IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

**International Journal of Digital Application & Contemporary Research**
**Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)**

# BER Performance of WiMAX System using Discrete Cosine Transform

Sheena S Mary
M. Tech. Scholar
Electronics & Communication Engineering
Choukesy Engineering College, Bilaspur, C.G. (India)
sheenamary37@gmail.com

Rahul Gedam
Head of Dept.
Electronics & Communication Engineering
Choukesy Engineering College, Bilaspur, C.G. (India)
engg.rahul2801@gmail.com

*Abstract* –**This paper presents simulation of the OFDM Physical layer specification of IEEE 802.16. Performance analysis of higher data rate is analysed with changing the different modulation techniques using Discrete Cosine Transform (DCT). Forward error correction codes (Reed Solomon and Convolution code) are implemented to improve the BER under higher data rate. The performance analysis is recorded based on the simulation results of Bit-Error-Rate (BER) and Signal-to-Noise Ratio (SNR). The simulation of above mentioned system is done by MATLAB 2014a.**

*Keywords* –**BER, DCT, ETSI, NLOS, OFDM, SNR, WiMAX.**

## I. Introduction

WiMAX (Worldwide Interoperability for Microwave Access) is the trade name of a group of wireless technologies that emerged from the WirelessMAN family of standards. Specifically, in 2001 the WiMAX Forum was created to promote the standard and to help ensure compatibility and interoperability across multiple vendors, something similar to what the Wi-Fi Alliance does for the IEEE 802.11 family of standards X and have become a key facet of the IEEE standards process. Although the term WiMAX is only a few years old, the 802.16 standard has existed since the late 1990s, first with the adoption of the 802.16 (10-66GHz) standard in April 2002 and then with the 802.16a (2-11GHz) In January 2003. Despite the establishment of the 802.16a standard, it never ceased to take off in the market, although it is worth mentioning that during that period the entire telecommunications industry was struggling [1].

Thus, in principle, this 802.16 standard focused specifically on the efficient use of bandwidth, in the region between 10GHz and 66GHz and defined a medium access control layer capable of supporting multiple physical layer specifications , Developed for the use of this frequency band. Shortly afterwards, not even a year had passed, the first revision of the standard was carried out in order to incorporate an additional branch, called 802.16a, to cover the frequency range of 2GHz to 11GHz and contemplates the use Of two modulation techniques, OFDM and OFDMA. In the same way, successive and significant improvements have also been introduced in the following years. In summary, version d of the IEEE 802.16 standard, 802.16-2004 (previously known as Revision D, or 802.16d), was ratified in July 2004 and includes earlier versions (802.16-2001, 802.16b / c 2002, and 802.16a in 2003) and covers both direct line of sight (LOS) and non-line of sight (NLOS) links in the 2-66GHz frequency range. As is customary in the IEEE standards, only the specifications of the PHY (Physical) and MAC (Media Access Control) layers are regulated. The changes introduced in the 802.16-2004 standard were aimed at the development of interoperability applications in the frequency range of 2-11GHz [2].

Thus, the current WiMAX systems are based primarily on two specifications, the IEEE 802.16-2004 standard and the ETSI (European Telecommunications Standards Institute) Hyperman standard. Two similar approaches have been called BWA (Broadband Wireless Access) technology. The differentiation of both is tremendously important for a reason. The first is oriented to communications in which the sending and receiving stations have a direct line of sight, something similar to what happens with the infrared emissions of the remote controls. In the second, the frequency bands used allow communication to be maintained without both ends being directly facing each other, and there may even be all kinds of obstacles that do not impede the transmission of data, as with existing Wi-Fi networks or with technology Bluetooth [3].

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)

Although the official publication of the 802.16-2004 standard laid the foundations for the initial deployment of the new wireless broadband access technology, WiMAX's final expectations go beyond being a wireless ADSL type system for urban and rural environments. Indeed the promoters of this project pursue the ambitious goal that WiMAX is the wireless technology that unifies the world of mobile telephony and data networks. To this end, in December 2002, the IEEE 802.16e Working Group was created to improve and optimize support for combining both fixed and mobile communication capabilities at frequencies below 6GHz. Complying with the scheduled schedule, on December 7, 2005, the official ratification of the new Mobile WiMAX standard (802.16e) was carried out. The new version of the standard introduces support for SOFDMA technology (a variation of the OFDMA modulation technique) which allows a variable number of carrier waves to be added to the existing OFDM and OFDMA modes. In addition, IEEE 802.16e offers enhanced support for MIMO (Multiple Input Multiple Output) and AAS (Adaptive Antenna Systems) technologies. It also includes enhancements for optimizing power consumption for mobile devices and decreasing it with the size or the CPE (Customer Premise Equipment) modem, as well as extensive security features [4].

