DEVELOPMENT OF TURBO CODED MIMO-OFDM SYSTEM IN TIME VARYING CHANNELS

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Abstract:

In OFDM,the transmission bandwidth is divided into many small subcarriers .Cyclic prefix is added to subcarriers to avoid inter carrier interference.However cyclic prefix length should be choosen to exceed the channel delay spread.therefore ,OFDM can eliminate the ICI and can overcome multipath fading.In transmitting data information ,another issue exists due to reduction of the error rate.so we use error correcting codes in the design of the OFDM transmission systems.Time domain synchronous orthogonal frequency division mutliplexing naturally suits for the proposed inter carrier interference mitigation algorithm because its receiver is able to easily estimate linear time varying.The proposed algorithm applies to all OFDM systems as long as linear time-varying channel estimation is applicable.In this paper, turbo codes are used to attain high date rate transmission in the OFDM system.These codes introduce error correction in the system at each stage which helps us to get the data output with reduced errors.when the multi input multiple output OFDM is overloaded then calculation of bits combindly is performed efficiently than calculating separately for single stream .

Index Terms- **MIMO –OFDM,Turbo encoder,Turbo decoder,Bit error rate,Mean square error**

I.INTRODUCTION

In wireless communications,telecom industry plays a vital role.In Military,satellite and cellular technologies there is growing demand for the wireless technologies .At present orthogonal frequency division multiplexing is utilized to overcome fading and to enhance data rate transmission[1].IThe technology and the implementation of digital systems have increased the data rate to unmatched levels to convey the information between two entities. Multipath fading and inter carrier interference can be overcomed in OFDM systems because of equalizers.But system complexity is increased due to equalizers single carrier modulation technique,only one carrier is utilized for modulation purpose.OFDM is the multi-carrier modulation technique is used in which information signal is divided into several small signals .each data stream is modulated separately on each carrier.these reduces the fading of the information.Due to multiple carriers in OFDM,there arises problem of orthogonality between the carriers.Becauses of, reduction in orthogonality property between the carriers,inter carrier interference (ICI) occurs[2].By using the cyclix prefix and guard band in beween the data symbols,inter carrier interference and inter symbol interference (ISI) is almost reduced[3].In [4], for the linear time varying channels a low complexity inter carrier interference (ICI) is proposed where channel estimation is done for the linear time varying channels.[4] proposed that signal to noise ratio of 2 dB is achieved when the Doppler frequency is 0.1 and the uncoded bit error rate is 10^-3. This method is worked very well when the receiver antennas are more than the transmitter antennas.

Eventhough complexity of ICI mitigation is reduced,OFDM systems has synchronization errors.which reduceds the data transmission rate.In [5]turbo codes had been introduced which are extension to the block codes and convloutional codes .Turbo codes have the bit error rate which is closer to the Shannon limit in terms of bit error rate(BER).Turbo code encoder are obtained when two convolutional codes are parallelly concatenated .The bit error rate of systematic convolutional is higher than the non systematic convolutional code [5].Interleaver blocks are introduced in between the encoder blocks to reduce the errors at each stage on the transmitter side.Interleavers uses a square matrix where bits are read pseudo randomly. De-interleaver blocks are introduced between the decoder blocks present at the receiver side. The soft decoding process of turbo codes is always preferred than the hard decoding process. In [6] for broadcasting the signal from the transmitted side to the receiver side spae time block codes had been introduced with the decoding process having less complexity [7]The two major problems in the OFDM systems are the estimation and equalization of the channel to reduce the inter carrier interferences.In these they used kalman filter for estimation of the channel and MAP algorithm for decoding purpose.Also they mentioned the reasons which degrade the system performance are inter carrier interference and inter block interference or inter symbol interference.The main for causing the IBI is the dispersion that caused in the channel and carrier interference are caused by the variations in the channel.In [8] the error rate is improved by using the channel coding and diversity. Diversity gives the more improvement for the system.Turbo codes are the combination of the block codes and convoultional codes.Block codes along with the turbo codes made the coding of the channel easily preformed.

