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# Improving Bit Error Rate of Wimax Modem Using Singular Value Decomposition

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## ABSTRACT

Currently Wimax is improving Communication Systems to accelerate business environment using some specific standards to avoid shortcomings of coverage area, data rate and data security. Orthogonal frequency division multiplexing (OFDM) is one of the major applications which are in use to reduce the Bit Error Rate on Wimax Physical Layer. Many techniques are in use to further upgrade and optimize the OFDM systems by inserting useful blocks in the OFDM model to improve bit error rate (BER). These blocks are inter-leaver, convolutional coding, symbol mapping, IFFT which are used to reshape the OFDM and to minimize the impact of noise. In this research work, the concept of matrix factorization has been discussed to transmit the data by computing singular values of data matrices along with the implementation of other data interleaving techniques, i.e., convolutional encoding, symbol mapping, decoding and symbol de-mapping.

**KEYWORDS*:*** Wimax Physical Layer, Convolutional Decoding, Bit Error Rate, Singular Value Decomposition

## 1 INTRODUCTION

**1.1** The application of orthogonal frequency division multiplexing (OFDM) is in use by Telecom sector to transmit data with high speed on multiple carriers in both directions of wireless systems. The integrated circuits of OFDM application of 1960s are currently in use by Telecom and other industries to promote digital operations on high speed. The concept of Discrete Fourier Transform (DFT) has been proposed in 1971, on transmission of data beside the implementation of modulation and demodulation techniques 1. In 1980s, the researchers introduced OFDM technology in Mobile Communication Systems as well as in manufacturing of modem devices for high speed communication.

**1.2** Different techniques of Encoding, Symbol Mapping, Modulation and Demodulation were aimed to include in WIMAX devices to upgrade in order to reduce the bit error rate (BER). To reduce the BER, bit loading algorithms are being used along with modulation schemes to optimize the OFDM systems in the presence of static frequency multiple channels while coding techniques are being in use to mitigate the effects of fading across OFDM subcarriers. However, the implementation of these methodologies is not easy to apply in OFDM systems as described in 1 due to the following reasons:

1. Nonzero correlation of interleaved data between adjacent coded bits.
2. The channel gain may not be concluded by the fading distribution channels.
3. The BER has been considered to be evaluated in supposed symmetric channels and the minimization of BER is supposed to decrease the error rate of the initial and real encoded transmitted data.

**1.3 2. CURRENT OFDM SYSTEM**

**1.4 2.1Overview:** In order to have high data communication over multicarrier transmission technology OFDM is one of the best applications. In OFDM systems the data of high power can be spread over multicarrier channels in the OFDM system in which each carrier is a low rate carrier.

**1.5** In this environment, the provided carriers are orthogonal with respect to each other that mean the dot product of carriers will be zero and the space in the frequency can be gain by the use of the Fast Fourier Transform (FFT) as elaborated in 2.

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OFDM has been derived from FDM, in which each signal is carried over separate carrier frequencies. As per research detail in 2, in case of FDM, at the receiver the separation of signal can be achieved by taking the channels far apart by inserting the guard bands to remove inter symbol interference.

OFDM provides a comprehensive results and solutions for problems found in the wireless system that is based on poor bandwidth efficiency, high signal processing complexity, multipath conditions and interference and capacity issues 3.

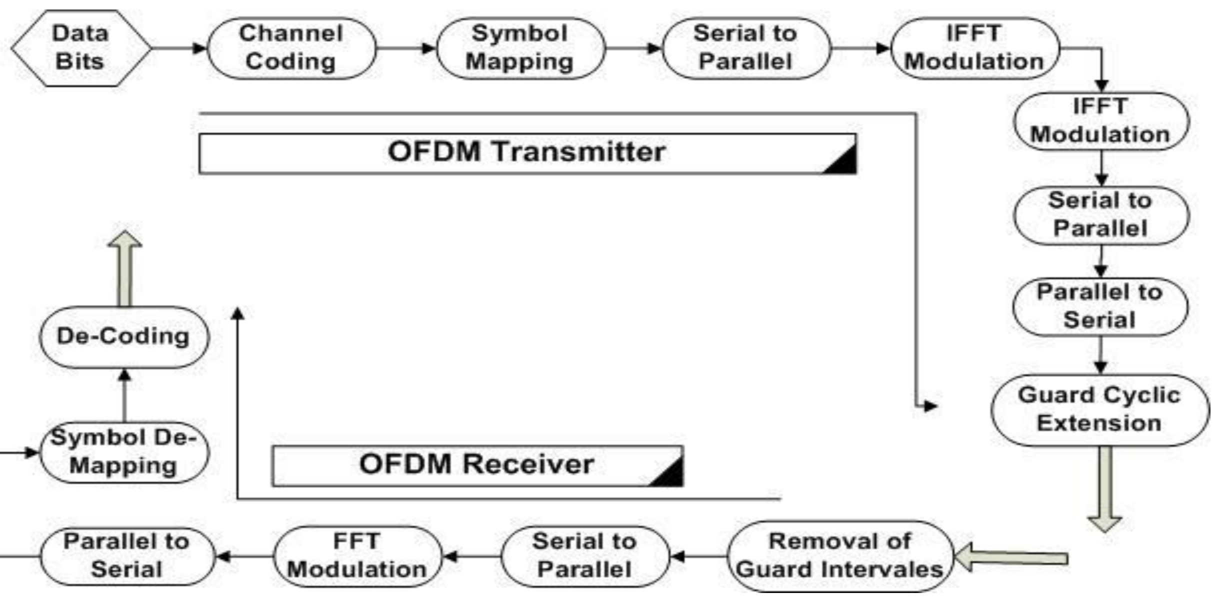


**Fig 1**: **Block Diagram of OFDM System**

**1.6 2.2 Proposed Design Strategy for OFDM:** OFDM is required to be used for multicarrier technology in current mobile systems for removing problems, such as

i. Sensitivity to multipath circumstances and low bandwidth efficiency.
ii. Issues of Interference and issues of data capacity and complexity during the processing of High signal.
iii. Insufficient presentation of high-speed data broadcasting.