Finally, there are also the IEEE 802.16f and IEEE 802.16g working groups that are responsible for the fixed and mobile operation management interfaces [5].

This paper analyses OFDM Physical layer specification of IEEE 802.16. Performance analysis of higher data rate is analysed with changing the different modulation techniques using Discrete Cosine Transform (DCT).

## II. PROPOSED METHOD

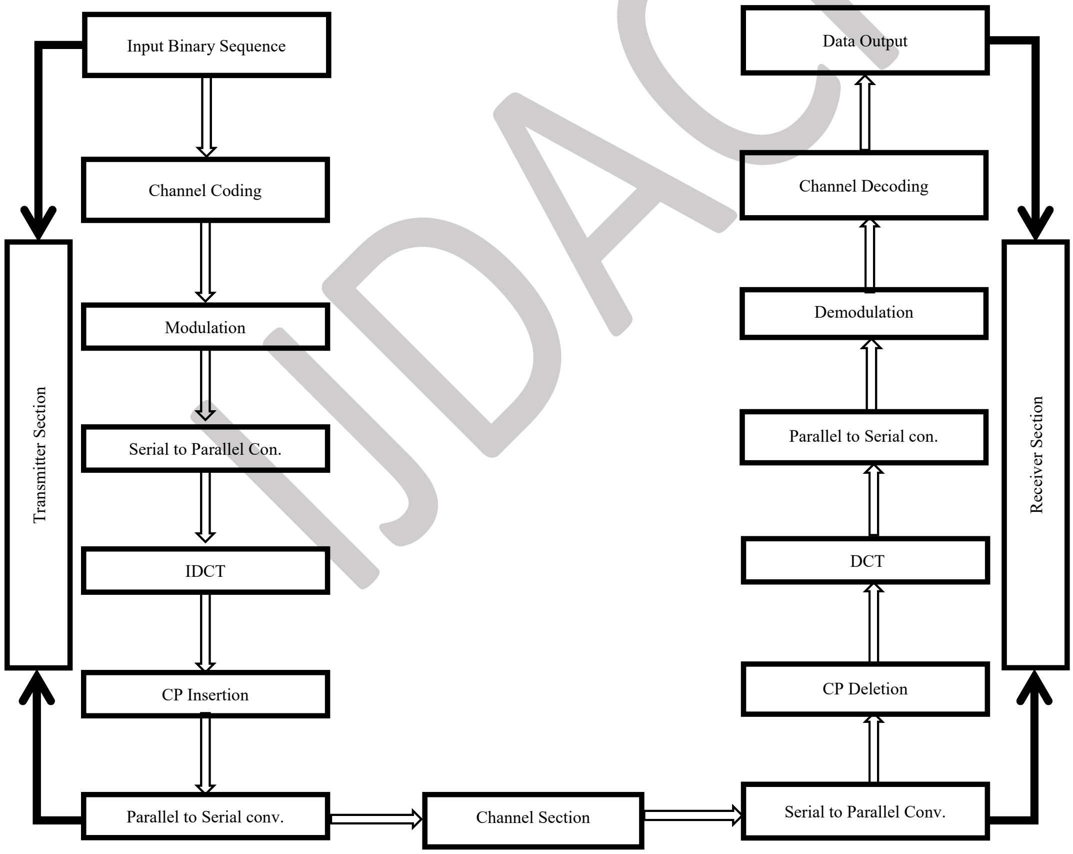


Figure 1: Flow diagram for proposed work

As per the flow diagram, it is clear that there are three sections namely; transmitter section, channel section and receiver section. In transmitter section, binary sequence is inserted as input data, then channel encoding is done using convolution coding and turbo codes. Modulated is done in the next section. After that serial to parallel conversion is done. Then IDCT is applied on parallel data stream.

IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)

Cyclic prefix (CP) is added to the output of IDCT section. After CP insertion, data is again converted from parallel to serial stream. This data is transferred through channel section. At the receiver section the reverse process of transmission section is applied to get the data from the data output.
A Cyclic Prefix (CP), which is a copy of the last part of the samples is appended to the front of the serial data stream before Radio Frequency (RF) up conversion and transmission. The CP combats the disrupting effects of the channel which introduce Inter Symbol Interference (ISI).
In the receiver the whole process is reversed to recover the transmitted data, the CP is removed prior to the DCT which reverses the effect of the DCT. The complex symbols at the output of the DCT, $Y_0 \, .. Y_{N-1}$ are then demodulate and the original bit steam recovered.
Instead of using complex exponential functions, co-sinusoidal functions can be used as orthogonal basis to implement multi-carrier scheme [6]. This can be synthesized using discrete cosine transform (DCT). For fast implementation algorithms DCT can provide fewer computational steps than FFT based OFDM. The effect of carrier frequency offset (CFO) will introduce inter-carrier interference (ICI) in DCT-OFDM. The minimum FΔ required to satisfy Eq. (1) is 1/2T Hz.

$$\int_0^T \sqrt{\frac{2}{T}}\cos(2\pi F_\Delta t)\sqrt{\frac{2}{T}}\cos(2\pi m F_\Delta t)\,dt = \begin{cases}1, k = m\\ 1, k \neq m\end{cases} \quad (1)$$

**Channel Coding**
Channel coding is done by three steps:

- Randomization
- Forward Error Correction (FEC)
- Interleaving

***Randomization***
When the data is transmitted on the downlink and uplink then the process of andomization occurs. This is implemented with a Pseudo Random Binary Sequence (PRBS) generator which uses a 15-stage shift register with a generator polynomial of $1+x^{14}+x^{15}$ with XOR gates in feedback formation.

***Forward Error Correction (FEC)***
Forward error correction (FEC) or channel coding is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The main concept is the sender encodes their message in a repetitive way by using an error-correcting code ECC). The redundancy allows the receiver to detect a limited number of errors that may occur anywhere in the message, and often to correct these errors without retransmission. FEC gives the receiver the ability to correct errors without needing a reverse channel to request retransmission of data, but at the cost of a fixed, higher forward channel bandwidth. FEC is therefore applied in situations where retransmissions are costly or impossible, such as when broadcasting to multiple receivers in multicast. FEC information is usually added to mass storage devices to enable recovery of corrupted data. FEC improve performance of digital data by adding redundant data bit in the transmitted message.
In this research work FEC is done using the following phases:

*Reed Solomon code*
Reed–Solomon (RS) codes are non-binary cyclic error-correcting codes invented by Irving S. Reed and Gustave Solomon. They described a systematic way of building codes that could identify and correct multiple arbitrary symbol errors. By adding $t$ check symbols to the data, an RS code can detect any combination of up to $t$ erroneous symbols, and correct up to $\lfloor t/2 \rfloor$ symbols. As an erasure code, it can correct up to t known erasures, or it can detect and correct arrangements of errors and erasures. Furthermore, RS codes are suitable as multiple-burst bit-error correcting codes, since a sequence of $b+1$ successive bit errors can influence at most two symbols of size $b$. The decision of $t$ is dependent upon the architect of the code, and may be chosen inside wide limits.

In Reed–Solomon coding, source symbols are viewed as coefficients of a polynomial p(x) around a restricted field. The original idea was to create n code symbols from k source symbols by oversampling p(x) at n > k distinct points, transmit the sampled points, and use interpolation methods at the sink to improve the original message. That is not by what means RS codes are utilized today. Instead, RS codes are viewed as cyclic BCH codes, where encoding symbols are determined from the coefficients of a polynomial developed by multiplying p(x) with a cyclic generator polynomial. This gives rise to efficient decoding algorithms (described below).
Reed–Solomon codes have since found important applications from deep – space communication to consumer electronics. They are prominently used in consumer electronics such as CDs, DVDs, Blu-ray Discs, in data transmission technologies such as DSL and WiMAX, in broadcast systems such as

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)

DVB and ATSC, and in computer requisitions, for example, RAID 6 frameworks.

*Original view (transmitting points)*

The original concept of Reed–Solomon coding (Reed & Solomon 1960) describes encoding of $k$ message symbols by viewing them as coefficients of a polynomial $p(x)$ of maximum degree $k - 1$ over a finite field of order $N$, and evaluating the polynomial at $n > k$ distinct input points. Sampling a polynomial of degree $k - 1$ at more than k points creates an over determined system, and allows recovery of the polynomial at the receiver given any $k$ out of $n$ sample points using interpolation. The sequence of different points is made by a generator of the limited field's multiplicative gathering, and incorporates 0, in this way allowing any estimation of $n$ up to $N$.