First turbo codes have been introduced in [5] with rate of the code is ½ for the thermal noise channel with the binary phase modulation technique. Turbo encoders and turbo decoders are utilized in the coding of the thermal noise channel.In the turbo encoder,convoultional codes which are systematically recursive are sent parallel to the turbo decoder.In between the encoders,interleaver blocks are incorporated. These interleaver blocks helps the coding burden by reducing the errors in the intermediate levels.so that overall error degradation is improved for the system.In the turbo decoder,the information code is received from the encoder in the serial form.several decoding algorithms are came into existence like log maximum A posteriori,viterbi algorithm etc..Based on the complexity of the MIMO system the different decoding process are used for the efficient performance.Normally for the turbo multi carrier system MAP decoding process is used.In [9] a conventional decoding for the turbo codes is implemented.In the conventional decoding method,each block is detected and decoded which makes decoding process more efficient.Joint turbo decoding is introduced which means decoding is done parallely for all the decoding blocks.so that it reduces the complexity of the decoding process.

II.SYSTEM MODELS

The model for the conventional based MIMO OFDM system in the receiver side antennas.Let $Y_{i,j}$ denotes the information of the symbol which is received from the transmitter for the j^{th} number of transmitters and i^{th} is the number of receivers,with the symbol length be the L.Then there will be k-th tappings of the channel between the j-th transmitter and the i-th receiver.The time slot t by $G_{k,i,j}^{(t)}$=0,1….K-1 where K is the complete channel length .For the time varying channel,There are two sections one is time varying part and other is time varying factor.In the equation (1) the time invariant is given as

$$G_{k,i,j}=\frac{1}{L}\sum_{t=1}^{L+K-1} G_{k,i,j}^{(t)} \qquad (1)$$

and the time varying is given as $\beta_{k,i,j}$ for the k-th channel tap.The equation for the single step is given as $h_a=\frac{a}{L}-\frac{L-1}{2L}$.

The complete equation for the time varying channel is obtained in equation (2) as

$$G_{k,i,j}^{(t)} = G_{k,i,j} + h_{a-k}\beta_{k,i,j} \qquad (2)$$

The time domain signal received from the j^{th} transmitter at the i^{th} receiver can be formed as

$$y_{i,j} = (H_{i,j} + C_{i,j}D)x_j \qquad (3)$$

Where X_j is the transmitted sequence of the time domain from the j-th transmitter, $H_{i,j}$ is a L×L circular matrix with the first column to be transpose of $[h_{0,i,j}, h_{1,i,j}, \ldots . h_{k-1,i,j}, 0 \ldots, 0]$, $C_{i,j}$ is a L×L matrix with the first column to be transpose of $[\beta_{0,i,j}, \beta_{1,i,j}, \ldots . \beta_{k-1,i,j}, 0 \ldots, 0]$.D is a diagonal matrix such that D=Transpose of Diag($\beta_0, \beta_1, \beta_2, \beta_3 \ldots . \beta_{K-1}$).Frequency domain signals are formed from the time domain signals and are represented by the below equation (4)

$$Y_{i,j}=(H_{i,j} + C_{i,j}D)X_j \qquad (4)$$

Where conversion is done by multiplying transmitter and receiver time domain vectors with the components of E_L.so the received frequency vector is given by the $Y_{i,j} = E_L y_{i,j}$ and the transmitter frequency vector is given by the $X_{i,j} = E_L x_{i,j}$.The diagonal matrices are $H_{i,j}=E_L H_{i,j} E_L^H$=Diag $(\{H_{i,j,L}\}_{L=1}^{L})$ and $C_{i,j}=E_L C_{i,j} E_L^H$=Diag $(\{C_{i,j,L}\}_{L=1}^{L})$ based on the circular matrix.Then $\{H_{i,j,L}\}_{L=1}^{L}$ and $\{B_{i,j,L}\}_{L=1}^{L}$ represents the L-point of discrete fourier transform of the sequences $[h_{0,i,j}, h_{1,i,j}, \ldots . h_{k-1,i,j}, 0 \ldots, 0]^T$ and $[\beta_{0,i,j}, \beta_{1,i,j}, \ldots . \beta_{k-1,i,j}, 0 \ldots, 0]^T$.Where precalculated matrix is represented by $D_{i,j}=E_L D_{i,j} E_L^H$.