OFDM is an element for performing experiments on broadband wireless systems, which works based on particular frequency and time variant channels. Hutter presented a suitable design criterion for the OFDM symbol duration in 4 based on two (02) parameters i.e. the maximum delay time, reflecting the bandwidth efficiency, system robustness and maximum Doppler frequency.

Ting-Ting Cao et al, in 5 stated that MIMO (OFDM) communication systems provides high data rate. Therefore they constructed MIMO-OFDM communication systems in their research work. The Least Square algorithm, the Minimum Mean Square Error algorithm and (SVD) algorithm were studied on the MIMO-OFDM communication systems for getting comparisons to evaluate its performance in 5.

Subsequently, in this paper, the strategy to add the block of SVD in OFDM has been adopted for data needs to be sent on multicarrier in this way, one data matrix was divided into the diagonal matrix. The only diagonal matrix computed by this means throughout the whole OFDM procedure which not only reduces the probability of noise impact on the OFDM data but also increases the probability of receiving the correct data. The concept was implemented and analyzed the graph of OFDM-SVD with Rayleigh AWGN.

Therefore, the purpose of the research is to conclude that the Rayleigh Channel with equalization concept, Gray Code QPSK, Interleaving, and Convolution Encoding reduce the BER. However, by applying the concept of SVD further increases the probability of receiving correct data on WiMAX modems against WiMAX physical Layer attributes for WiMAX communication more reliable and transparent.

**1.7** **2.3 Related Work:** Peng Wang et al, in 6 proposed a solution for enhancing the data rate by using of SBJA algorithm with total transmit power and quality of service (QoS). Yuping Zhao 7 in his paper presented the way to calculate the theoretical BER in OFDM systems by using ICI self cancellation algorithm. Zhao Li in 8 described a new scheme for elimination of ICI in OFDM systems by applying concept of Repeated Symbol. Zhenyu Zhou proposed the SAIC i.e single antenna interference cancellation algorithm to reduce the BER due to Co Channel Interference in OFDM systems as mentioned in detail in 9.

**1.8** Xia WangXi'an presented an algorithm for de-correlation of interference cancellation by using equalization at the receiver in the domain of frequency as narrated in 10. He described that instead of using the iterative operation in computations, by recurring embedding algorithm. XueLi et al, proposed an ICI cancellation scheme known as Total ICI elimination function in 18 which entirely removed the impact of Interference in OFDM systems. This proposal has no impact on bandwidth efficiency and takes benefits of the orthogonality of the ICI affected matrix for removing the ICI perfectly.

**1.9** Zhenyu Zhou proposed the SAIC i.e single antenna interference cancellation algorithm to reduce the BER due to Co Channel Interference in OFDM systems as mentioned in detail in 25. The proposed algorithm together decodes the preferred and intrusive data by the use of a joint trellis, which describes all forms of encoder trellis about Base station. The results reduced the Bit Errors for OFDM systems under brutal CCI conditions.

**1.10** Elnoubi, S. 19 did work on OFDM. In broadband wireless communication, the adaptive antenna array (AAA) is combined with (OFDM) to minimize the (ISI) and the directional interferences. His work obtained the optimum weight set based on minimum bit error rate (MBER) criteria in pilot-assisted OFDM systems under multipath fading channel.

**1.11** Radio Frequency impairment may cause expansion and rotation in the signal constellation, and distort the performance of OFDM. NguyenThanhHieu et al, 20 derived an expression for OFDM system to calculate the BER according to amplitude, phase non identical error parameters. This minimizes BER and experimental values become closer to theoretical values.

**1.12** Yuping Zhao et al, proposed a scheme according to which at transmitter, we will modulated one symbol of data on group of contiguous subcarriers. 21The weighting coefficients were used to minimize the ICI. At the receiver side, the received signals were combined linearly to reduce the ICI. Yung-Fang Chen proposed the adaptive beam forming schemes for OFDM-based systems. This beam forming vector is eigenvector based on consequential matrix. Simulations presented in 22 utilize the OFDM to demonstrate the effectiveness of planned hypothesis.

**1.13** Yuan-PeiLin in 23 analyzed the BER performance in 23 of pre-coded OFDM with equalization schemes. If the SNR value become very high then response of optimal pre-coders become just like that of MMSE receivers. Gupta, B stated in 24 that, for wideband transmission the OFDM technology along with MIMO technology can minimize the inter symbol interference. MIMO-OFDM systems keeping the factor of space and frequency diversity improved the performance of system.

**1.14** In his work, the Space-Frequency (SF) block coding for MIMO-OFDM the equalizers were investigated and the analysis regarding BER are presented in 24 based on different equalizers.

