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# Performance Analysis of WiMAX Systems for Zigzag-Coded Modulation Scheme

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***Abstract— The IEEE 802.16 family of standards is known as Worldwide Interoperability for Microwave Access. The IEEE 802.16 standard defines Wireless MAN (metropolitan area network).It has been designed to provide high data rate communication in metropolitan area wireless networks [1,2]. The WiMax, for broadband wireless access is employed for high speed and low cost, which is easy to deploy, and provides a better alternative for extension of fiber-optic backbone. The base stations of WiMAX can provide greater wireless coverage of about 5 miles, with LOS (line of sight) transmission within the bandwidth of up to 70 Mbps. In this paper, we evaluate bit-error rate performance of WiMAX system with zigzag coded modulation with different code rate and code length. The results show that the proposed zigzag-coded modulation presents a stronger error correcting capability as compared to the Reed Solomon with Convolutional code.***

*Index Terms* -**WiMAX, OFDM, Zigzag codes, RS codes, CC codes, Turbo codes, BER& SNR.**

## I. INTRODUCTION

WiMAX has now become one of the most promising techniques which has changed the scenario of the industry completely. Today WiMAX is considered as the most interesting opportunity which can provide data throughput up to 70 Mbps and radio coverage distances of almost 50 kilometers, and to complete the wired network architectures, ensuring a cheap and flexible solution for the last-mile. WiMAX can be thought as the fourth generation (4G) of mobile communications systems. WiMAX is an IEEE 802.16 standard based technology which is responsible for bringing the Broadband Wireless Access (BWA) to the world as an alternative to wired broadband. WiMAX is expected to have an explosive growth in future, as well as the WiFi, but compared with the Wi-Fi WiMAX can provides broadband connections in wider areas, measured in square kilometers, even with links not in line of sight. For these reasons WiMAX is a MAN, highlighting that "metropolitan" is referred here as an extension of the areas and not to the density of population [3].

It implements both packet-oriented data transmission and standard mobile telephony. It provides better performance than traditional wireless communication standards, especially for applications which require high and stable throughput. The earlier version of the IEEE 802.16 standard operates in the 10–66 GHz frequency band and requires line of sight towers. Later this standard extended its operation through different physical layer specification to 2–11 GHz frequency band which enables non-line of sight connections, which require such techniques that efficiently mitigate the impairment of fading phenomenon and multi-path [4]. The 802.16 standard standardizes two characteristics of the air interface - the PHY (physical) layer and the MAC (Media Access Control) layer.

### *A. MAC Layer*

The main focus in this layer is to handle resources of the air link. This is mainly divided into these sub-layers:

1. Service specific convergence sub-layer (SSCS) – It provides an interface to upper layer through a CS service access point (SAP).
2. The MAC common part sub-layer (CPS) - It serves the core MAC functions. This layer further includes uplink scheduling, connection control; automatic repeat request (ARQ) and bandwidth request and grant [5].

### *B. PHY Layer*

This IEEE standard specifies the air interface for fixed point to-multipoint broadband wireless access (BWA) system in wireless MAN.

1. For 10–66 GHz air interface this standard specifies a single-carrier modulation which is known as Wireless MAN-SC air interface.
2. For below 11 GHz frequencies, Wireless MAN-OFDMA, Wireless-MAN-OFDM air interfaces and the Wireless MAN-SC are specified [5].

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## II. FIXED WIMAX AND MOBILE WIMAX

### A. Fixed WiMAX

The IEEE 802.16 Working Group is the IEEE group for wireless metropolitan area network. The IEEE 802.16 standard defines the Wireless MAN (metropolitan area network) air interface specification (officially known as the IEEE Wireless MAN standard). This wireless broadband access standard could supply the missing link for the "last mile" connection in wireless metropolitan area networks. Wireless broadband access has been set up like cellular systems, using base stations that can service a radius of several miles/kilometers. In this system the base stations do not necessarily have to reside on a tower, the base station antenna will be located on a rooftop of a tall building or other elevated structure such as water tower or any high object. A customer premise unit, similar to a satellite TV setup, is all it takes to connect the base station with the customer. The signal is then routed via standard Ethernet cable either directly to a single computer, or to an 802.11 hot spot or a wired Ethernet LAN [4].