The time invariant components are present in $H_{i,j}$ matrix and inter carrier interference components are present in $C_{i,j}$matrix .For the SISO-OFDM systems where i=j=1.Then with the diagonal matrices $H_{i,j}$ and $C_{i,j}$,and with the C calculated by the FFT, the model for designing of low complexity ICI mitigation can be obtained which reduces the complexity in calculating the received symbols of $Y_{i,j}$ .When we consider the MIMO-OFDM system,the complexity is increased because signal from one transmitter interfers with other number of transmitters resulting in the interference of the signals.The received signal at the j-th receiver is represented by the superposition of the received signals from different transmitters and is given by the equation(5).

$$Y_n = \sum_{i=1}^{I} Y_{i,j} = \sum_{i=1}^{I} (H_{i,j} + C_{i,j} D) X_j + V_n \qquad (5)$$

V_n is the frequency domain noise vector at the j-th receiver.

Y=Transpose of $[Y_1^T, Y_2^T, Y_3^T \ \dots . Y_J^T]$

X=Transpose of $[X_1^T, X_2^T, X_3^T \ \dots . X_I^T]$

V=Transpose of $[V_1^T, V_2^T, V_3^T \ \dots . V_N^T]$

Then $Y = \begin{bmatrix} H_{1,1} & H_{2,1} & \cdots & H_{i,1} \\ H_{1,2} & H_{2,2} & \cdots & H_{i,2} \\ \vdots & \vdots & \vdots & \vdots \\ H_{1,j} & H_{2,3} & \cdots & H_{i,j} \end{bmatrix} X + V$

With

$$\mathrm{H_{i,j}} = \mathrm{H_{i,j}} + \mathrm{C_{i,j} D} \qquad (6)$$

The energy of the signal is distributed to the subcarriers and is mentioned below in the equation (7)

$$\mathrm{Y_i} = \mathrm{H_{i,j} X_i} + \sum_{j=0, i \neq j}^{j-1} \mathrm{H_{i,j} X_j} + \mathrm{V_n} \qquad (7)$$

With 0 ≤ I ≤ J-1 from the above we can say that $H_{i,j} X_i$ part is free from inter carrier interference and second part consists of the all signals including noises.For the transmitted signal ,the loss of energy in the i-th subcarrier is,

$P_{i,j} = E\left[\left| H_{i,j} X_j \right|^2 \right]$=E$\left[H_{i,j} H_{i,j}{}^{*} \right]$ where * represents the conjugate operator.

III. TURBO ENCODER AND DECODER

Due to the error correcting codes,a large number of codes along with corresponding different decoding algorithms.In some application where error correcting capability should be strong enough ,however it makes the decoding system more complicated. In 3G standard,turbo codes are used for the iterative decoding mechanism. Turbo codes are built using the various permutations of the information sequence by applying more encoding process. With the help of interleaving ,the constitutent codes are used parallelly so that we can overcome the complex decoder systems.The concatenation of the codes can be done serially,but one code is encoded with the second code.where we need to do calculations for checking the parity of parity.This additional parity check is not needed,when the parallel codes are utilized.Concatenating the codes parallely is the best idea for the Shannon’s coding theorem,when the channel capacity is achieved for the long codes.This also means that if the code is very long,it does not have to be optimal.The long length codes gives the best error correcting capabilities when the concatenating coding is used. Encoders used can be of recursive systematic convolutional codes(RSC) type. Generally brute force algorithm will decode all the codewords possible.Likewise when much more efficient decoding algorithm is implemented then it gives the better results.Better trade off can be achieved with the concatenated codes between the complex decoder algorithm and the error correction techniques.