Using a mathematical formulation, let $(x_1, x_2, \ldots\ldots, x_n)$ be the input sequence of $n$ distinct values over the finite field $F$; then the codebook $C$ created from the tuplets of values obtained by evaluating every polynomial (over $F$) of degree less than $k$ at each $x_i$ is:

$$C = \{(f(x_1), f(x_2), \ldots, f(x_n)) \mid f \epsilon F[x], \deg(f) < k\} \quad (2)$$

Where $F[x]$ is the polynomial ring over $F$, and $k$ and $n$ are chosen such that $1 \leq k \leq n \leq N$. As described above, an input sequence $(x_1, x_2, \ldots\ldots, x_n)$ of $n = N$ values is created as $(0, a^0, a^1, \ldots\ldots, a^{N-2})$, where $\alpha$ is a root of $F$. When omitting 0 from the sequence, and since $a^{N-1} = 1$ it follows that for every polynomial $p(x)$ the function $p(\alpha x)$ is also a polynomial of the same degree, and its codeword is a cyclic left-shift of the codeword derived from $p(x)$; consequently, a Reed–Solomon code could be observed as a cyclic code. This is followed in the standard observation of RS codes, defined consequently.

As outlined in the section on a theoretical decoder, the original view does not give rise to an effective decoding algorithm, although it indicates that such a code can work.

***Convolution Encoder***

A Convolution encoder contains a shift register that offers temporary storage and a shifting process for the input bits and exclusive-OR logic circuits which produce the coded output from the bits currently held in the shift register. In general, $k$ data bits can be shifted into the register at once, and n code bits generated. In practice, it is often the case that $k = 1$ and $n = 2$, giving rise to a rate ½ code. A rate ½ encoder illustrated in figure 2 and this is used to explain the encoding operation.

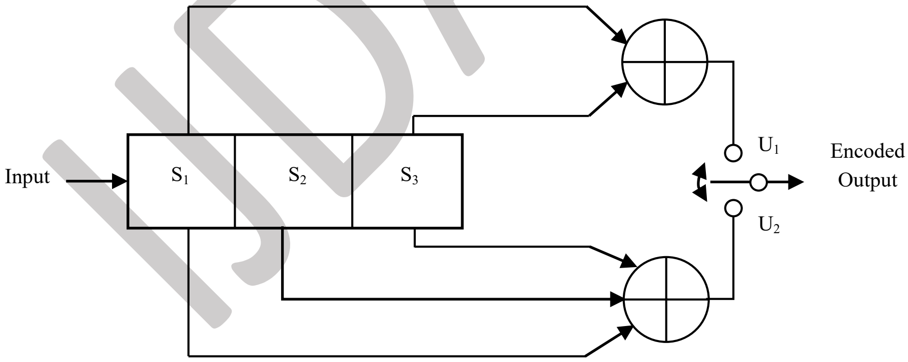


Figure 2: A ½ rated Convolution Encoder [7]

In the beginning, the shift register holds all binary 0s. The input data bits are fed in continuously at a bit rate $R_b$, and the shift register is clocked at this rate. As the input changes through the register, the rightmost bit is moved out so that there are always 3 bits held in the register. At the end of the message, three binary 0s are devoted, to return the shift to its initial condition. The commutator at the output is switched at twice the input bit rate so that two output bits are produced for every input bit shifted in. At any one time the register holds 3 bits which from the input to the exclusive-OR circuits. Convolutional codes have been extensively applied to satellite communications. In cellular mobile communication, the channel characteristics is less favourable with burst errors arising from multipath (reflection), shadowing of the signal and co-channel interference, but the necessity to achieve coding gain at the adequate target Bit Error Rates yet again dictates that convolutional codes should be used [8].

