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Performance Evaluation of WiMAX Physical Layer Using Matlab Simulink

* Remigius O. Okeke, Ifeoma B. Asianuba,
*University Of Port Harcourt Department Of Electrical/ Electronic Engineering Choba Rivers State Nigeria.
Corresponding Author: Remigius O. Okeke

ABSTRACT: *WiMAX standard operation given as IEEE 802.16d for fixed wireless users and 802.16e for mobile wireless applications provides a worldwide interoperability for microwave access. It is known that WiMAX is a superior technology for Broadband Wireless Access (BWA) such that it can cover an approximate range of 30Km to 50Km. The Physical layer of the WiMAX operates on the principle of Orthogonal Frequency Division Multiplexing (OFDM). This multiplexing approach is a transmission scheme that provides high-speed data for the video and multimedia streaming. It is used by variety of commercial broadband technique systems which include Digital Subscriber Line and Wireless-Fidelity. Besides WiMAX, OFDM is a refined and efficient scheme for high data rate transmission in a non-line-of-sight and multipath fading radio environment. Due to the multipath fading, temporal variation in channel, an Adaptive Modulation and Coding (AMC) technique is beneficial with OFDM to aid in minimizing the multipath effect. This technique consists of a variety of modulation and channel encoding schemes to provide the QoS. This is achieved by adapting channel SNR variation that provides maximum output while improving Bit Error Ratio performance at all channel conditions. In this paper, a model of WiMAX, is formulated and analysed under different modulation techniques with different coding rates using the MATLAB 7.9.0 (R2009b) Simulink. All the parameters used are European Telecommunications Standards Institute (ETSI) & Institute of Electrical and Electronics Engineers (IEEE) Standard.*

KEYWORDS: *WiMAX, 16-QAM, 4-QAM, 64-QAM, BER-to-SNR, Physical Layer.*

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I. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) is an advanced alternative broadband wireless communication technology that sustains excellent speed of data transfer for communication purpose over long distance. The IEEE standard nomenclature for WiMAX is established on radio frequency scheme known as Orthogonal Frequency Division Multiplexing (OFDM). OFDM can further be described as a single modulating scheme which splits a high data rate signal into slow narrow band modulated signal with subcarriers of close interval. This characteristic is peculiar to OFDM and is invariably responsible for its reduced frequency selective fading associated with the modulation scheme. WiMAX is different from other alternative broadband technologies because it provides a higher data rate, high speed of broadband service, and cost effective which in turn makes it easier to be deployed to remote areas. It operates at a higher speed over great distance for a number of users due to its broad coverage [1].

In the telecommunication industry, the Open Systems Interconnection model (OSI model) is applied to allow for interoperability of various communication systems. This is achieved by partitioning the system into layers for effective communication process to be achieved. The Physical layer is the first layer that connects a link layer device to a physical medium. It is the layer responsible for the transmission and reception of raw bit streams and interfaces between devices. It is the point where data is been converted to signals, consequently it handles the transmission of bits over a communication channel and act as the central point of choice for wired or wireless communication.

Research has shown that this physical layer from the OSI model is the most unreliable layer in any wireless system which makes it prone to errors. It is however a major challenge to achieve an error-free communication in WiMAX. In order to achieve the required higher throughput, it is expedient to minimize the

BER as much as reasonably possible to achieve a higher SNR. The Problem is therefore the ability to improve the SNR at a certain limit based on the cellular network architecture.

II. REVIEW OF RELATED WORKS

Several studies have been done on performance evaluation of WiMAX physical layer.In [2] the performance of mobile WiMAX was evaluated for the various modulation schemes. The research outcome depicts that for very poor channel quality, energy efficient scheme like QPSK was deployed but when the channel quality is improved other higher modulation schemes were employed. This invariably portrayed the fact that the modulation scheme is dependent on channel condition. In [3], it was shown that the performance of WiMAX physical layer was based on the IEEE 802.16e standard. The essence was to evaluate and asses various modulation schemes and coding rate. The results showed the current trend for high rate mobile wireless services. Extensive analysis was carried out using OFDMA and scalable OFDMA modulation schemes for mobile WiMAX application [4]. In [5] the theory of the various adaptive modulation schemes was explored to give the implication for the choice of any modulation approach chosen for wireless mobile activity. In [6] the performance analysis of mobile WiMAX was evaluated using scatter plots, BER and SNR for different channel condition.

The location based performance of WiMAX network with optimal base station has been reported in [7]. Performance is evaluated for the scenarios with different number of stationary and mobile nodes. The research helped for the deployment of WiMAX system to any country with good QoS. The results showed that QoS has affected voice over IP and Moving Picture Expert Group (MPEG) format.

III. METHODOLOGY

In the Performance Evaluation of WiMAX Physical Layer, lot of Simulations were performed in actualizing this work. Identification of the type of simulation tool and parameters to be used is paramount, as it will determine the performance Analysis and results. The outcome is required to plot the BER and SNR in terms of Signal Strength and Constellation Diagrams. Another important consideration is the type of Modulation that was used to achieve the result.