**1.15** **2.4 Proposed Methodology:** Scientists are using windowing and frequency domain coding to remove the ICI and to get better the BER routine of OFDM in wireless GSM channels. Hence, ICI cancellation improved the presentation more and more. Even then BER performance is worse as compared to BER concert of OFDM done without ICI.

Further, ICI self-elimination reduced the ICI at the low transmission rate and reduced the efficiency of the bandwidth. Other frequency domain programming functions did not minimize the data rate and formed less reduction in ICI. Based on above, the purpose of the Research is to find out a solution to minimize the Bit Error Rate by first implementing the OFDM in MATLAB. This OFDM has been finalized first by programming the basic OFDM structure including the given below blocks/units and implementing the concept of SVD so that we can improve the BER using OFDM system.

**Transmitter:**

- Bits Interleave Block.
- Convolutional Encoder Block.
- QPSK Modulation Block
- IFFT Block.
- Addition of Guard Intervals

Addition of Cyclic Prefix.

Addition of Noise held when data with guard intervals and cyclic prefix will be sent in space/air. After addition of noise the data will be received by receiver and data passes through the following bocks of the receiver.



**Receiver:**

Removal of Cyclic Prefix Block. 2) Removal of Guard Intervals Block. 3) FFT Block. 4) QPSK Demodulation Block.5) Convolutional Decoder Block. 6) De-Interleave Block. After programming the complete implementation of OFDM, the concept of Singular Value Decomposition (SVD) has been applied to reduce the BER and to make the OFDM performance better.

*2.5 Structure of OFDM:* **The Block wise functionality of the OFDM is as given below:**

**Bits Interleave Block and Convolutional Coding:** The binary data receives by inter-leaver where binary data re-arrange in non-contagious form to increase system performance. Convolutional encoder encodes the data in order to correct random errors as well as burst errors using shift registers 11 from where, data moves towards Carrier Modulation block.

**Symbol Mapping:** Carrier Modulation shifts the frequency operation to higher values providing better coverage and reducing the length of the antenna to a practical size according to the transmission wavelength. There are two (02) classes of carrier-modulated techniques that are used in a wireless network, 1) Traditional Radio Modem. 2) Spread Spectrum Modems by changing Amplitude, Frequency and, Phase Modulation Techniques. The two (02) most commonly used modulation techniques in traditional wireless networks are GMSK and π/4 QPSK.

**Serial to Parallel Conversion:** OFDM has been derived from FDM which is used for spacing the sub-channels closer to each other. This is due to orthogonal frequencies that are perpendicular on mathematical basis, permitting the spectrum of each sub-channel to overlap with one another without interference. Therefore during implementation of OFDM, this block has been added to convert the data in serial transform into parallel transform.

**IFFT Modulation:** OFDM system is implemented by the use of FFT and IFFT functions that are equivalent to DFT/IDFT as described by the author in 12, but more efficient to implement. An OFDM system takes the data from symbol mapping block in frequency domain. IFFT will take these symbols from frequency domain to time domain. The IFFT takes in X symbols equivalent to no of subcarriers in the system. Each input symbol has a specific Time Period in T seconds. The value of the symbol finds the amplitude/phase of the sinusoid against that subcarrier. IFFT output is the sum of all X sinusoids.

**Parallel to Serial Conversion:** After IFFT/FFT modulation and demodulation respectively, the data in OFDM is converted from Parallel to Serial transformation in order to have data in series to back to original format to recover the data.

**Guard Interval & Cyclic Prefix:** Use of guard interval is also one of the basic purposes of using OFDM, so that it can deal with multipath fading. The input data will be divided into multiple sub carriers. Guard intervals can be used for removing inter symbol interference. But these guard intervals can't remove intera symbol interference. Cyclic prefix will be used to remove the intra symbol interference. At the transmitter the constellation diagram in Figure 2.

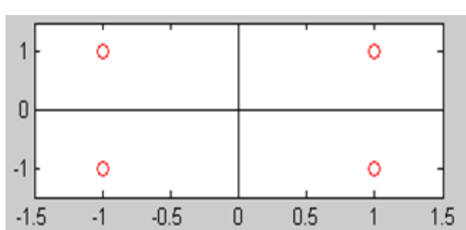


**Fig 2: Constellation diagram at Transmitter**

**Receiver Blocks:** At the end of receiver first the Guard Removal Block will remove all the added guard intervals in the input data stream. After removal of guard intervals the Cyclic Prefix will be removed from the remaining data. After removing the cyclic prefix the remaining data will be gathered and OFDM symbols sort out together to get the data back into the Original shape.

**Serial to Parallel Conversion:** After removal of Guard Intervals and Cyclic Prefixes, the matrix data will be converted from Serial to Parallel for implementation of FFT algorithm as the FFT function requires the data in the Serial Shape of matrix.

**FFT:** FFT is mathematically equivalent to function IDFT but more efficient to implement. At receiver FFT block is used to process the received signal data and bring the data into frequency domain.

**Parallel to Serial Conversion:** The received data from the FFT block of OFDM will be Parallel matrix that will be converted into Serial form of matrix data so that this data will be transferred to the block of Symbol De-Mapping.

**Symbol DE Mapping:** For QPSK demodulation, coherent demodulator is used. For this the receiver must know about the carrier frequency and phase of the transmitted data. This phenomenon may also called Phase Lock Loop. In the de-modulator the referenced frequency will be multiplied with signal data. A threshold detector will be used to distinguish the integrated bits. The bits on the in phase arm are known as the even bits and on the quadrature arm are known as odd bits.

