+x2+1

Field Generator Polynomial:

g(x) = (x +λ.0) (x +λ.1) (x +λ 2) (x +λ3)

The properties of Reed-Solomon codes make them suitable to applications where errors occur in bursts.

Reed-Solomon error correction is a coding scheme which works by first constructing a polynomial from the data symbols to be transmitted, and then sending an oversampled version of the polynomial instead of the original symbols themselves. A Reed-Solomon code is specified as RS (n, k, t) with l-bit symbols which means that the encoder takes k data symbols of l bit each and adds 2t parity symbols to construct an n- symbol code word. Thus, n, k and t can be defined as: n: number of bytes after encoding; k: number of data bytes before encoding, and t: number of data bytes that can be corrected. The error correction ability of any RS code is determined by (n − k), the measure of redundancy in the block.

CONVOLUTION ENCODER

The outer RS encoded block is fed to inner binary Convolution encoder. Convolution codes are used to correct the random errors in the data transmission. A convolution code is a type of FEC code that is specified by CC (m, n, k), in which each m-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code.

PUNCTURING PROCESS

Puncturing is the process of systematically deleting bits from the output stream of a low-rate encoder in order to reduce the amount of data to be transmitted, thus forming a high-rate code. The process of puncturing is used to create the variable coding rates needed to provide various error protection levels to the users of the system. The different rates that can be used are rate 1/2, rate 2/3, rate 3/4, and rate 5/6.

Table 1: Puncture bits

Rate	Puncture vector
1/2	[1]
2/3	[1110]
3/4	[110110]
5/6	[1101100110]

RSCC encoded data are interleaved by a block interleave. The size of the block depends on the numbers of bit encoded per sub channel in one OFDM symbol, N_{cbps}.

MODULATION

Modulation depending on their size and on the basis of different modulation schemes like BPSK, grey mapped QPSK, and the modulation is done on the basis of incoming bits by dividing among the groups of i. Hence there are 2i points. The total number of bits is represented according to constellation mapped to different modulation techniques. The size for BPSK, QPSK, and 16 QAM is 1, 2, 4 and 16 respectively. Guard band, pilot carriers and DC carrier are inserted in the structure before using the IFFT to convert the frequency domain signals into time domain.

INVERSE FFT

The OFDM symbol treats the source symbols to perform frequency-domain into time domain. If N number of subcarriers is chosen for the system to evaluate the performance of Wi-MAX, the basic function of IFFT receives the N number of sinusoidal and N symbols at a time.

CYCLIC PREFIX INSERTION

To maintain the frequency orthogonal and reduce the delay due to multipath propagation, cyclic prefix is added in OFDM signals. Before transmitting the signal, CP is added at the beginning of the signal. The ISI is totally eliminated by the design when the CP length L is greater than multipath delay. The receiver blocks are basically the inverse of the transmitter blocks. When communicating over a wireless radio channel the received signal cannot be simply modelled 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.

VI. RESULTS AND DISCUSSIONS

The slope of the BER curves is an indicator of the degree of diversity that has been achieved. The degree of diversity is defined as the performance improvement in BER, in terms of power of ten, for a 10 dB higher SNR. As can be observed, the curve for the SISO (1×1) system improves its error probability with a factor 10, i.e. power of 1 for a 10 dB rise in SNR. In this case, the degree of diversity is said to be equal to one, i.e. no diversity at all. However, when simulating with a SIMO (1×2) or MISO (2×1) system, which have diversity order of two, better performance is achieved. Likewise, the degree of diversity achieved with the MIMO (2×2) system is of order four.

The results of the performance of MIMO-OFDM system on Wi-MAX physical layer for different digital modulation techniques BPSK, QPSK, and 16-QAM for Rayleigh channel are derived using MATLAB simulation. The BER values as a function of SNR are determined for different MIMO-OFDM system (SISO, SIMO, MISO, MIMO) on Wi-MAX physical layer with different modulation schemes for studying their relative performances for digital modulation. The SNR values are determined as a function of BER for each BPSK, QPSK and 16-QAM modulation schemes. The bit-error-rate performances derived as a function of SNR for different MIMO-OFDM multiplexing system on Wi-MAX physical layer are shown in Fig. 7 for BPSK modulation, Fig. 8 for QPSK modulation and Fig. 9 for 16- QAM modulation. The parameters are coding rate 1/2, Bandwidth 10MHz, convolution coding 2/3, interleaving [1;1;0;1], FFT size 256, channel 16, simulation 50,000 bits, Noise AWGN.

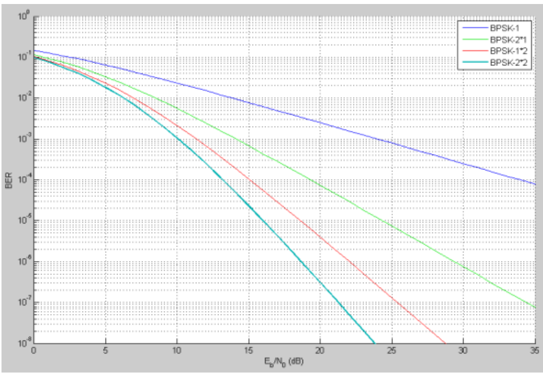

Fig. 7: SNR Vs BER performance analysis in Wi-MAX networks for BPSK modulation

It is seen from Fig. 7 that the BER values decreases as SNR increases for all the four types of MIMO systems. The figure indicates that at BER ~10^{-3}, the SISO (1x1) shows that the SNR ~23.5 dB, MISO (2x1) SNR ~14.5 dB, SIMO (1x2) SNR ~11 db and MIMO (2x2) SNR ~9 dB can be achievable for the BPSK modulation. Further the figure shows that there is a large improvement in SNR from SISO to MIMO system ~ 14.5 dB The result clearly demonstrates that at BER ~10^{-3} the SNR values are found to be lowest ~9 dB for 2x2 MIMO system compared to other MIMO systems suggesting that for BPSM modulation the 2x2 MIMO systems are more efficient for MIMO-OFDM implementation on Wi-MAX networks.

