BER ANALYSIS OF WiMAX IN MULTIPATH FADING CHANNELS

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Abstract

In this paper, an effort has been made to inspect the performance of WiMAX OFDM physical layer under the effect of noise. An End-to-end baseband WiMAX OFDM physical layer has been modelled in Multipath fading environment using MATLAB Simulink. BER has been evaluated for the Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16 QAM) and 64 Quadrature Amplitude Modulation (64 QAM) schemes over a range of SNR (dB). The BER of a digital communication system is an important figure of merit for quantifying the integrity of data transmitted through the communication system. Several plots between BER and SNR (dB) for the abovementioned modulation schemes in Rayleigh and Rician fading channels have been investigated for the analysis.

Keywords: *BER (Bit Error Rate), SNR (dB), Multipath Rician Channel, Multipath Rayleigh Channel, WiMAX, BPSK, QPSK, 16 QAM, 64 QAM.*

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1. INTRODUCTION

Wireless communication systems have been continually evolving for many years now as a result of constant and massive developments in the field over the time. WiMAX is one of the culminations of such an expansion. WiMAX stands for "Worldwide Interoperability for Microwave Access". It is a part of the IEEE 802.16 standards and was developed by the Institute of Electrical and Electronics Engineers (IEEE). WiMAX was introduced as a standard, designated as 802.16d-2004 (fixed wireless) and 802.16e-2005 (mobile wireless) for providing worldwide interoperability for microwave access. At present, telecommunication industries have a concern for the wireless transmission of data which can use various transmission modes, from point-to-multipoint links. WiMAX contains full mobile internet access feature. A white paper for creating an executable specification has been provided by Mathworks which serves as a useful resource to build a simulation model for the WiMAX Physical layer [1].

In wireless signal propagation, the biggest challenge is to overcome the effects of fading. The multipath nature of channel leads to ISI (Inter Symbol Interference) and as bandwidth is increased, ISI affects the channel severely. Some unpreventable circumstances attenuate the signal energy and make it difficult to achieve the desired results from the system. The radio link between the Base Station (Source or Transmitter) and User can be a LOS (line-of-sight) or it can be a NLOS (non line-of-sight) the latter being severely obstructed by the environmental objects and features like buildings, weather conditions etc. In wireless communication, user has the freedom of mobility and mobile user changes its location with respect to base station. As a result of this relative motion, received signal strength is affected by three major fading phenomena – Diffraction, Scattering and Reflection [2].

The performance of wireless communication systems is highly determined by noise. Particularly, if signals are in a fade, the signal-to-noise ratio will be low and bursts of error will occur. Noise in wireless communication systems is any unwanted fluctuation, instability or disruption that induces itself within the transmitted data signal via different mediums and interfering objects. This abrupt fluctuation is also a basic characteristic of data signals, which are modulated electromagnetic waves that travel through the air from electronic communication devices and circuits. Noise in wireless communication systems can be categorized into many types ranging from the noise originating from electronic devices to that originating from external environmental factors. Scientists and researchers have taken significant steps to quantify and remove noise from data signals in order to facilitate wireless communication [3].

This paper is aimed at exploring performance of WiMAX system from BER perspective for differently modulated signals through Multipath Fading Environment. Noise will be added to the WiMAX Multipath fading channel in Simulink by using Additive White Gaussian Noise. BER variations will be noted over a particular SNR (dB) range for various modulation schemes.

Remainder of the paper is divided in following sections. Section 2 explores Multipath fading environment. Section 3 explores Modulation Schemes used. Section 4 shows the WiMAX Simulink model used and lists the WiMAX specifications used for implementing IEEE 802.16 Physical Layer in MATLAB. Section 5 lists and analyses the results. Section 6 concludes the work.

2. MULTIPATH FADING CHANNELS

In wireless mobile communications, the transmitted signal from the Base Station do not directly reach the Mobile user. There are several environmental obstacles that block the LOS (line of sight path). A signal travels from transmitter to receiver over a multiple-reflection path and causes fluctuations in the receiver signal's amplitude and phase. The sum of the signals arriving at the receiver of Mobile user can be constructive or destructive. The multipath propagation scenario is given in Fig -1 depicting three mechanism – Reflection, Scattering and Diffraction, influencing the signal propagation from Base Station to Mobile User [4].