When the data sequence for the given information is systematic.The decoding of the error rate of the given information code can not exceed the channel error rate.When the received data sequence is of random symbols then the decoding the information becomes more complex.The parity bits should give some information so that the after decoding the error rate can be less than the channel error rate.The important information of the sequence should be present in constituent codes,so that when the rate is half then turbo code becomes 1/3.Lower rates of the constitutent codes is selected when the repetition is needed.Interleaver comes in to factor when we talk about the turbo codes.so Joint decoding in turbo codes is introduced recently which helps to reduce the coding process and eliminate errors when overloading occurs.In this paper MIMO OFDM system with turbo codes and without turbocodes is compared based on the bit error rate.Turbo encoder and decoder are more efficient in increasing data rate than the other coding techniques for the OFDM system.

The parallel concatenation of two recursive convolutional encoders which are separated by the interleaver blocks is know as turbo encoder.RSC Encoders generates two different codes one is systematic output and the second one is parity bits. But each RSC encoders takes different bit stream as an input. The first one will take original data as input and second will take interleaved data as input. Interleaving is a process in which bits are rearranged by using the desired algorithm. The Turbo Encoder gives output of 28 bits which is a combination of input data and an output of two RSC encoders which is thrice the length of the input bits.The Turbo encoder is designed with two RSC encoders and is separated by block interleavers.

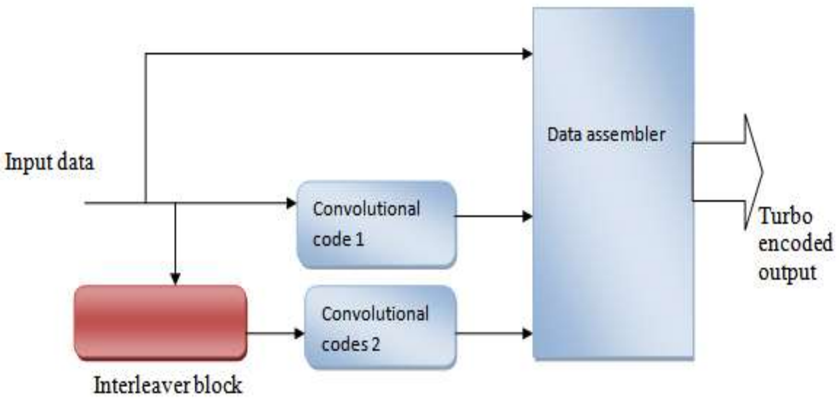


Fig 1.Turbo encoder diagram

IV.SIMULATION RESULTS

Simulation results are evaluated the performance of the proposed alogirthm.The number of receivers taken here are 4.In figure (2),the information of the data at the receiver side is taken. In fig 3 the noise signal is added to the channel.