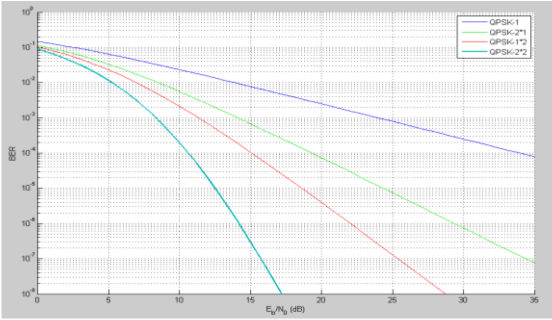

Fig.8: SNR Vs BER performance analysis in Wi-MAX networks for QPSK modulation

It is seen from Fig. 8 that the BER values decreases as SNR increases for all the four types of MIMO systems. The figure indicates that at BER ~10^{-3}, the 1x1 shows that the SNR ~24.2 dB, 2x1 SNR ~14.6 dB , 1x2 SNR ~11.5 db and 2x2 SNR ~9.5 dB can be achievable for the QPSK modulation. Further the figure shows that there is a large improvement in SNR from SISO to MIMO system ~ 14.7 dB The result clearly demonstrates that at BER ~10^{-3} the SNR values are found to be lowest ~9.5 dB for 2x2 MIMO system compared to other MIMO systems suggesting that, even in case of QPSK modulation the 2x2 MIMO systems are more efficient for MIMO-OFDM implementation on Wi-MAX networks.

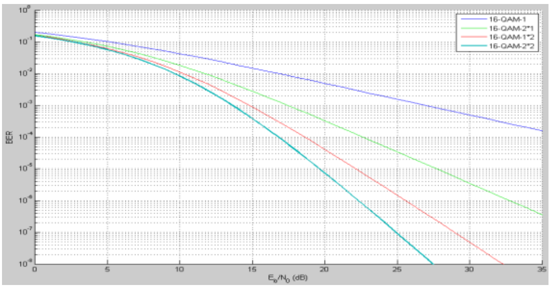

Fig.9: SNR Vs BER performance analysis in WiMAX networks for 16-QAM modulation

It is seen from Fig. 9 that the BER values decreases as SNR increases for all the four types of MIMO systems. The figure indicates that at BER ~10^{-3}, the 1x1 shows that the SNR ~26.5 dB, 2x1 SNR ~17 dB, 1x2 SNR ~14.8 db and 2x2 SNR ~13.4 dB can be achievable for the 16-QAM modulation. Further the figure shows that there is a large improvement in SNR from SISO to MIMO system ~ 12.5 dB The result clearly demonstrates that at BER ~10^{-3} the SNR values are found to be lowest ~ 13.4 dB for 2x2 MIMO system compared to other MIMO systems suggesting that even in case of 16 – QAM modulation the 2x2 MIMO systems are more efficient for MIMO-OFDM implementation on Wi-MAX networks.

The performance of SNR Vs. BER for 2x2 MIMO-OFDM system for BPSK modulation with and without implementation on Wi-MAX network are tabulated and compared in the following table 2 [22].

Table-2- Comparison of MIMO Systems with and without implementation network, SNR Values for different modulation techniques for BER ~10^{-3}

MIMO-OFDM	**BPSK (dB)**	**QPSK (dB)**	**16-QAM (dB)**
Without implementation on Network	12.5	12.9	13.6
With implementation on Network	9	10	13.4

It is clearly evident from the Table 2 that at BER ~10^{-3}, the SNR values increase with increasing modulation from BPSK to QPSK modulation as expected. Further the table shows that implementation of the MIMO-OFDM transmission on Wi-MAX networks for BPSK modulation there is a significant improvement in SNR ~3 dB The SNR values are found to be lowest ~9 dB for Wi-MAX networks. The result of the analysis indicates that the 2x2 MIMO system implementation on Wi-MAX networks offers better performance

VII. CONCLUSIONS

It can be concluded from the results presented that,
1. The results indicate that the MIMO-OFDM system implementation on Wi-MAX networks show that at BER ~10^{-3}, the SNR values increases by >12 dB between SISO to MIMO system and indicates in every case the lowest values of SNR for 2x2 MIMO system.
2.The MIMO-OFDM system implementation on Wi-MAX networks shows that at BER ~10^{-3} for the 2x2 MIMO system the SNR increases with modulation schemes from BPSK to 16- QAM modulation is in accordance with theory.
3. The implementation of 2x2 MIMO on Wi-MAX networks shows significant improvement in SNR ~3 dB at BER 10^{-3} for BPSK modulation with the lowest achievable value for SNR ~9 dB.
4. It can be concluded from the simulation studies that 2x2 MIMO-OFDM transmission system on Wi-MAX networks offers better SNR performances for BPSK modulation.

ACKNOWLEDGEMENT

We wish to acknowledge the support given by Principal, RV College of Engineering, Bangalore for carrying out the present research work and HoD Department of Telecommunication for constant encouragement.

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