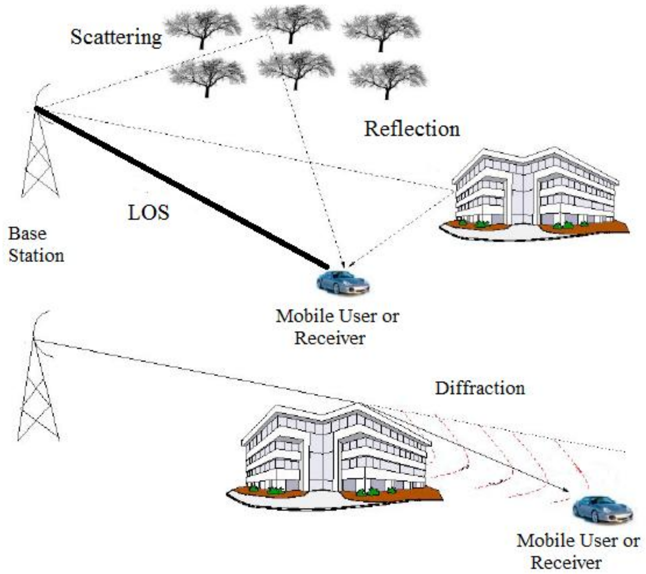

Fig -1: Fading Scenario

Rayleigh fading and Rician fading models, employing Rayleigh distribution and Rician distribution respectively, are most widely used to model the wireless channel. Rayleigh fading and Rician fading are statistical models for the effect of a propagation environment on a radio signal. Rayleigh fading is most applicable when there is no line of sight between the transmitter and receiver, and all received multipath signals have relatively the same signal strength. Rician fading is most applicable when there is a strong dominant component, usually LOS, in addition to other multipath NLOS signal components. [5]

2.1 Multipath Rician Fading

When a LOS propagation path exist between Base Station or Transmitter and Mobile User or Receiver, there is a dominant signal component. In this case the fading distribution follows Rician fading model. At the receiver, the signal appears as a continuous component added with a random multipath component. The Rician distribution is given by:

$$p(r) = \frac{r}{\sigma^2}\exp-\left(\frac{r^2+A^2}{2\sigma^2}\right)I_0\left(\frac{Ar}{\sigma^2}\right), \qquad r \geq 0 \qquad (1)$$

where 'r' is the received signal, σ^2 is the variance of received signal, 'A' denotes the peak amplitude of the dominant signal and $I_0()$ is the modified Bessel function of the first kind and zero order. The Rician distribution is often described in terms of parameter K, which is the ratio between the deterministic signal power and the variance of the multi-path component:

$$K = \frac{A^2}{2\sigma^2} \qquad (2)$$

The parameter K completely specifies the Rician distribution. For K=0, the Rician distribution reduces to a Rayleigh distribution.

2.2 Multipath Rayleigh Fading

When there is no LOS propagation path between Base Station or Transmitter and Mobile User or Receiver, the fading distribution follows Rayleigh fading model. The received multipath components have relatively same strength. The Rayleigh distribution has the pdf (probability distribution function) given by:

$$p(r) = \frac{r\, e^{-\left(\frac{r^2}{2\sigma^2}\right)}}{\sigma^2} \qquad 0 \leq r \leq \infty \qquad (3)$$

Where 'r' is the received signal, σ^2 is the variance of received signal.

3. MODULATION SCHEMES

The variation of the property of a signal, such as its amplitude, frequency or phase is called modulation. This process carries a digital signal or message. Modulation techniques used in the WiMAX OFDM Physical simulation in this paper are listed below.

3.1 BPSK

This is also known as two-level Phase Shift Keying as it uses two phases separated by 180º to represent binary digits. The principle equation is,

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & binary\ 1 \\ A\cos(2\pi f_c t + \pi) & binary\ 0 \end{cases} \qquad (4)$$

The BPSK signal constellation is given below,

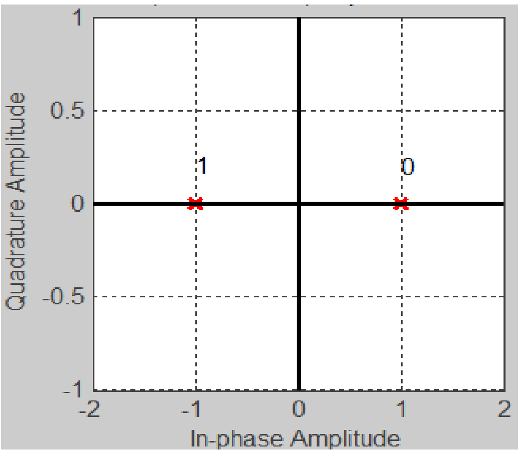

Fig -2: BPSK Constellation

BPSK is very effective and robust against noise especially in low data rate applications but it can modulate only 1bit per symbol.