Procedures For Implementing The Performance Analysis

- Identification of Simulation Tool; MATLAB 7.5.0 (R2007b), Simulink 7 and MATLAB 9.1.0 (R2016b) Simulink.
- Type of Modulation schemes used for the simulation; Binary Phase-Shift Keying (BPSK), Four Phase Quadrature Amplitude Modulation (4-QAM), 16-Point Quadrature Amplitude Modulation (16-QAM), 64-Point Quadrature Amplitude Modulation (64-QAM).
- Steps taken in achieving a workable running simulation.
- Blocks used in achieving the simulation of WiMAX physical layer; Random Integer Generator, Multipath Rayleigh Fading Channel, Error Rate Calculation, Adding Zero Forcing Equalizer.
- Plotting of BER Vs SNR graph

Research Analysis

The Model of the physical layer of WiMAX used in this work was built from the standard documentations of IEEE 802.16e using MATLAB 7.5.0 (R2007b), Simulink 7 and MATLAB 9.1.0 (R2016b) Simulink. MATLAB was the choice computer software application used to run the simulation because all the mandatory source blocks (systems) needed for the simulation is available in the MATLAB software tool box.

Types Of Modulation Used

The modulations formats used in evaluating WiMAX Physical Layer’s Performance include:

- BPSK
- 4-QAM
- 16-QAM
- 64-QAM

Block Arrangement

To implement this work, it is necessary to first achieve a BER plot of the physical layer of WiMAX. This is achieved by arranging the necessary blocks appropriately to give the desired result. The arrangement can be seen as shown in figure 1 below:

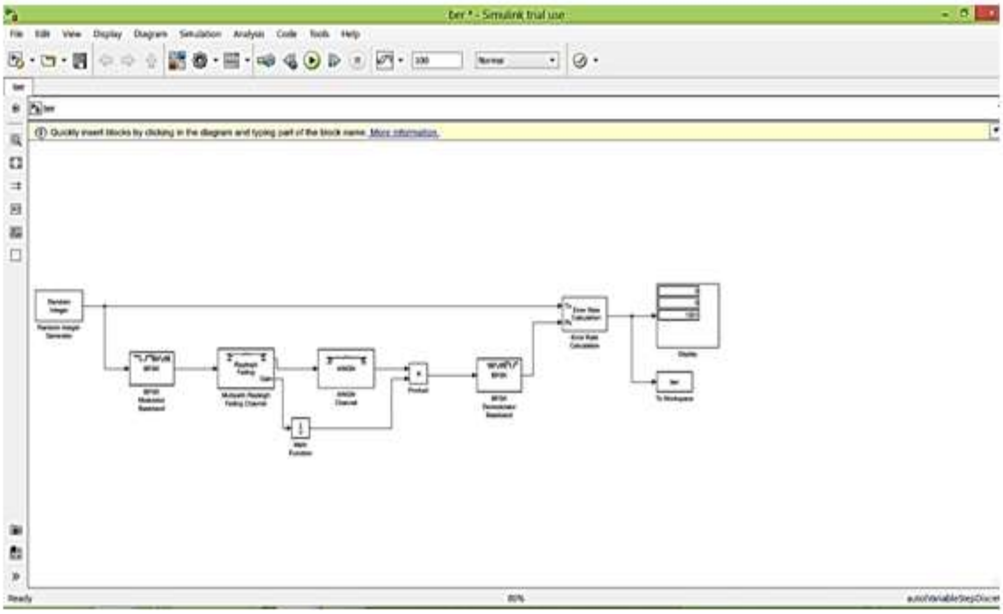

Figure 1: Block arrangement for BER plot in Simulink Environment.

Random Integer Generator

The same process of block resetting was done by double clicking on the Random integer generator block and changing the M-ary number to "2" and reducing the sample time to "0.1" This adjustment was done to give a suitable transmitting end together with the modulator block with a sample time that is fair enable for visible observation of the signal generated.

Multipath Rayleigh Fading Channel

The Multipath Rayleigh fading channel and AWGN (artificial white Gaussian noise) channel acts as the channel path for the model and proportionate adjustment were made to suite the standard. The Maximum Doppler shift figure was changed to "0.001Hz" and for the Doppler spectrum type, "Jakes" was selected. The Discrete path delay vector was adjusted to zero. For the Average path gain vector, the setting was adjusted to “0”. Since 100 is chosen as target number of error, the simulation time is set from the standard function ribbon section to "100" and then the simulation can be run. This adjustment is for the block to function the way these channels are meant to be.

Error Rate Calculation

The error rate calculation block is needed to calculate the bit error rate and to achieve this, the block parameters is reset to suit the demand. The output data portion was set to "Port". In the "stop simulation" section "100" was set as the "target number of error" and "1e4" was chosen as the maximum number of symbols.

Probability Of Symbol Error (Pe)

Pe is an important parameter which helps to determine the rate of error occurrence in a system. It is necessary to determine this probability since it affects fading and noise both at the transmission or receiving end of the system. The probability of Error for M-array PSK can be determined using Fading, and Doppler shift can increase the Probability of Error of the system thereby degrading the performance of the physical layer. At this circumstance, the channel is modelled as a Rayleigh distribution. The different error probability is presented in figure 1 for all adaptive modulation schemes.