**OFDM Convolutional Decoder:** Viterbi algorithm for the purpose of decoding the encoded data received at the receiver was introduced by scientists Andrew J. Viterbi.13 Viterbi algorithm recreates the most nearest path of the input sequences in such a way that the decoded data will be exactly like that of the input data symbols.

## 3. PROPOSED SYSTEM

Singular Value Decomposition (SVD) Singular value decomposition (SVD) is a way of transforming correlated variables into a set of uncorrelated variables which shows the relationship among original items of data. Singular Value Decomposition (SVD) is a technique to find out and sort the dimensions of data points to know about data points showing more variations. So in this way we can determine the best approximation of the original data points using fewer dimensions.

Hence, SVD can be used for data reduction. In case of 2 dimensional data points the regression line running through them will show the best approximation of original data with a line of 1 dimensional object. This minimizes the distance between each original point and the line. In case we have a perpendicular line from each point towards regression line and by taking intersection of those lines we may have reduced representation of data.

Incase if we get a second regression line perpendicular to the first line and it captures the variation which shows that less variation. In this way a set of uncorrelated data points may not be visible at first glance. Based on this idea SVD algorithm has been designed.

If we take highly dimensional and highly variable set of data points and if we reduce the data to lower dimensional space then we can expose the substructure of the original data and we can sort that data from most variation to the least. Hence, SVD can be used for Natural Language Processing applications and we can ignore variation below a particular threshold to massively reduce the data.

SVD is used to break a rectangular matrix into product of three Matrices 14. If there is matrix A that will be divided into three matrices such as given below:

2. An orthogonal matrix U.
3. A diagonal matrix S.
4. Transpose of an orthogonal matrix.

We may present the theorem as given below.

$$A_{xy}=U_{xx}S_{xy}V^{T}_{yy}$$

Here $U^TU=I$, $V^TV=I$. the columns of U are orthogonal eigenvectors of $AA^T$, the columns of V are orthogonal eigenvectors of $A^TA$, S is a diagonal matrix containing the square roots of eigenvalues from U or V in descending order

**3.1 Addition of Singular Value Decomposition:** SVD is extensively used in processing the data and reduction. SVD of several vectors may generate matrix of negative elements. SVD minimizes the errors and create positive matrices during computation. SVD can also be used for matrices decomposition, when SVD give in the essentials beyond the range of zero-one, while modified SVD decomposition produces the data in correct range at any step. 15.
SVD is a well-known technique used for factorization. SVD will decompose the matrix into set of orthogonal factors as well as to reconstruct the decomposed matrix. In reality a matrix will be decomposed into a smaller number of factors and will pres[illegible]he information in the matrix. The SVD expands the data in a system of coordinates with covaria[illegible]in diagonal 16.



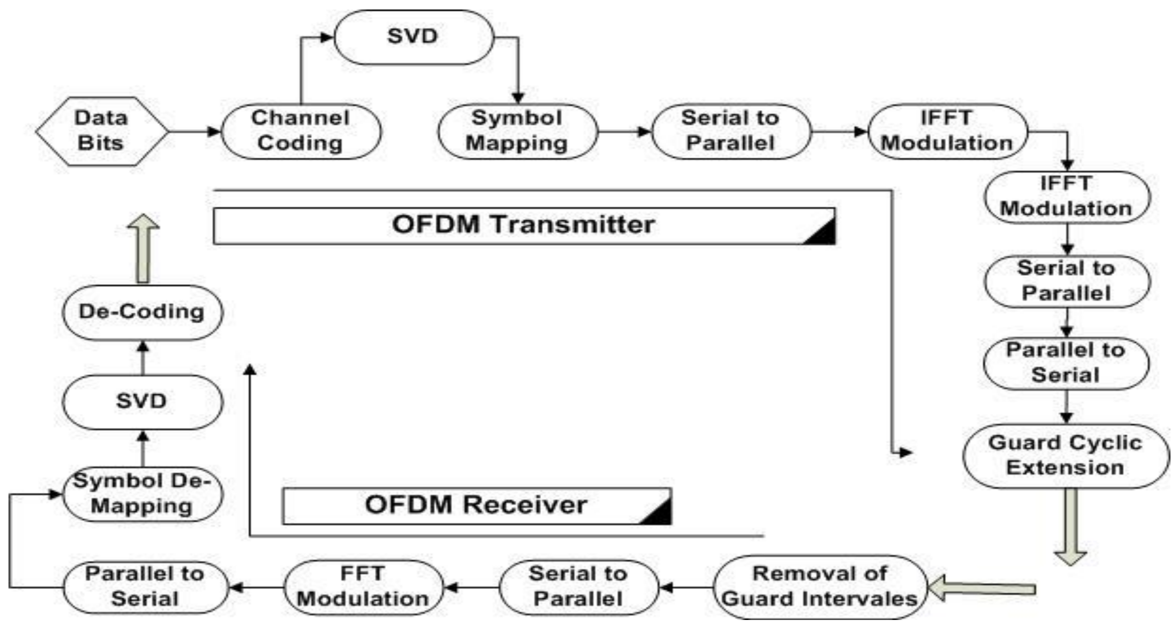


**Fig: 3 Proposed SVD OFDM Block Diagram**

SVD finds out the dimension of a matrix known as rank. The dimension of a matrix represents the no of rows or columns. The SVD can also obtain the inverse of a matrix and provides solutions to least-squares problems when matrices are singular 16.
**3.2 Impact of Singular Value Decomposition on WiMAX Modem***:* People in all over the world are using wireless communication systems. The most modern system WiMAX is using IEEE standard 802.16.
WiMAX technology has improved the data rate, security and coverage area of our wireless communication system. WiMAX provides the followings 17:

1. Broadband and IP connectivity for last miles
2. Provide LOS and non LOS wireless communication.

WiMAX is using OFDMA. OFDM is using the modulation technique on the physical layer of WiMAX along with the concept of cyclic prefix. The receiver removes the cyclic prefixes at the receiver to minimize the inter symbol interference and to improve the bit error rate 17.