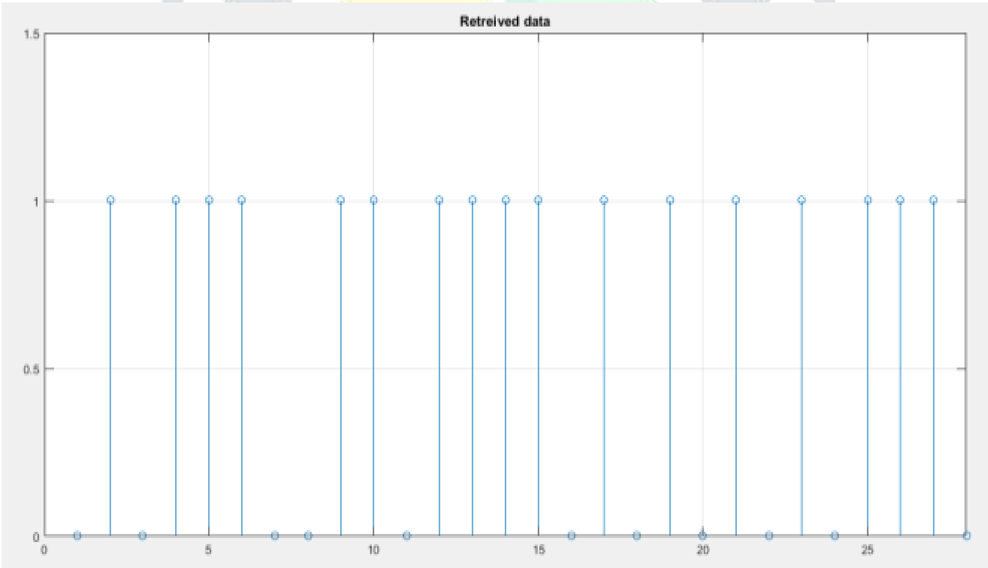


Fig 2.Information (binary data) at the receiver side

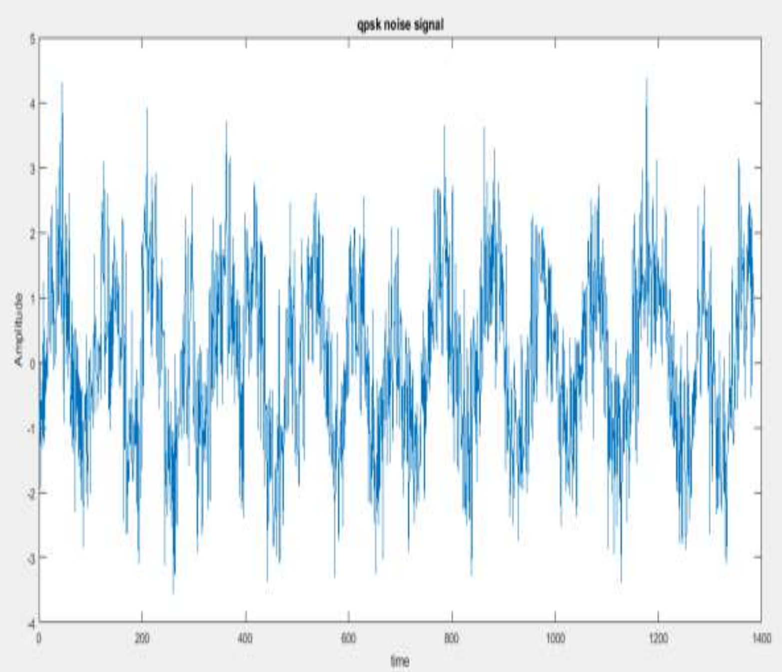


Fig 3. Noise signal

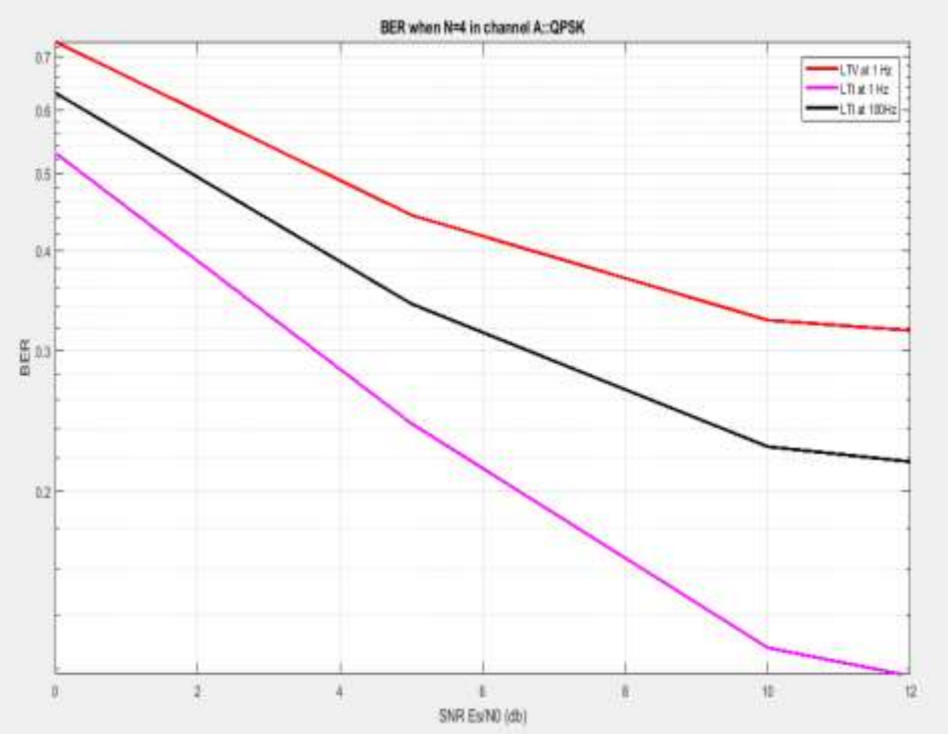


Fig 4. BER performance of QPSK modulation when i=4