**Modulation**

Modulation is the technique by which the signal wave is transformed in order to send it over the

IJDACR
ISSN: 2319-4863

IJDACR International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)

communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique. After this, IDCT is performed on the modulated signal which is further processed by passing through a parallel to serial converter. In order to avoid ISI we provide a cyclic prefix to the signal. Following are the modulation techniques which have used in this project:

- Binary Phase-Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- Quadrature Amplitude Modulation (QAM)

**Serial to Parallel Convertor**

Information to be transmitted is regularly as a serial information stream. Serial to parallel conversion block is required to change over the input serial bit stream to the data to be transmitted in every single OFDM symbol. The information designated to every symbol relies on upon the modulation scheme utilized and the amount of subcarriers. For example, in case a subcarrier modulation of 16-QAM each subcarrier carries 4 bits of data, and so for a transmission using 100 subcarriers the amount of bits for every symbol would be 400. Throughout symbol mapping the information is changed over into complex value constellation points, as per a given constellation. Common constellations for remote provisions are, BPSK, QAM, and QAM.

The measure of information transmitted on every subcarrier relies on upon the constellation. Channel condition is the integral element for the sort of type of constellation to be utilized. In a channel with high interference a small constellation like BPSK is promising as the essential SNR in the receiver is low. For interference free channel a bigger constellation is more helpful because of the higher bit rate. Known pilot symbols mapped with known mapping plans could be embedded at this instant. Cyclic prefix is embedded in each block of information as indicated by the framework detail and the information is multiplexed to a serial design.

**Cyclic Prefix**

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is evacuated at the sink before demodulation.

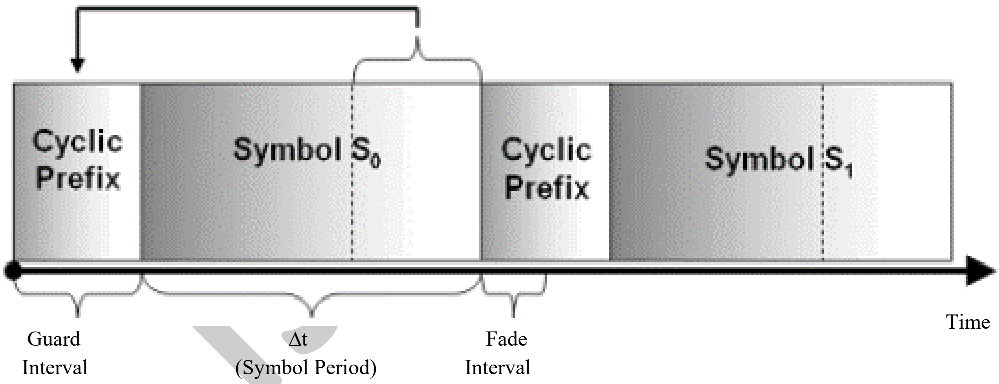


Figure 3: Cyclic Prefix

The cyclic prefix has to two important benefits –

- The cyclic prefix acts as a guard interval. It eliminates the inter-symbol interference from the previous symbol.
- It acts as a repetition of the end of the symbol thus allowing the linear convolution of a frequency – selective multipath channel to be modelled as circular convolution which in turn maybe transformed to the frequency domain. This methodology takes into consideration simple frequency – domain processing, for example, channel estimation and equalization

**Communication Channel**

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

***AWGN Channel***

The AWGN channel hypothesis consists in assuming that the set of perturbations undergone by the signal transmitted by the transmitter can be

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

**International Journal of Digital Application & Contemporary Research**
**Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)**

modeled as a single source of noise placed between the transmitter and the receiver. All of the disturbances include imperfections in electronic transmission and reception equipment (at the component level, connectivity), disturbances caused by the transmission medium (cable, air, etc.) and disturbances or interference due to the presence other systems and / or other users of the system.

### Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. DCT of the signal is done after it is made to pass through a serial to parallel converter. A demodulator is used, to get back the original signal.

The Bit Error Rate and the signal–to–noise ratio is calculated by taking into consideration the unmodulated signal data and the data at the receiving end (Sink).

## III. Simulation And Results

The performance of proposed method has been studied by means of MATLAB simulation.

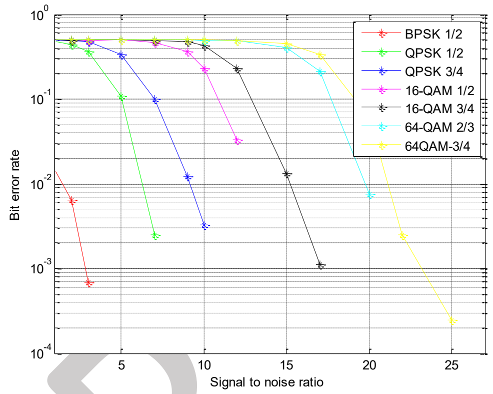


Figure 4: Comparative analysis of BER performance for WiMAX OFDM using different modulation schemes