Table 1: The parameters in the OFDM settings have been derived by using the Wimax Physical Layer attributes as per detail

| **Wimax Physical Layer OFDM Parameters** | |
|---|---|
| **Parameter** | **Type** |
| **Channel Bandwidth= BW** | **1.75 MHz** |
| **Number of Sub Carriers= Nused** | **200** |
| **Sampling Factor = n** | **8/7** |
| **Time of NULL Bits** | **1/4,1/8,1/16,1/32** |
| **Size of FFT** | **255** |
| **Sampling Frequency= Fs** | **Floor(n.BW/800)*8000** |
| **Spacing in Sub Carrier = Δf** | **Fs/NFFT** |

| | |
|---|---|
| **Time of Symbol = Tb** | **1/Δf** |
| **Time of CP= Tg** | **G.Tb** |
| **Time of OFDM Symbol= Ts** | **Tb+Tg** |
| **Time of Sampling** | **Tb/NFFT** |

**3.3 Analysis of Proposed System***:* The goal was to design the OFDM on WiMax Physical layer and to reduce the impact of noise on data to be transmitted on multiple carriers.

The OFDM was first implemented without convolution coding using AWGN Noise. At the Receiver End the Results of OFDM were derived as shown below.



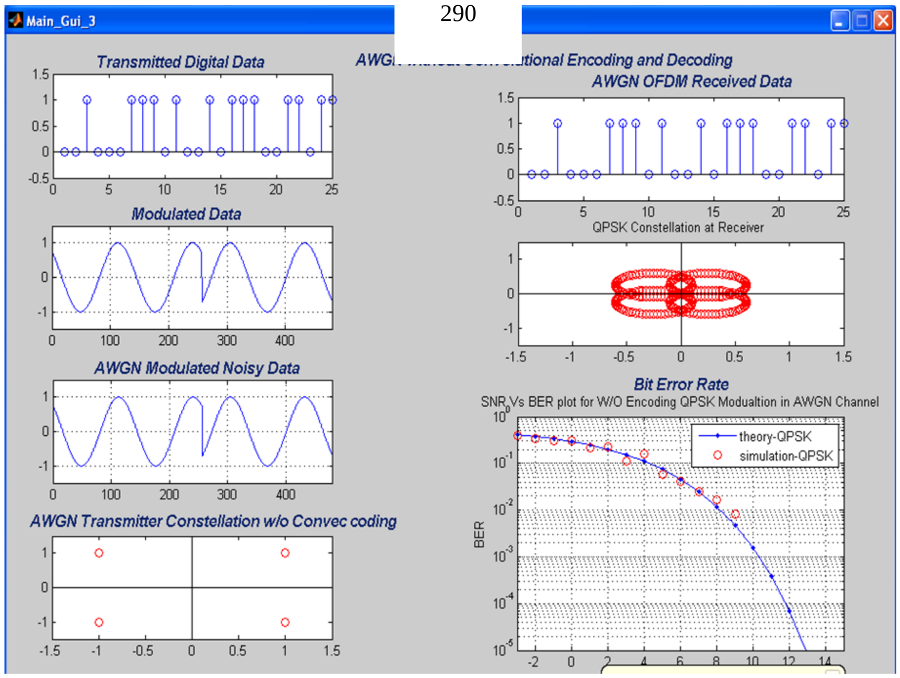


**Fig: 04 OFDM Results with ZERO AWGN Noise and without Convolution Code**

After this the OFDM was made with Convolution coding with AWGN Noise using Rayleigh channel. Then at the receiver end the Constellation diagram and graph between BER and SNR was shown as given below:

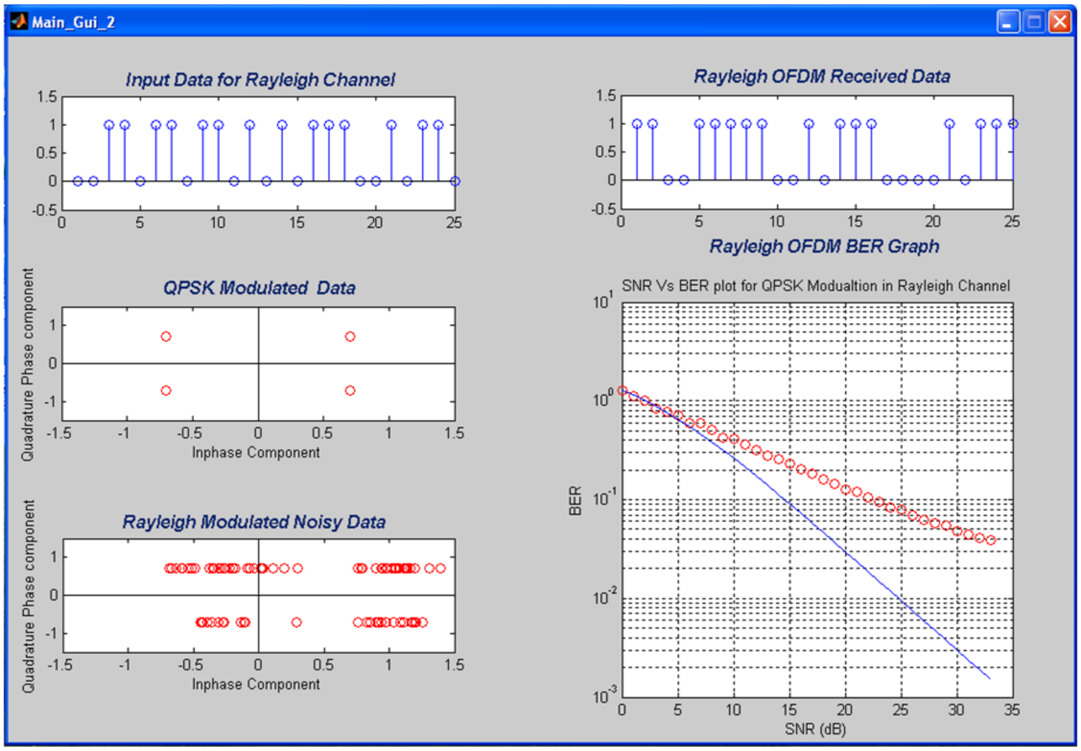


**Fig: 05 OFDM Results with Convolution Coding and Rayleigh Channel**

Then Comparison graph was made between AWGN and Rayleigh outputs with Noise. This shows deviations from theoretical graphs as shown below.

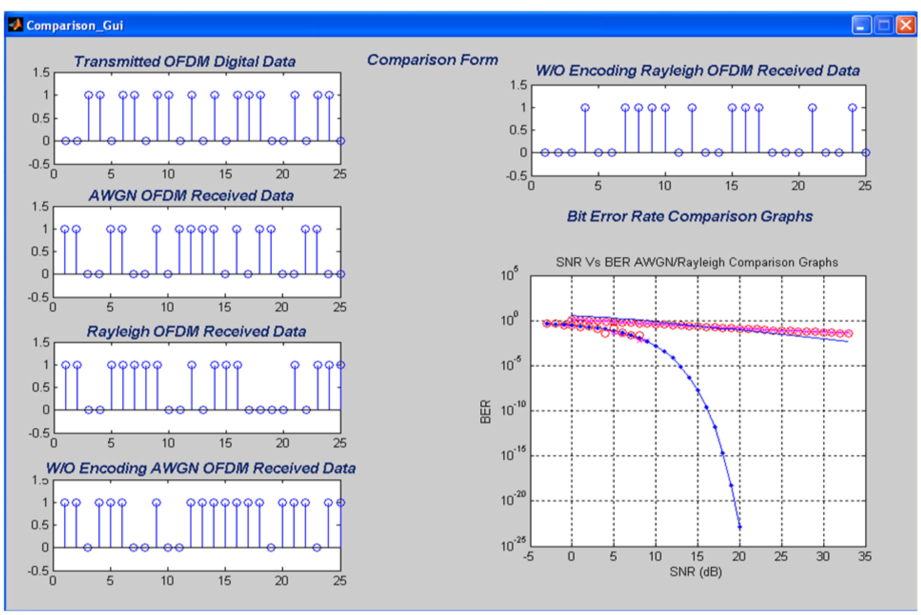


**Fig: 06 OFDM Comparisons of Results with Noise**

Then in next step it was decided to make the OFDM with implementation of SVD with noise variance i.e 0.5. Then at the receiver side the constellation diagram and received signals shows maximum similarity as compared to input signal. Hence, the comparison graph of AWGN and Rayleigh Channel with implementation of SVD was concluded as given below.

## 4. RESULTS AND DISCUSSION

In order to make this wireless communication system more robust and reliable this system should work against IEEE standard. There are many WiMAX shortcomings w.r.t coverage area, data rate and security.

For minimizing these demerits, OFDM has been decided to use by WiMAX on its physical layer. This combination of OFDM and WiMAX physical layer attributes is better to reduce the interference among the symbols and to reduce the bit errors. For achieving above mentioned goal, it was first decided to program the OFDM and to program the OFDM in MATLAB, it was necessary to understand the concept of each block of OFDM. Therefore, this research addresses the implementation of the OFDM blocks as mentioned above, in MATLAB.

The blocks known as Inter-leaver, Convolution Encoding, Modulation with QPSK, addition of guard interval and cyclic prefixes were programmed in such a way that if we execute these blocks in reverse then the output should be same as the input was given. Therefore for reverse order operation, the blocks such as removal of cyclic prefixes and guard interval, demodulation, Viterbi decoding and de-interleaving were programmed in MATLAB. Each block has its own specification.

After implementation of this block the system was introduced with Noise. This noise is the source of interruption of data sequences in space. Therefore our basic purpose of this research work was to design the OFDM on WiMAX physical layer in such a way that the impact of this noise on the data would be small enough. The bit loading algorithms have been discussed by some authors whereas in this thesis the algorithm of SVD has been thoroughly investigated. The basic purpose of SVD is the factorization of Matrix data. This factorization of data not only reduces the impact of noise on the transmitted data but also can increase the reliability of received data particularly in MIMO-OFDM.