An earlier version known as IEEE 802.16a that was updated to IEEE 802.16-2004 (also known as IEEE 802.16d) is a WiMAX standard that supports fixed Non Line of Sight services (NLOS).The basic goal of IEEE 802.16-2004 standard was to provide a fixed wireless transmission with data rates higher than those provided by digital subscriber line (DSL). This feature makes fixed WiMAX an alternative for cable, DSL and T1. Fixed WiMAX uses Orthogonal Frequency Division Multiplexing (OFDM) for the transmission of data, thus serving a large number of users. Some of the features of IEEE 802.16d standards are [4] as follows:

1. Support for both frequency-division duplex (FDD) and time-division duplex (TDD).
2. 256 OFDM PHY with BPSK, QPSK, 16-QAM and 64-QAM modulation techniques.
3. Support for point-to-point multi-point mesh topology.
4. Support for advanced antenna and adaptive modulation, and coding techniques.
5. Low latency for delay-sensitive services, thus improves the quality of service (QoS) parameters.
6. Designed to provide fixed NLOS broad band services to fixed, portable and nomadic users.

### B. Mobile WiMAX

IEEE 802.16-2005, is known as IEEE 802.16e or Mobile WiMAX, is an improvement of the IEEE 802.16-2004 standard. It is more complex technology as compared to its predecessor IEEE 802.16-2004 standard. The mobile WiMAX allows the convergence of mobile and fixed broadband networks through a common wide-area broadband radio access technology and flexible network architecture. Some of the features of IEEE 802.16e standards are [7] as follows:

1. Provides resistance to multi-path interference by developing fast Fourier transform (FFT) algorithms.
2. It uses scalable OFDM for transmission to carry data-supporting channel bandwidths between 1.25 MHz and 20 MHz with up to 2048 sub-carriers.
3. Provides an improved coverage range with the use of an adaptive antenna system.
4. IEEE 802.16-2005 standard offers support both fixed and mobile access over the same infrastructure.

## III. THE WIMAX MODEL

The model presented in this paper is built on the following parameters:

| | |
|---|---|
| Modulation: | QPSK, M-QAM |
| Bandwidth: | 15MHz |
| $N_{FFT:}$ | 2048 |
| Sampling factor: | 7/6 |
| Length of Cyclic prefix: | 1/8 |
| $F_{s:}$ | 2075 MHz |
| Symbol Time ($T_b$): | 79.5 |
| Length of Cyclic Prefix ($T_g$): | 10.2 |

The modeling setup includes MATLAB R2010a and communications block set running on windows XP. The model shown in Fig. 1 consists of three main components transmitter, receiver and channel.

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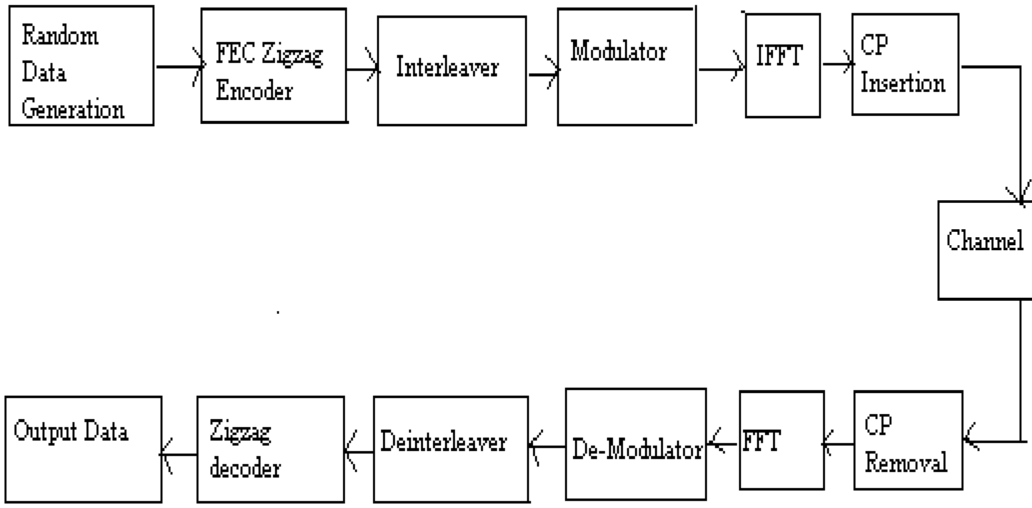