Adding Zero Forcing Equalizer

To achieve this adding of zero forcing equalizer, a complex path gain port is added to the Rayleigh fading channel. A math function and a product function are further introduced to the system; the math function was further changed to "Reciprocal". The complex path gain port of the RFC was linked to the math function.

To further get the appropriate result, the output of the AWGN channel and the math function was linked to the input of the product function with the corresponding output connected to the input of the BPSK demodulator. This therefore put the block in the right state for simulation of the BER plot.

Plotting Ber Against Snr

These plots are used to determine and investigate the performance of different modulation schemes of WiMAX. In order to achieve this task, the following procedures were followed;

- Save the current stage of work with a unique name on a unique location on the workstation.
- Reset the "simout" block as follows: Change the variable name to "ber", the limit data points to last to "2", Save format to "Array", from Save 2-D signals as; select "2-D array (concatenate along first decimation)
- Link the "simout" output to the input of the display block.
- Reset the AWGN channel block as follows: change the "Eb/No(dB) column to "EbNo"
- Go to the command window of MATLAB, type: >>bertool and press the ENTER button.
- The Simulink displays a new window called "Bit Error Rate Analysis Tool", from where the function was adjusted.
- Click the "Theoretical" icon and the click plot; the system displays the plot of the chosen modulation type.
- Click the "Monte Carlo" icon and adjust the Eb/No range to 1:5:20.
- Save the current model arrangement on the Simulink environment.
- Choose the file saved in the "simulation MATLAB file or Simulink model" column
- Change the BER variable name to "ber"
- Click "Run simulation"
- From the "Theoretical" icon, the desired modulation scheme was adjusted (2-PSK, 4-QAM, 16-QAM, 64-QAM) for sampling as appropriate with the process repeated appropriately for each modulation scheme.

IV. TESTING AND RESULT

Performance Evaluation

Based on the WiMAX PHY Layer Model and tests carried out, the performance was established based on thousand symbols. In each case, the graphical representation is a logarithmic plot of BER versus SNR time-scatter plots for each module. This includes the Signal-to-Noise Ratios, time-scatter plot for the output from the transmitter and Fast Fourier Transform (FFT) scope diagram for the transmitted signal.

The BER plot obtained in the performance analysis showed that the model works well according to the channel condition. The time-scatter plots demonstrate the scattering of the transmitted and received signals for various values of the SNR. The result obtained also describes the fact that; at very low SNR the symbols are very difficult to recognize.

Wimax SIMULATION

Following the system arrangement for WiMAX on the Matlab Simulink environment, the screen shot shown below, shows different modulation techniques can be selected from the "bertool" dash board to observe the relationship between the performance responses of WiMAX to various modulation schemes. From the Binary Phase shift keying (BPSK) to the 4-QAM up to the 64-QAM modulation techniques. Samples are made to present a graphical evidence of the features of each technique used.

In this work, simulations were performed using the BPSK, 4-QAM, 16-QAM and the 64-QAM, at the same time. A comparative plot was presented for the different scheme under consideration.

Simulation Using Bpsk

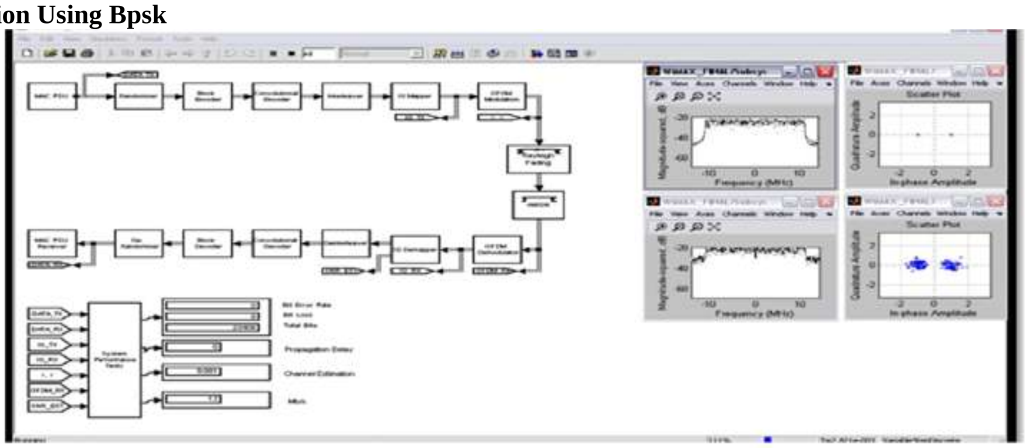

Fig. 2: System arrangement of the WiMAX on MATLAB.