Table 1: BER performance comparison of WiMAX OFDM for different modulation schemes

| SNR | Bit Error Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | BPSK 1/2 | QPSK 1/2 | QPSK 3/4 | 16-QAM 1/2 | 16-QAM 3/4 | 64-QAM 1/2 | 64-QAM 3/4 |
| 1 | 0.0139772727272727 | 0.477989130434782 | 0.485250000000000 | 0.499813829787234 | 0.499313380281690 | 0.498750000000000 | 0.499521028037383 |
| 2 | 0.00636363636363636 | 0.441032608695652 | 0.484500000000000 | 0.499973404255319 | 0.496320422535211 | 0.500473684210526 | 0.499929906542056 |
| 3 | 0.000681818181818182 | 0.366521739130435 | 0.471857142857143 | 0.496037234042553 | 0.499066901408451 | 0.499986842105263 | 0.499626168224299 |
| 5 | 0 | 0.107880434782609 | 0.338678571428572 | 0.498404255319149 | 0.498169014084507 | 0.499657894736842 | 0.496939252336449 |
| 7 | 0 | 0.00250000000000000 | 0.101142857142857 | 0.470239361702128 | 0.492887323943662 | 0.497263157894737 | 0.498831775700934 |
| 9 | 0 | 0 | 0.0121428571428571 | 0.363058510638298 | 0.471003521126761 | 0.500328947368421 | 0.502079439252336 |
| 10 | 0 | 0 | 0.00325000000000000 | 0.229335106382979 | 0.427411971830986 | 0.495565789473684 | 0.501285046728972 |
| 12 | 0 | 0 | 0 | 0.0328191489361702 | 0.230052816901409 | 0.488039473684211 | 0.491296728971963 |
| 15 | 0 | 0 | 0 | 0 | 0.0132218309859155 | 0.409078947368421 | 0.450058411214953 |
| 17 | 0 | 0 | 0 | 0 | 0.00110915492957746 | 0.211157894736842 | 0.334778037383178 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0.00751315789473684 | 0.0601752336448598 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00248831775700935 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000245327102803738 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## IV. Conclusion

The implementation of IEEE 802.16.e model is presented with the analysis of the capabilities of WiMAX in AWGN channel. The simulation uses MATLAB and the effect of different modulation schemes has been evaluated over OFDM system using Discrete Cosine Transform. Forward error correction code (Reed Solomon and Convolution codes) with different modulation techniques is analyzed and its performance evaluation is done with BER. On comparing the variations of the BER for different SNR in the MATLAB simulation, it is observed that the BER performance of BPSK is

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 10, May 2017)

better than QPSK, 16-QAM and 64-QAM modulation schemes.

## REFERENCE


[1] Andrews, J.G., Ghosh, A. and Muhamed, R., 2007. Fundamentals of WiMAX: understanding broadband wireless networking. Pearson Education.

[2] Prakash, G. and Pal, S., 2011. WIMAX technology and its applications. International Journal of Engineering Research and Applications (IJERA), 1(2), pp.327-336.

[3] Correia, L.M., 2010. Mobile broadband multimedia networks: techniques, models and tools for 4G. Academic Press.

[4] Sen, J., 2011. Cross-layer protocols for multimedia communications over wireless networks. In Advanced Communication Protocol Technologies: Solutions, Methods, and Applications (pp. 318-354). IGI Global.

[5] Ghosh, A., Wolter, D.R., Andrews, J.G. and Chen, R., 2005. Broadband wireless access with WiMax/802.16: current performance benchmarks and future potential. IEEE communications magazine, 43(2), pp.129-136.

[6] S Sukhsawas and K Benkrid, —A High-level Implementation of a High Performance Pipeline FFT on Virtex-E FPGAs‖, Proc. Of the IEEE Comp. Society Annual Symp. on VLSI Emerging Trends in Systems Design (ISVLSI'04), pages 229–232, February, 2004.

[7] Islam, M., Mondal, R.U. and Hasan, M., 2009. Performance evaluation of WiMAX physical layer under adaptive modulation techniques and communication channels. arXiv preprint arXiv:0910.0819.

[8] Band, S.R., Dorle, M.S. and Dorle, S.S., 2016, February. BER performance of WIMAX system using wavelet packet modulation technique. In Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave), World Conference on (pp. 1-5). IEEE.