**Fig. 1.WiMAX (IEEE 802.16) Model**

The binary data after randomization is fed into the forward error correction (FEC) encoder. We consider convolutional turbo codes (CTCs), convolutional codes (CC), Reed-Solomon (RS) and especially concatenated zigzag codes. After bitwise interleaving the bits, they are fed into the modulator. Where mapping the bits to QPSK, 16-QAM, 64-QAM and 8-QAM symbols is performed. According to the IEEE 802.16 standard, a special sub-carrier allocation pattern is used to account for the specialties dealing with an OFDMA uplink. The OFDM signal in the time domain is computed via the inverse fast Fourier transform (IFFT). Finally, the cyclic prefix (CP) is added for the guard band. Here the channel is assumed to be a time-variant multi-path channel, modeling mobile users in an NLOS scenario. The receiver noise is modeled by an additive white Gaussian noise (AWGN) process which is added to the received signal [3].

Assuming perfect synchronization, the receiver removes the cyclic prefix and extracts the useful symbol time. The receiver extracts the user-specific information after the computation of the frequency domain signal via the FFT. With the assumption that the delay spread of the channel is smaller than the cyclic prefix (CP) and the time variance of the channel during one OFDM symbol is negligible [3].

Orthogonal frequency-division multiplexing (OFDM) scheme is used in most wireless communications systems due to its high spectrum efficiency and robustness in multi-path propagation. OFDM is a special form of multi-carrier modulation and mitigate inter symbol interference (ISI) by multiplexing the data on orthogonal property. Moreover, it is, spectrally, more sufficient technique as compared to a conventional single carrier modulation technique [9].

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation scheme which is suited for high data rate transmission in delay dispersive environments. It converts a high data rate stream into a number of low data rate streams that are transmitted over parallel, narrowband channels which can be easily equalized [11]. OFDM provides high bandwidth efficiency because in this scheme the carriers are orthogonal to each other and multiple carriers share the data among themselves. The most important advantage of this transmission technique is their robustness to channel fading in wireless communication environment.

## IV. CHANNEL ENCODING

Channel coding represents the source information over the channel in such a manner that minimizes the error probability in decoding by adding the redundant bits systematically with the data. Channel coding is important for wireless channel because it reduces the bit error rate at the receiver. Hence in this way the reception quality

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improves. In general channel coding can be performed by error detecting and correcting codes. Coding methods are based on logical or mathematical operations [4].

Convolutional turbo code (CTC) is one of the communication channel encoding schemes under the WiMAX standard, with a variety of optional code rates and flexible block length. CTC is a kind of duo-binary turbo code, which possesses many advantages over classical turbo codes. The minimum freedom distance changes and the transmission spectrum efficiency decreases; there is a better flexibility in choosing the code rate .Its interleave depth is half that of classical turbo code, with the shortened decoding delay. With the fact in mind that most practical communication systems need processing with higher bandwidth efficiency, bandwidth efficiency can be increased from two aspects: modulation type and code rate. Therefore in this paper we have introduced a new code which has some advantages as compared with CTC and classical turbo code. Zigzag code has a big advantage, in that it can choose a higher code rate. Modulation used here is of the M-QAM modulation type, and possesses such advantages as small radiation outside the band and higher bandwidth efficiency. It is robustly applicable in practical communication systems [4].

### *A. Encoding of Zigzag Codes*

A coded modulation scheme is used for ultra-high speed transmission. This paper introduces a family of error-correcting codes called zigzag codes. A zigzag code is described by a highly structured zigzag graph [10]. A zigzag code is a type of linear error-correcting code. In this coding the input data is partitioned into segments of fixed size and the sequence of check bits to data is added, where each check bit is the exclusive OR of the bits in a single segment and of the previous check bit in the sequence. Zigzag codes show upto 0.5 dB performance gain over structured low density parity check codes (LDPC). This paper deals with bit-error-rate (BER) performance of WiMAX systems that uses the various coding and modulation schemes [4].