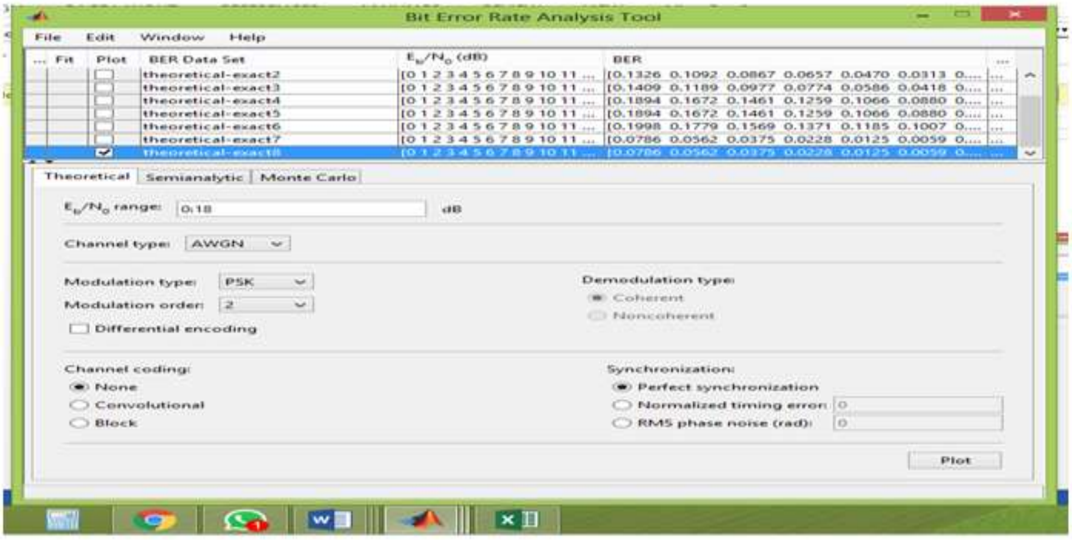

Fig. 3: BER Performance Analysis of BPSK

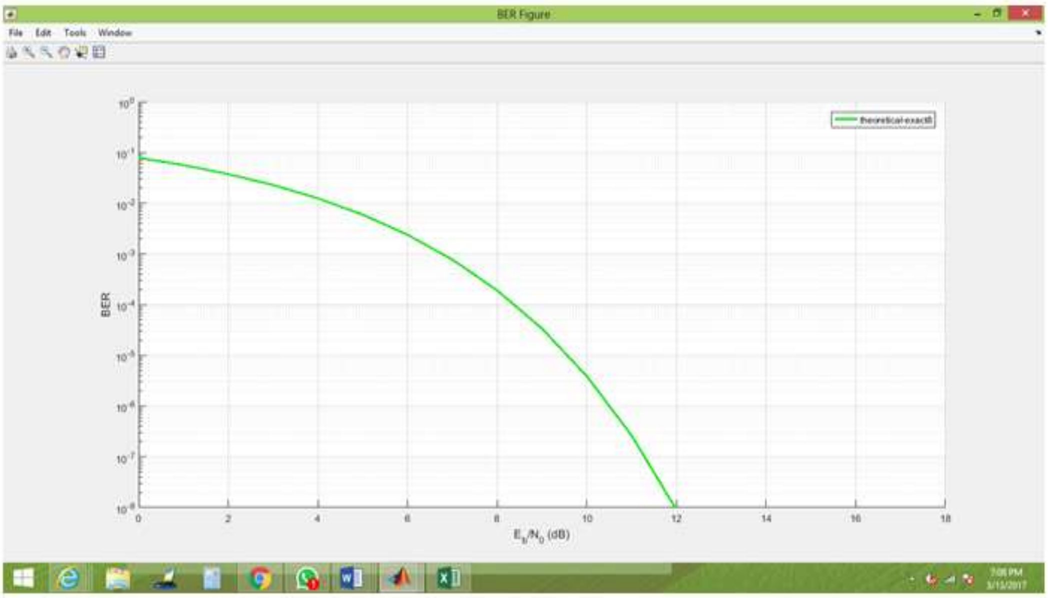

Fig. 4: BER-to-SNR Plot of BPSK

V. DISCUSSIONS

After the iteration of simulation, the result of signal-strength was obtained to disclose how the signal fades after passing through the channel. Constellation diagram shows the inter symbol interference.

It is known that in AMC concept when the channel has more noise, then WiMAX adopts the lower modulation technique. Now, the general question that arises is why the system does not function with higher modulation whereas the higher modulation technique gives the freedom of sending more data as compared to lower modulation technique.

The result shows that the higher modulation technique is not appropriate for the noise channel. This is because; it can be clearly observed that when SNR is too low, then the BER is nearly negligible, that’s why Binary Phase-Shift Keying (BPSK) is useful for noise channel.