Our proposed alogrithm is absorbed at both the LTV and LTI .In fig 4 and 5 the MSE and bit error rate (BER) performance is calculated with the QPSK modulation at 1HZ ,100 HZ.

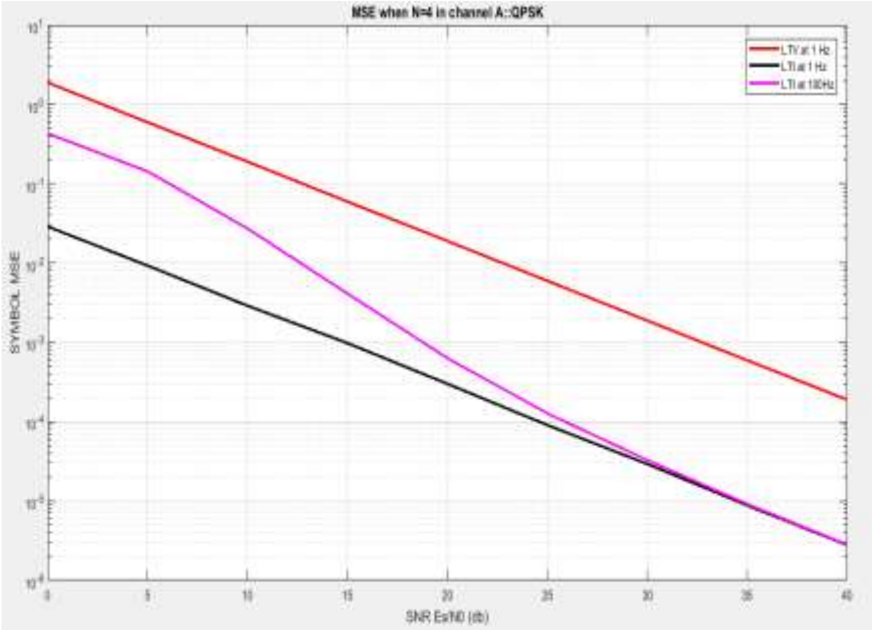
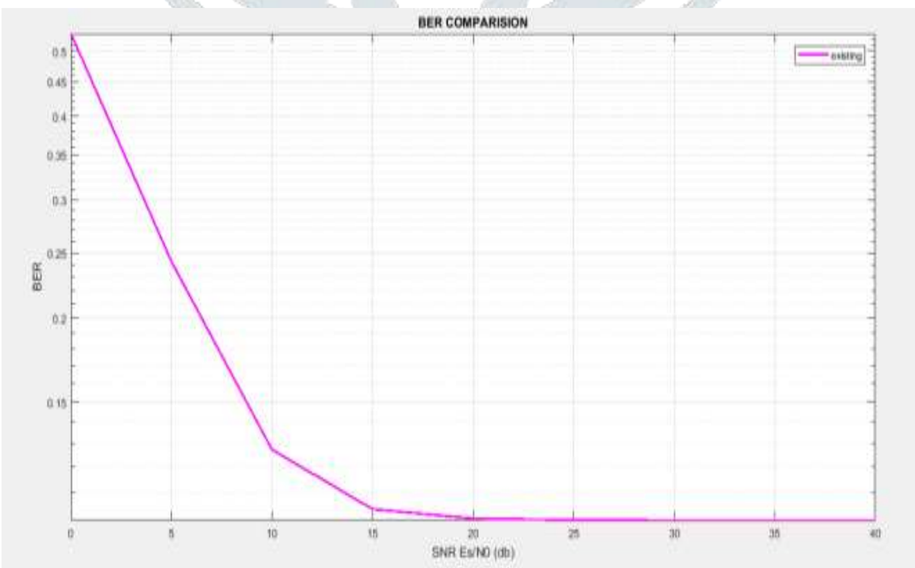