The structure of zigzag code is shown in Fig. 2, where node $\oplus$ represents the modulo-2 summation. An **(I,J)**-zigzag code is a systematic code with **I** parity bits in the form of a column vector **p,** and **I.J** information bits in the form of an **I×J** matrix **D** [4] , where **p** and **D** are given by,

$$D = \begin{bmatrix} d(1,1) & d(1,2) & \dots d(1,J) \\ \vdots & \vdots & \dots \quad \vdots \\ d(I,1) & d(I,2) & \dots d(I,J) \end{bmatrix}_{I\times J} \quad \text{and} \quad p= \begin{bmatrix} p(1) \\ \vdots \\ p(I) \end{bmatrix}_{I\times 1} \tag{1}$$

The parity check bits are generated according to

$$P(i) = \left(p(i-1) + \textstyle\sum_{j=1}^{J} d(i,j)\right) mod\ 2, \qquad 1 \leq I \leq I, \tag{2}$$

With the initial value p(0) = 0.

### *B. Concatenated (I,J) Zigzag Codes*

If we concatenate several component zigzag codes then a stronger code can be obtained. The first constituent code encodes the original data $\Pi_1(D)=D$,and the remaining K-1 constituent codes encode K-1 different interleaved versions of D using K-1 length (I×J) random interleavers. The kth constituent code generates a parity check vector $p_k = [p_k(1),\ldots,p_k(I)]^T$ and the parity check matrix is denoted by [4]

$$P = \begin{bmatrix} p1(1) & \cdots & pk(1) \\ \vdots & \ddots & \vdots \\ p1(I) & \cdots & pk(I) \end{bmatrix}_{I\times K} \tag{3}$$

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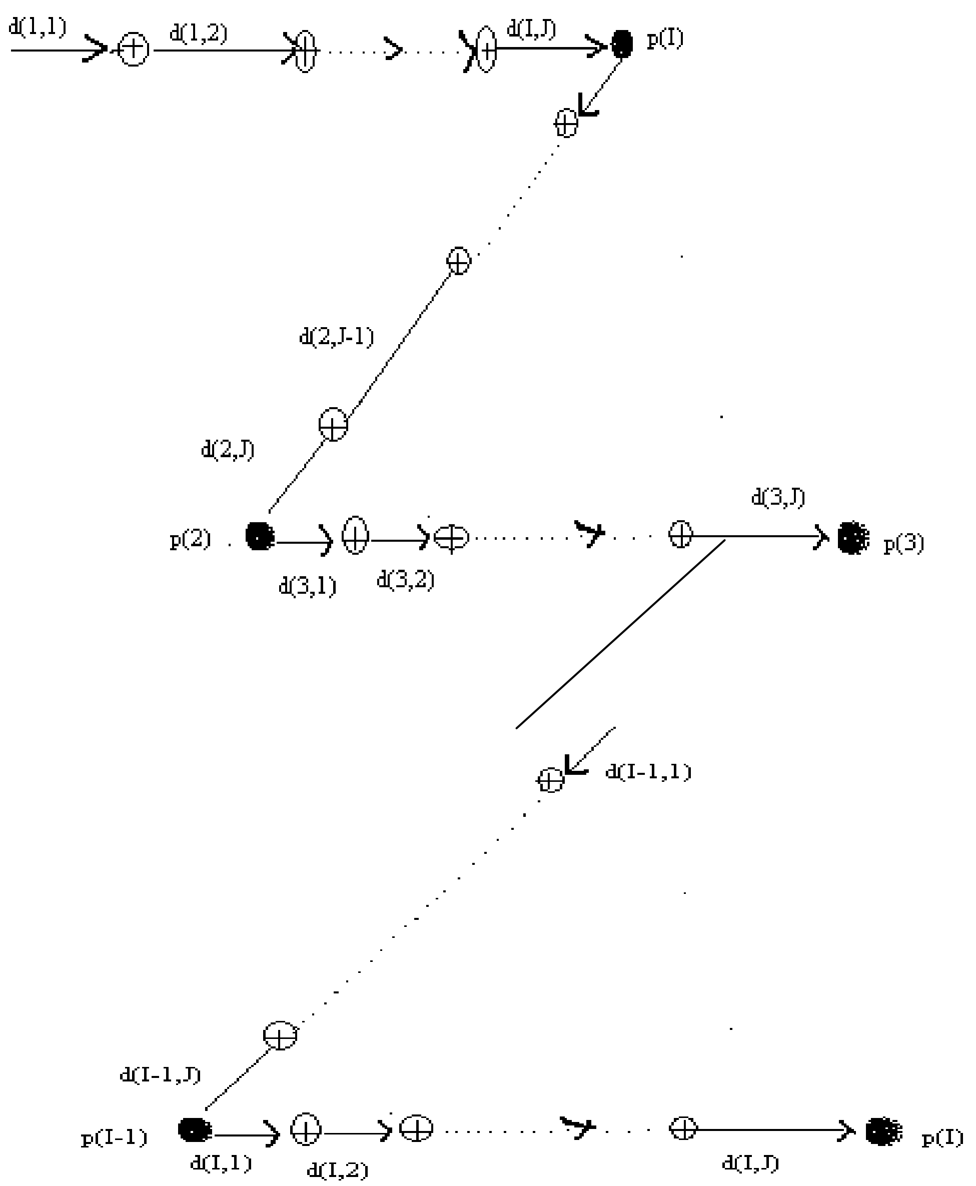