Simulation Using 4-Qam

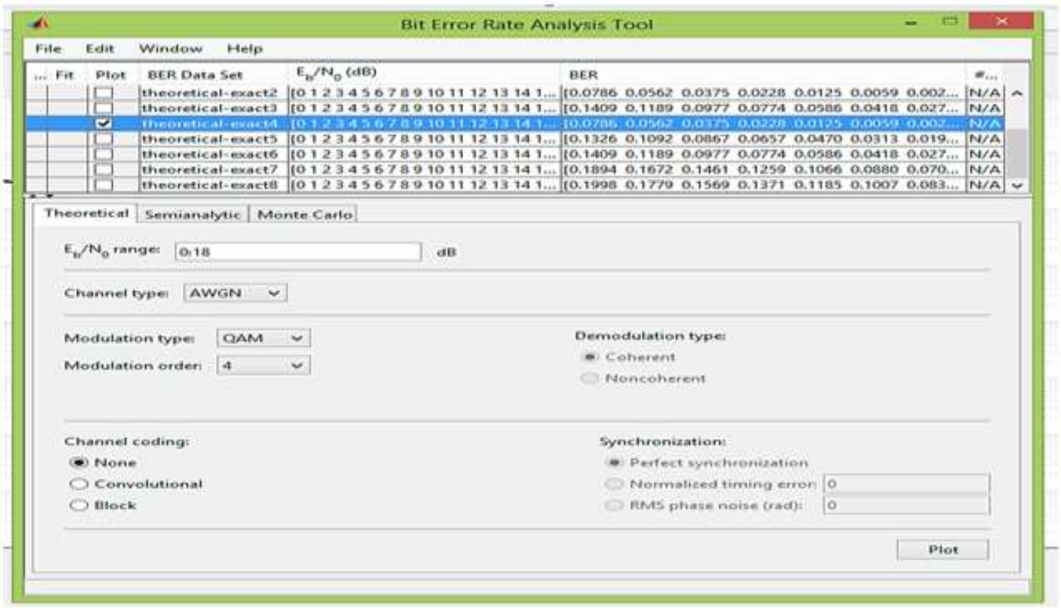

Fig. 5: BER Performance Analysis of 4-QAM

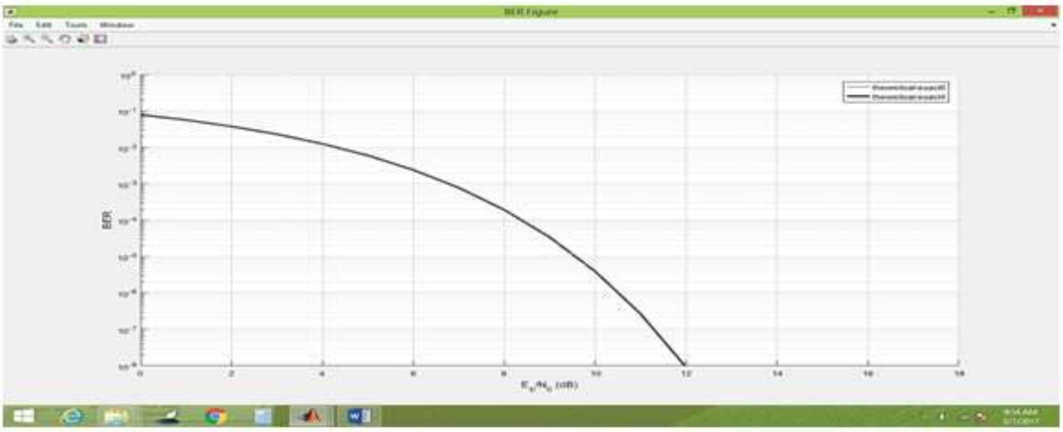

Fig. 6: BER-to-SNR plot of 4-QAM

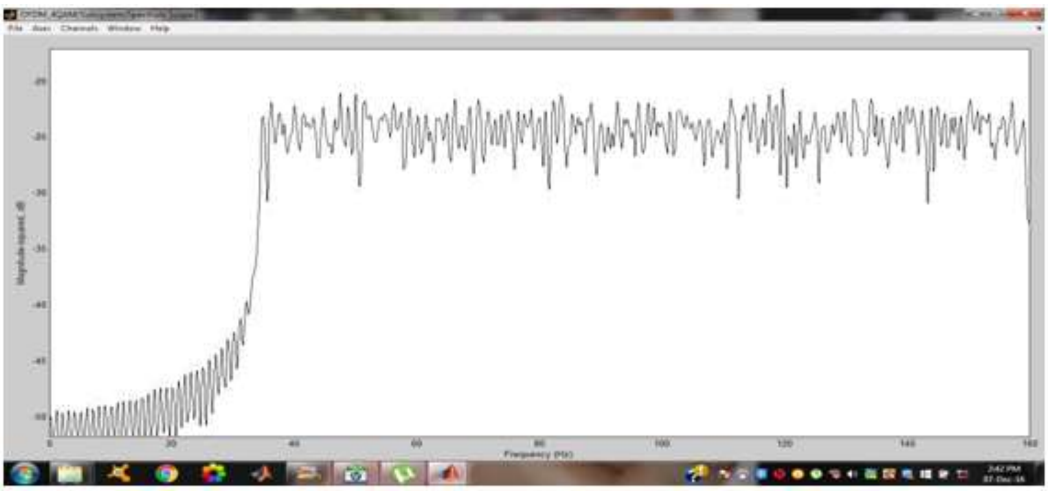

Fig. 7: 4- QAM result in term of Signal Strength

In figure 5, it is observed that 4-QAM with code rate of 1/2 have the greater capability to find and correct the errors through R-S encoding scheme. In 4-QAM with 1/2 code rate, the error correcting capability is 2t=8, where 4-QAM with code rate of ¾, is 2t=4. So it can be seen that the BER performance of 4-QAM with code rate of 1/2 is better than 4-QAM 3/4. When the channel condition is somewhat good, the upper modulation technique can be opt with choice of different code rate. The main advantage with higher modulation technique is that more number of bits can be imposed on a same carrier cycle, so large data throughput can be achieved.