Therefore, the OFDM first implemented without SVD and analyses were made by using OFDM with convolution coding as well as without convolution coding. Then use of OFDM was made with AWGN and then AWGN with Rayleigh Channel. Separate graphs were plotted for each section. According to the results of OFDM, it has been concluded that the OFDM without convolution coding shows poor performance as compared to the OFDM with convolution coding **(**see Fig. 7).

As far as symbol mapping is concerned, the Gray code of QPSK is much better than procedural programming of QPSK because the Gray code QPSK compute the data on constellations which is helpful to identify the amount of data which is near to input results on constellations. Further, the OFDM with QPSK Gray Code and Convolution encoding was refined with guard intervals and cyclic prefix that reduced the probability of inter symbol interference (see Fig. 5). Beside this scheme even the Bit Errors can be realized in the flow of data as shown in Figure respectively. Then the strategy adopted to add the block of SVD in OFDM for data needs to be sent on multicarrier in this way one data matrix was divided into the diagonal matrix.

The only diagonal matrix computed by this means throughout the whole OFDM procedure which not only reduces the probability of noise impact on the OFDM data but also increases the probability of receiving the correct data. The concept was implemented and analyzed the graph of OFDM- SVD with Rayleigh AWGN. Figure 8 shows that the experimental SVD-Rayleigh graph is much closer to theoretical graph even with noise variance of 0.5 NV.

### Bit Error Rate Comparison Tables:

Table 2: Assessment of Bit Error Rate and SNR in OFDM using AWGN

| Description | Signal to Noise Ratio (dB) | Theoretical Bit Error Rate | Experimental Bit Error Rate | Remarks |
|---|---|---|---|---|
| **Evaluation of Bit Error Rate and SNR in OFDM using AWGN.** | -2 | 0.5 | 0.5 | Same |
| | 0 | 0.2 | 0.150 | Error |
| | 2 | 0.9 | 0.9 | Same |
| | 4 | 0.1 | 0.450 | Error |
| | 6 | 0.0 | 0.023 | Error |
| | 8 | 0.0 | 0.005 | Error |
| **Percentage Accuracy** | 33% | | | |
| **Percentage Error** | 67% | | | |

**Table 3: Assessment of Bit Error Rate and SNR in OFDM using AWGN without Convolutional Coding**

| Description | Signal to Noise Ratio (dB) | Theoretical Bit Error Rate | Experimental Bit Error Rate | Remarks |
|---|---|---|---|---|
| Evaluation of Bit Error Rate and SNR in OFDM using AWGN without Convolutional Coding | -2 | 0.5 | 0.15 | Error |
| | 0 | 0.2 | 0.45 | Error |
| | 2 | 0.9 | 0.45 | Error |
| | 4 | 0.1 | 0.1 | Same |
| | 6 | 0 | 0 | Same |
| | 8 | 0 | 0 | Same |
| Percentage Accuracy | 50% | | | |
| Percentage Error | 50% | | | |

**Table 4: Assessment of Bit Error Rate and SNR in OFDM using Rayleigh Channel with Convolutional Coding**

| Description | Signal to Noise Ratio (dB) | Theoretical Bit Error Rate | Experimental Bit Error Rate | Remarks |
|---|---|---|---|---|
| Evaluation of Bit Error Rate and SNR in OFDM using Rayleigh Channel with Convolutional Coding | 0 | 1 | 1 | Same |
| | 5 | 0.1 | 0.1 | Same |
| | 10 | 0.5 | 0.3 | Error |
| | 15 | 0.1 | 0.18 | Error |
| | 20 | 0.05 | 0.1 | Error |
| | 25 | 0.01 | 0.1 | Error |
| Percentage Accuracy | 33% | | | |
| Percentage Error | 67% | | | |

**Table 5: Assessment of Bit Error Rate and SNR in OFDM using Rayleigh Channel without Convolutional Coding**

| Description | Signal to Noise Ratio (dB) | Theoretical Bit Error Rate | Experimental Bit Error Rate | Remarks |
|---|---|---|---|---|
| Evaluation of Bit Error Rate and SNR in OFDM using Rayleigh Channel without Convolutional Coding | 0 | 1 | 0.1 | Error |
| | 5 | 0.1 | 0.13 | Error |
| | 10 | 0.5 | 0.18 | Error |
| | 15 | 0.1 | 0.45 | Error |
| | 20 | 0.05 | 0.08 | Error |
| | 25 | 0.01 | 0.1 | Error |
| Percentage Accuracy | 0% | | | |
| Percentage Error | 100% | | | |

**Table 6: Impact of SVD on BER in OFDM using Rayleigh Channel with AWGN and Convolutional Coding**

| Description | Signal to Noise Ratio (dB) | Theoretical Bit Error Rate | Experimental Bit Error Rate | Remarks |
|---|---|---|---|---|
| Impact of SVD on BER in OFDM using Rayleigh Channel with AWGN and Convolutional Coding | ZERO | 0.10 | 0.45 | Error |
| | 5 | 0.0 | 0.0 | Same |
| | 10 | 0.45 | 0.45 | Same |
| | 15 | 0.0 | 0.0 | Same |
| | 20 | 0.0 | 0.0 | Same |
| | 25 | 0.0 | 0.0 | Same |
| Percentage Accuracy | 84% | | | |
| Percentage Error | 16% | | | |