**Fig. 2. The structure of zigzag codes [4].**

## V. DECODING OF ZIGZAG CODES

We perform the A Posterior Probability (APP) decoding of zigzag codes, this process starts with the information of a posterior probabilities for each data bit then the data bit value is chosen which corresponds to the MAP probability for that data bit, after reception of a corrupted code-bit sequence, the process of decision making with APPs allows the MAP algorithm to determine the most likely information bit that have been transmitted at each bit time [4].

For each constituent code, based on the parity check relation, this algorithm performs forward and backward recursions and updates the log-likelihood ratio (LLR) of the information bits periodically. To perform the forward and backward recursions and update the LLR of the information bits, each decoder uses the output LLR of the information bits from the previous decoder [4]. LLR is a statistical test that is used to compare the fit of 2 models one of which is a special case of the other. This test is based on likelihood ratio, which defines how many times

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more likely the data bits are less than one model than the other. This ratio can be used to compare a critical value to decide whether to reject the model or to accept it [4].

## VI. SIMULATION RESULTS

The results of the simulation are presented in this section. At the time of simulation some parameters are set like CP length, coding rate, code length, modulation and range of SNR values. The input is generated randomly. We have plotted the BER vs. SNR figures for different modulation and coding.

In Fig. 3, we have shown the performance of the WiMAX for QPSK and M-QAM modulation by using code rate - ½ and ¾.In QPSK modulation with rate-3/4 we get a BER of 0.2 at a SNR of about 5 dB. In 16-QAM type modulation with code rate-3/4 we get a BER of 0.25 at a SNR of 11 dB and in 64-QAM type modulation with code rate -1/2 we get a BER of 0.3 at a SNR of 19 dB. The graph shows that the performance of zigzag coded modulation scheme with code rate ¾ for QPSK and 16-QAM types are better than the code rate-1/2 but in case of 64-QAM it is seen that the performance of WiMAX with zigzag coding with code rate- ½ is better than code rate-3/4.

In Fig. 4, we have shown the plot for BER vs. SNR for fixed WiMAX (IEEE 802.16d) system using 8-QAM modulation. The code rates were R=1/2 and ¾ respectively, the code lengths were N=256 and 512 bits. We have also used RS+CC and CTC codes here to check and compare the BER performance of the different channel coding scheme. CTC with code rate-1/2 gives a BER of 0.2 at a SNR of 5.8 dB. In zigzag coded modulation scheme with 8-QAM modulation type and code rate-1/2 gives a BER of 0.2 at a SNR of 10 dB. Similarly zigzag code with 8-QAM modulation and code rate-3/4 gives a BER of 0.25 at a SNR of 12 dB. RS+CC with code rate-1/2 give a BER of 0.9 at a SNR of 12 dB. It is seen from the graph that the combination of RS+CC performs worst. The CTC and zigzag code for 8-QAM is quite good.