Simulation Using 16-Qam

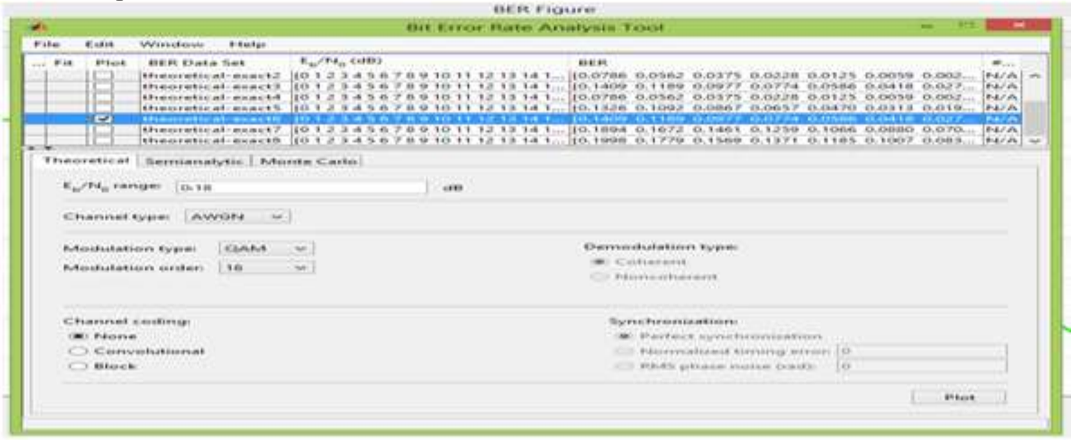

Fig. 8: BER Performance Analysis of 16-QAM

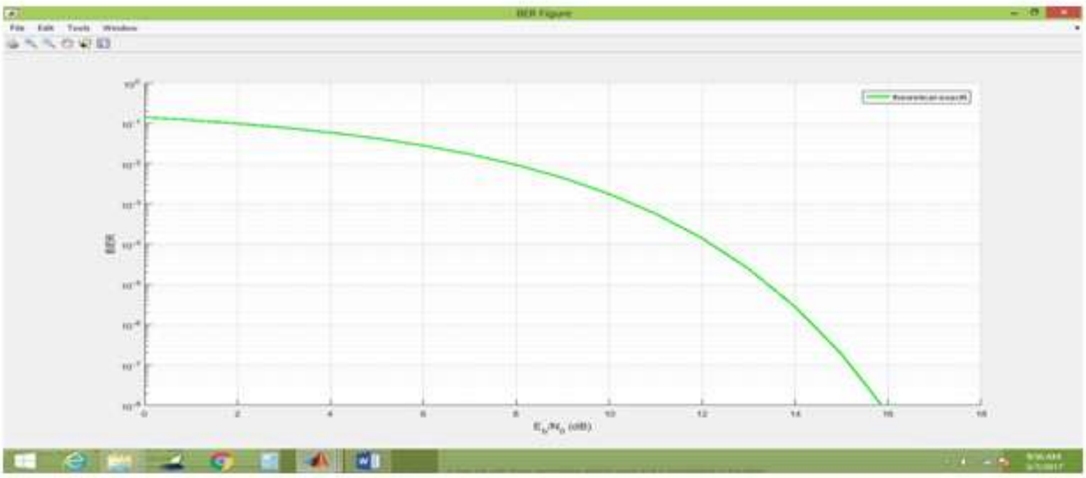

Fig. 9: BER-to-SNR plot of 16-QAM

Result Discussion

Apparently it is seen that 16-QAM with code rate of 1/2 have the greater capability to find and correct the errors through R-S encoding scheme. In 16-QAM with 1/2 code rate, the error correcting capability is 2t=16, where 16-QAM with code rate of ¾, is 2t=8. It is noticed that the BER performance of 16-QAM with code rate of 1/2 is better than 16-QAM 3/4. The question is, what is the need for 3/4 code rate whereas 1/2 is available which is more efficient? So the answer is, when the signal fluctuates for the less amount of noise level, then we have the choice under the less SNR level.