Fig 5.MSE performance of QPSK modulation when i=4

At 1HZ, the mean square error and bit error rate is observed for both time varying channels and time invariant channels.and at 100HZ for the time invariant channel ,the BER and MSE performance is observed.In fig 6 and fig 7 the BER performance for the conventional OFDM and OFDM with turbo codes is observed.

V.CONCLUSION

Turbo codes are having more importance practically which comes under the error control codes.Turbo Encoder is a parallel connection of Two Recursive Systematic Convolutional (RSC) Encoders and is isolated by interleaver. RSC Encoders creates two different codes one is methodical yield and the second one is equality bits.The bit error rate is calculated for the conventional OFDM and the turbo coded OFDM.The BER value is reduced for the Turbo coded OFDM when compared to the conventional OFDM. In digital communication,the efficiency of transmission is enhanced by the use of turbo codes.Interleaver in turbo codes is used mainly to randomize burst errors to decode the data correctly. Interleaver is a most popular interleaver used in digital data transmission. When compared with the other interleavers, it is very simple and easy to design and implement.



. Fig 6.BER performance of OFDM System in AWGN channel

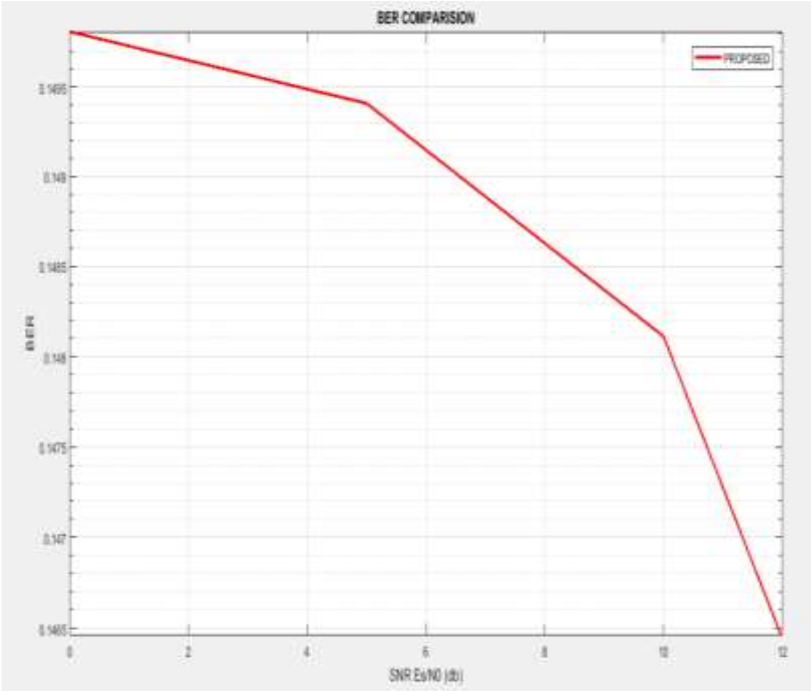


Fig 7. BER performance of TURBO coded OFDM system in AWGN channel.

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