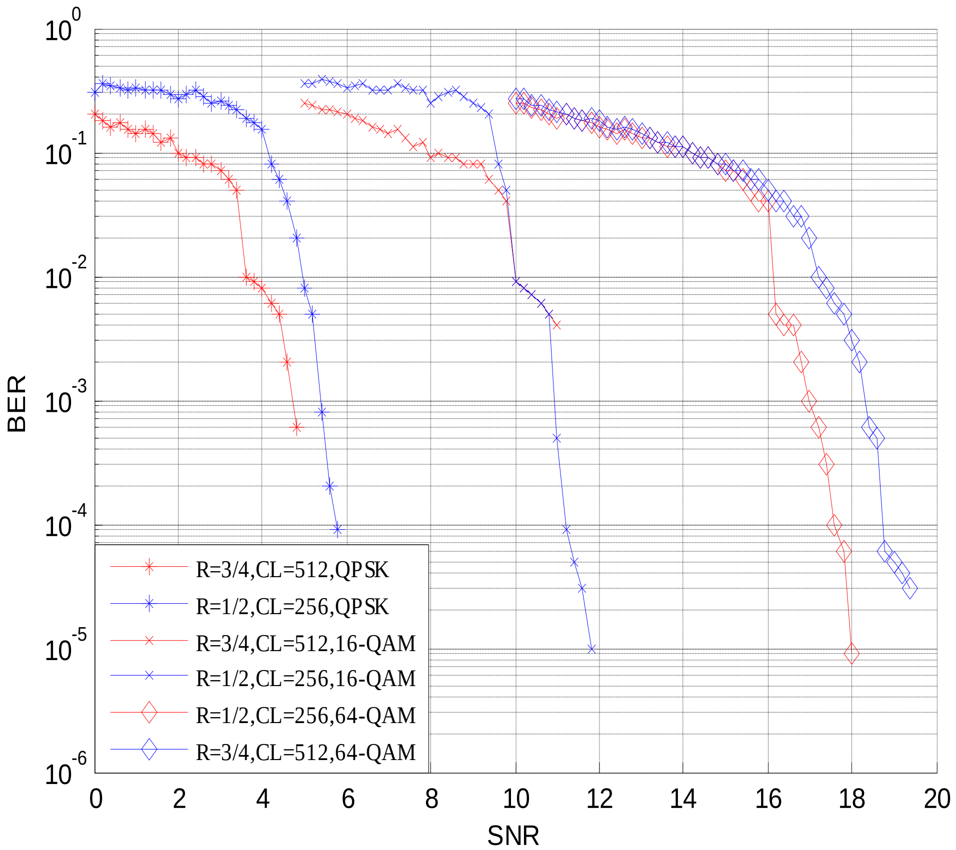


**Fig. 3. BER performance evaluation of different rate/modulation for WiMAX [4].**

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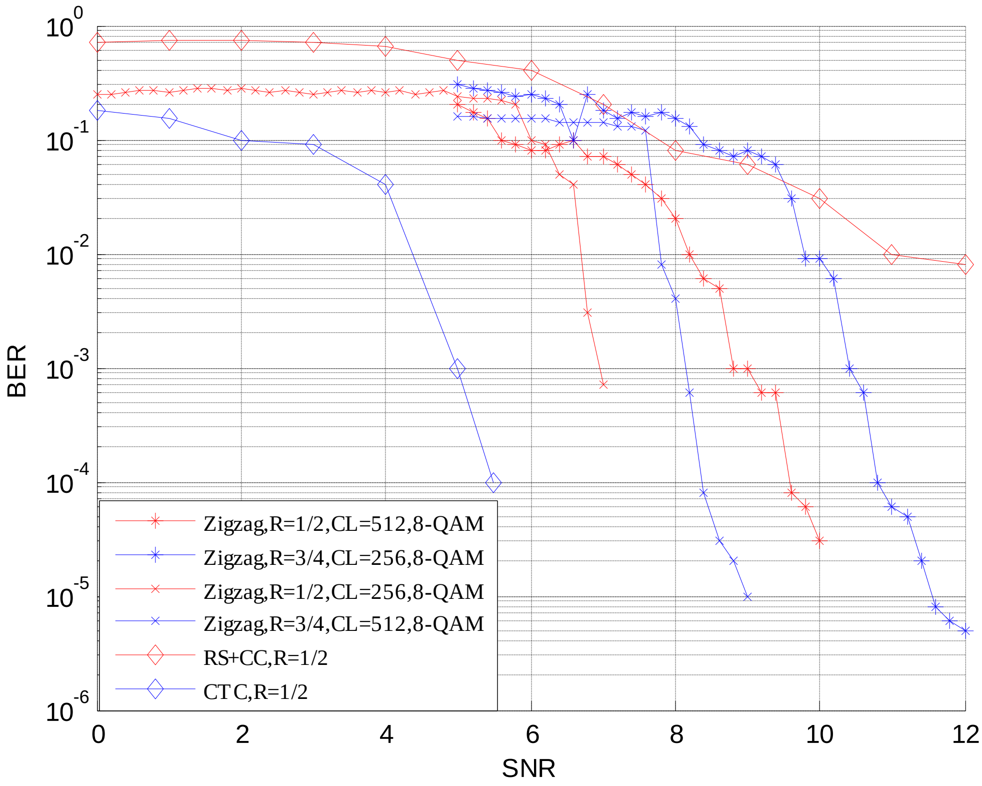


**Fig. 4. BER performance evaluation for R=1/2 and ¾,N=256 and 512 respectively, for 8-QAM modulation[4].**

## VII. CONCLUSION

For the transmission of reliable data over communication channel Forward- Error- Correction techniques are necessary. If the redundant bits are added to the data stream before its transmission so the effect of error which may occur during transmission can be reduced. The receiver in the system is enabled by the redundancy to detect and correct the errors. By the simulation results we can conclude that the zigzag codes with M-QAM modulation type performs better and gives a stronger error detecting and correcting capabilities.

## REFERENCES

[1] C. Eklund, R.B. Marks, K.L. Stanwood and S. Wang et. al, IEEE standard 802.16: a technical overview of the wirelessman air interface for broadband wireless access, IEEE Communications Magazine 40 (6) (2002) 98–107.

[2] IEEE Std. 802.16-2004, Standard for Local and Metropolitan Area Networks. Part 16: Air Interface for Fixed Broadband Wireless Access Systems, October 2004.