Simulation Using 64-Qam

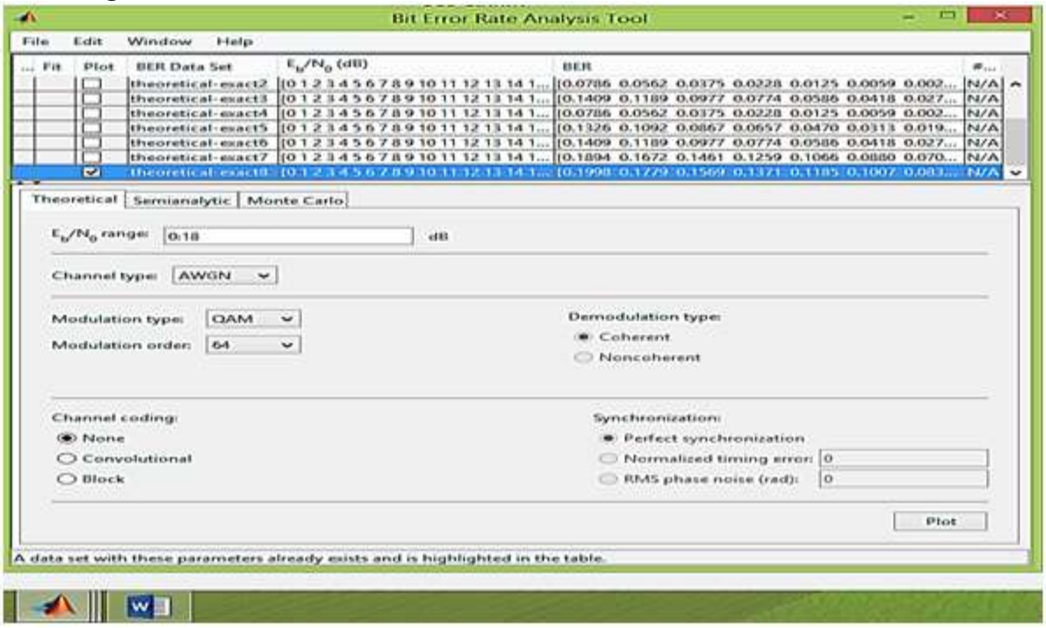

Fig. 10: BER Performance Analysis of 64-QAM

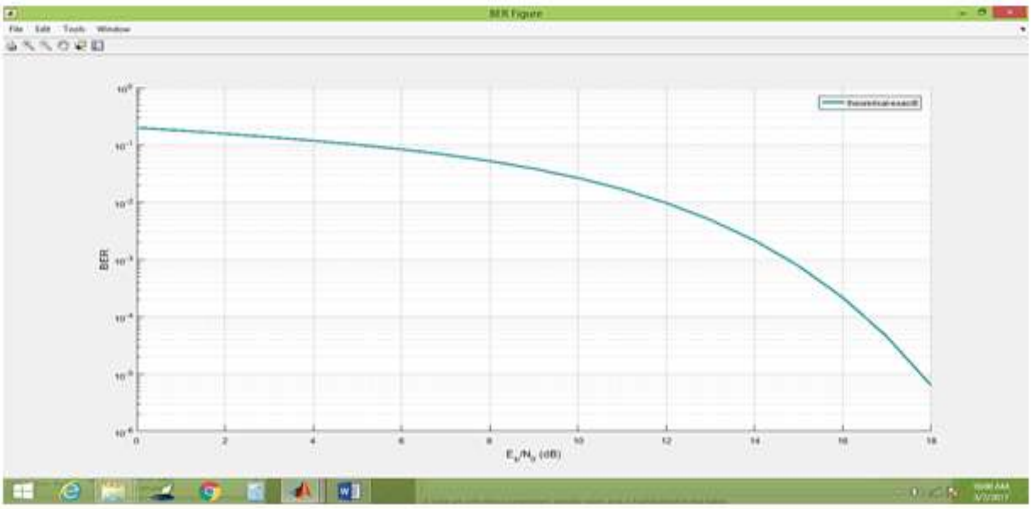

Fig. 11: BER-to-SNR plot of 64-QAM

Fig. 12: 64-QAM result in term of Signal Strength

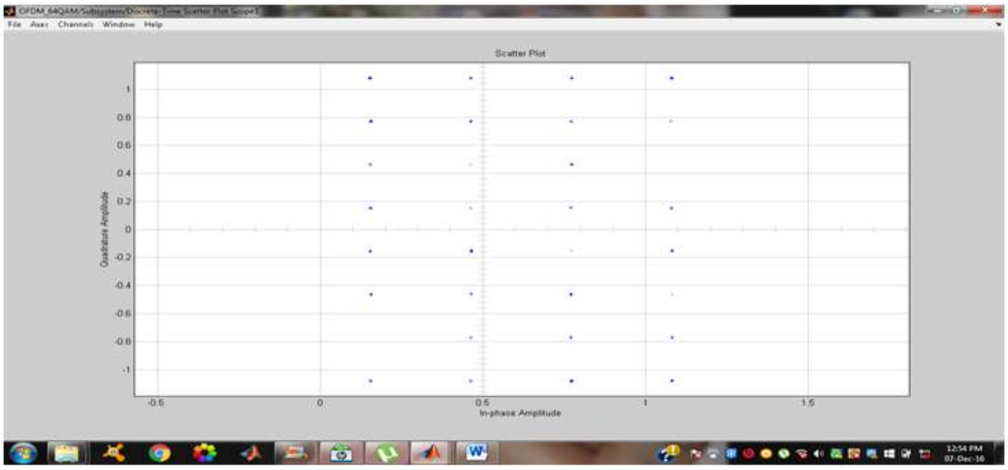

Fig. 13: Constellation diagram of 64-QAM

Result Discussion

In the last simulation, it can see that; when the SNR is high, a perfect communication process will be achieved. However; it can also be said that the BER depends on the FEC scheme. When the error correcting coding process is more efficient, then the BER is minimum.

The result shows that the higher rate (when more bits are sending on same time of interval) is only possible when the channel condition is good as we are saying in AMC. This invariably means that there is a trade-off between the throughput and BER on the constant SNR.