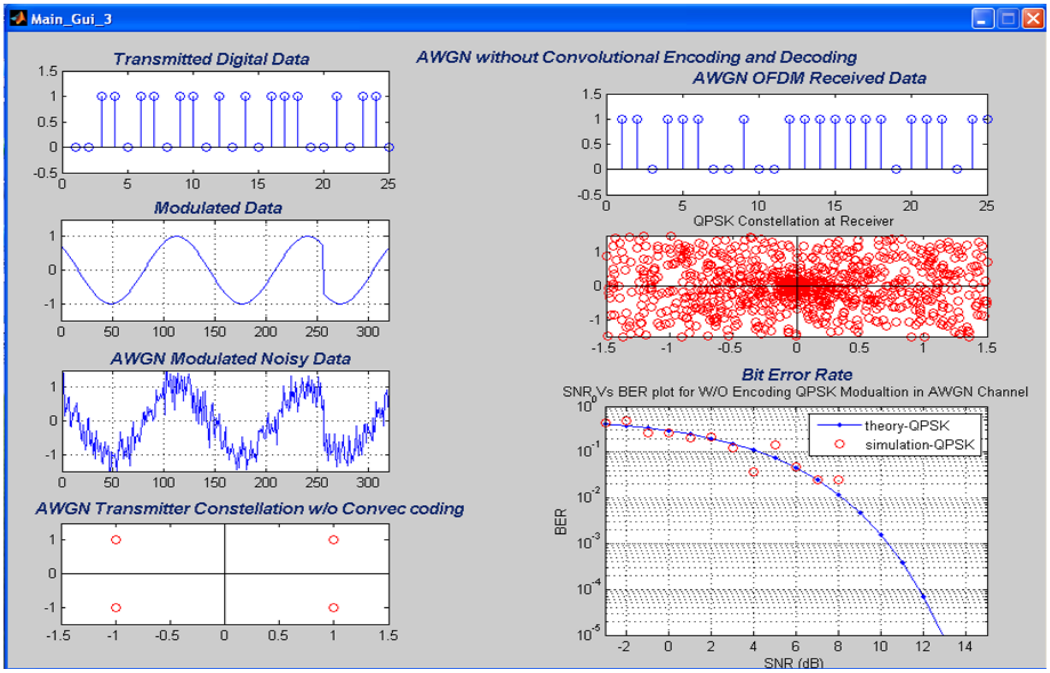


**Fig: 7 OFDM Results without Convolution Coding AWGN Noise**

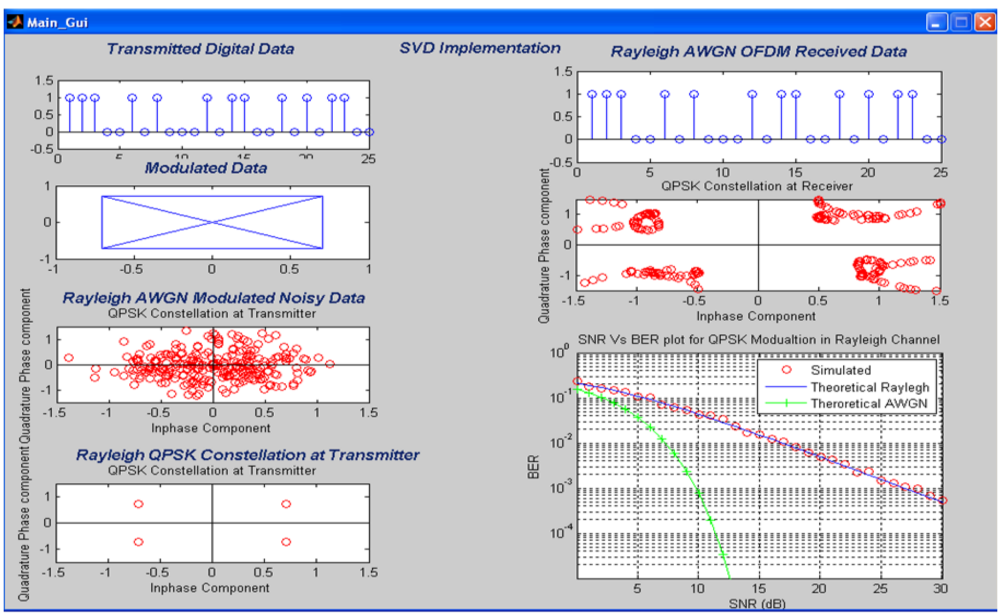


**Fig. 08: OFDM with SVD using Rayleigh Channel and AWGN with NV=0.5**

## 5. CONCLUSION

It has been concluded that Rayleigh Channel with equalization concept, Gray Code QPSK, Interleaving, and Convolution Encoding reduce the BER. However by applying the concept of SVD, further increased the probability of receiving the correct data. Hence if we implement this concept of SVD on WiMAX modems against WiMAX physical Layer attributes then our WiMAX communication can be more reliable and transparent. Further, the review of comparisons graph values have been discussed with respect to the graph plotted with different techniques as mentioned in Section 4 and snap shots. The comparison of BER values of OFDM with implementation of SVD is much better than the other researches in the literature.

By using SVD, one data Matrix was divided into the diagonal matrix. This diagonal matrix not only reduced the probability of noise impact on OFDM data but also increased the probability of receiving correct data. These results communication through Wimax Modem were more reliable and transparent.

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