[3] Bhavin S. Sedani, Nirali A.Kotak , Komal R. Borisagar and G. R. Kulkarni et. al. 2012 International Conference on Communication Systems and Network Technologies, pp. 630-634.

[4] Salim Kahevi et. al, “Performance Analysis of Zigzag-Coded Modulation Scheme for WiMAX Systems” ELSEVIER JOURNAL of THE FRANKLIN INSTITUTE, SEPTEMBER 2012, pp. 2717–2734.

[5] Divya Jain and Pravin Patdar, “Review Paper on Performance Analysis of WiMAX System,” National Conference on Recent Advances in Mechtronics and Computing Technology& Management,June-16,2013.

[6] WiMax Overview Sanida Omerovic, Faculty of Electrical Engineering, University of Ljubljana, Slovenia.

[7] WiMAX Forum, Mobile WiMAX-Part 1: A Technical Overview and Performance Evaluation, 2006.

[8] Muhammad Nadeem Khan and Sabir Ghauri et. al,WiMAX 802.16e Physical Layer The Model

[9] Usama S. Mohammed and H. A. Hamada et. al. JOURNAL OF TELECOMMUNICATIONS, VOLUME 2, ISSUE 2, MAY 2010,pp. 70-78.

[10] Li Ping,Xiaoling Huang and Nam Phamdo et. al, "Zigzag Codes and Concatenated Zigzag Codes," IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. 47, NO.2, FEBRUARY 2001,pp. 800-807.

[11] Andreas F.Molisch, "Wireless Communications", John Wiley & Sons edition.