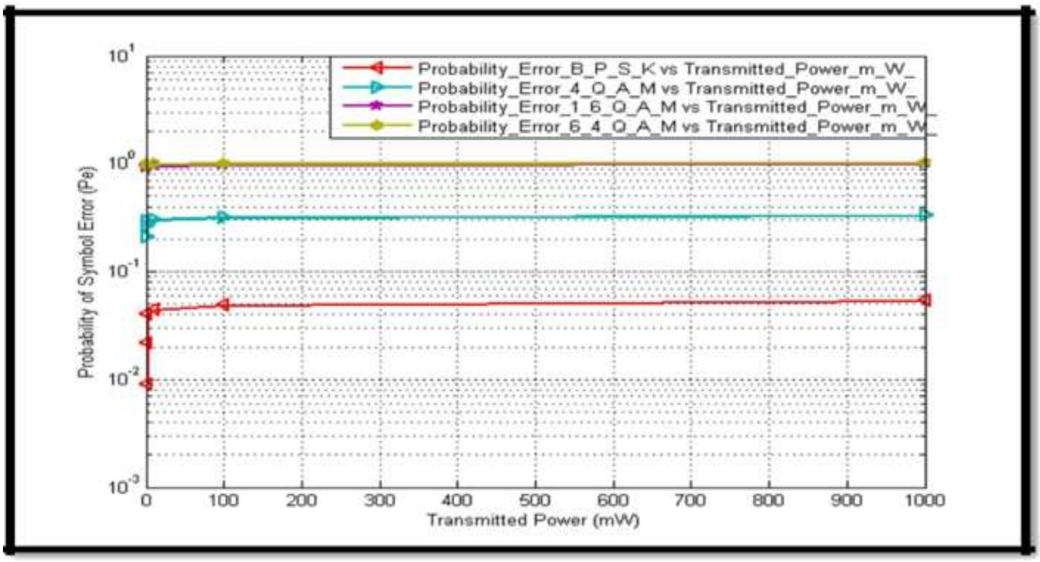

Fig. 14: Probability of symbol error for the different transmitted power

Analysis

After obtaining the result of two modules under the AMC, it is found that there is a trade off between BER and Modulation Scheme, i.e. when the channel condition is good then the system can choose the higher modulation scheme so that more data can be used without losing the bits. Choosing the higher modulation Scheme on the poor channel condition will deal with higher BER.

So the result shows that the lower modulation scheme gives the higher efficiency on the poor channel condition. This implies that, the lower the modulation scheme the better the SNR with respect to the BER. It can also be clearly seen in the result in table 1 below that the BPSK and QAM has the same values, this explains why the plot for BPSK was not visible from the plot shown in figure 4.

Table 1: SNR-BER Plot result for different modulation scheme.

Eb/No	BER			
	BPSK	4-QAM	16-QAM	64-QAM
0	0.0786	0.0786	0.1409	0.1998
1	0.0562	0.0562	0.1189	0.1779
2	0.0375	0.0375	0.0977	0.1569
3	0.0228	0.0228	0.0774	0.1371
4	0.0125	0.0125	0.0586	0.1185
5	0.0059	0.0059	0.0418	0.1007

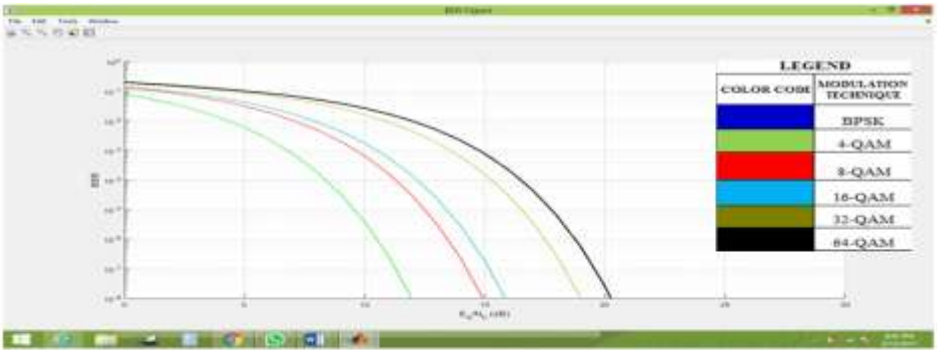

Fig. 7: BER-to-SNR plot showing results of different modulation techniques.

VI. CONCLUSION

In this work, the IEEE 802.16e physical layer has been modelled via simulation approach. This was achieved by investigating the performance of the different modulation scheme with respect to their coding rates. Since fading is one of the major challenges of wireless communication, it is important to model a scheme which will yield better transmission efficiency. The outcome of this research depicts that; for the same channel condition, the use of a lower modulation technique results in lower BER, reduced SNR and lower transmission efficiency. Whereas implementing a higher modulation technique will give a corresponding higher BER, SNR and also better transmission efficiency. This model will find useful application in analyzing the effect of different modulation technique and optimization of the entire communication system. And also by getting the probability of symbol error (Pe) we see that at lower power, the probability of error occurrence is very low for a constant bandwidth and at normal condition.

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