3.2 QPSK

QPSK is also known as four-level PSK where each element represents more than one bit. Each symbol contains two bits and it uses the phase shift of $\pi/2$, meaning 90º phase shift instead of shifting the phase 180º as in BPSK. The principle equation of the technique is:

$$s(t)=\begin{cases} A\cos(2\pi f_c t+\pi/4) & 11 \\ A\cos(2\pi f_c t+3\pi/4) & 01 \\ A\cos(2\pi f_c t-3\pi/4) & 00 \\ A\cos(2\pi f_c t-\pi/4) & 10 \end{cases} \quad (5)$$

The QPSK signal constellation is given below,

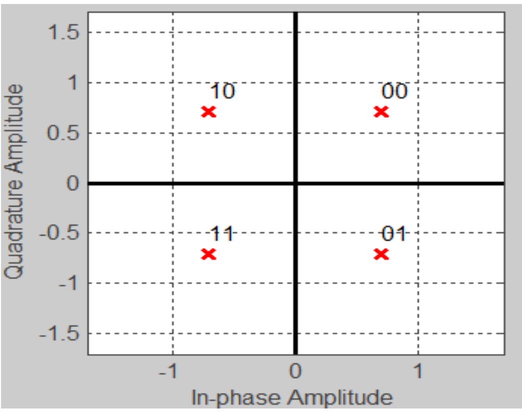

Fig -3: QPSK Constellation

Since in QPSK, the constellation consists of four points or four symbols, it ensures efficient use of bandwidth and higher spectral efficiency than BPSK [6].

3.3 QAM

Quadrature Amplitude Modulation is the most popular modulation technique used in various wireless standards. It is combined with ASK and PSK, where two different signals are sent concurrently on the same carrier frequency but one should be shifted by 90º with respect to the other signal. The principle equation of QAM is:

$$s(t)=d_1(t)\cos 2\pi f_c t + d_2(t)\sin 2\pi f_c t \quad (6)$$

16 QAM means 16-states Quadrature Amplitude Modulation i.e. four different amplitude levels used and the combined stream is one of 16 states. In 16 QAM, each symbol is represented by 4 bits [6].

The 16 QAM signal constellation is given below,

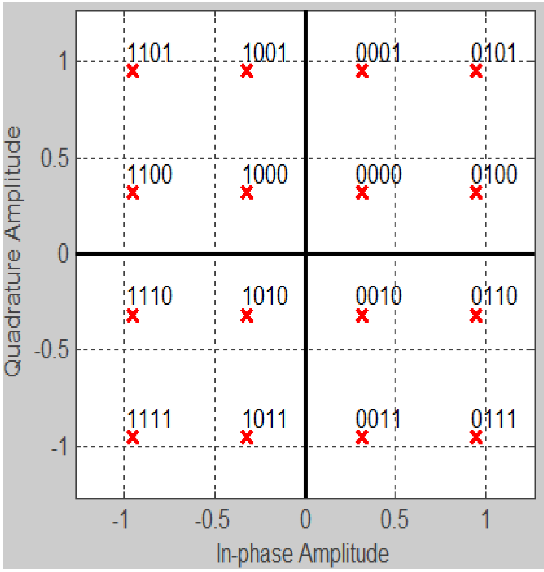

Fig -4: 16 QAM Constellations

64 QAM is same as 16 QAM except it has 64-states where each symbol is represented by six bits (2^6 = 64). The total bandwidth is increased due to increased number of states.

The 64 QAM signal constellation is given below,

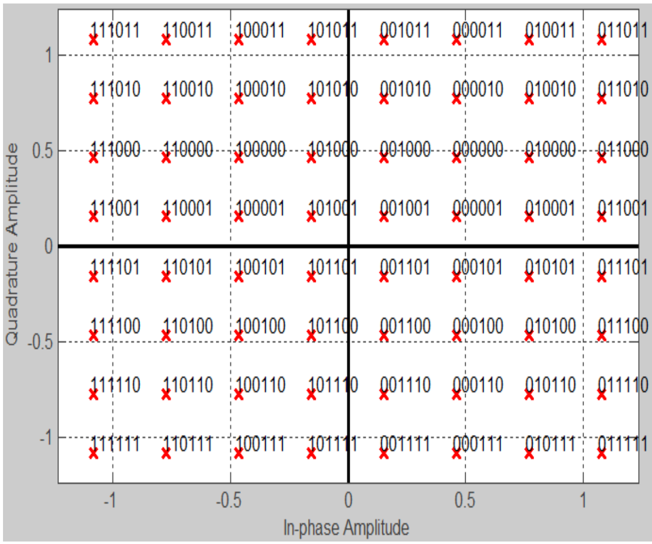

Fig -5: 64 QAM Constellations

4. WiMAX MODEL

Following are the parameters used in this paper for implementing WiMAX Physical Layer Simulink [3]:

Table -1: WiMAX Profile Parameters

Standard	IEEE 802.16e
Carrier Frequency	Below 11GHz
Frequency Bands	2.5GHz, 3.5GHz, 5.7GHz
Bandwidth	1.5 MHz to 20 MHz
Radio Technology	OFDM
Distance	10 Km
Modulation	BPSK, QPSK, 16 QAM, 64 QAM

Table 2: Model Parameters used for simulation

Channel Bandwidth	3.5MHz
No. of OFDM symbols per burst	2
Cyclic prefix factor	1/8

Block wise description of WiMAX Simulink:

- Data Source: Bernoulli Binary Generator is employed to generate a vector output with the Probability of a zero of 0.5 and Boolean Output data type.
- Modulator used to modulate signals as BPSK, QPSK, 16QAM or 64QAM.
- IFFT Input Packing to concatenate input signals of the same data type to create a contiguous output signal.
- Space-Time Block Coding using an Alamouti code [4].

This implementation uses the OSTBC Encoder and Combiner blocks in the Matlab.

- Orthogonal Frequency Division Multiplexed (OFDM) transmission using 192 sub-carriers, 8 pilots, 256-point FFTs, and a variable cyclic prefix length.
- Digital Pre-distortion Nonlinear Amplifier, a memory less non-linearity that can be driven at several back off levels with digital pre-distortion capability that corrects for the non-linearity.
- Multipath fading channel which can be either Rayleigh or Rician with AWGN for the STBC model. OFDM receiver that includes channel estimation using the inserted preambles.

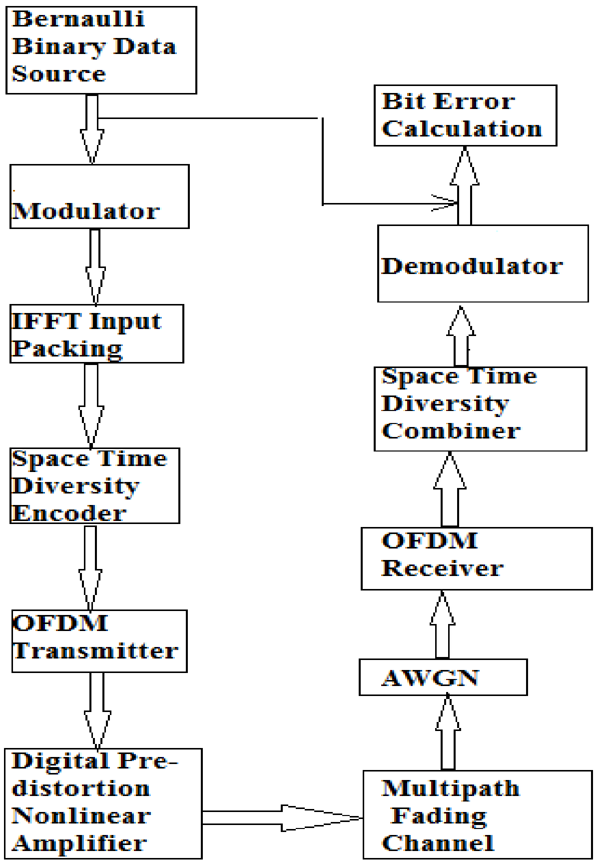

Fig -6: WiMAX OFDM Physical Layer Link

5. SIMULATION RESULTS

Simulation approach: Noise is varied by using AWGN block and corresponding readings of BER have been taken. This has been done for each of modulation schemes mentioned for both the Multipath Fading Channels. The readings are listed in the below sections.

5.1 Multipath Rician Channel

The K factor value is taken as 0.5. 4 NLOS and 1 LOS paths have been assumed in Channel profile.

Table -3: BER readings over the range of SNR for Multipath Rician Fading Channel

SNR (dB)	BER (Bit Error Rate)			
	BPSK	**QPSK**	**16QAM**	**64QAM**
5	0.0504	0.3848	0.4982	0.4986
10	0.0061	0.0781	0.4351	0.4988
15	0.0002	0.0081	0.0914	0.4838
20	0.000014	0.0004	0.0063	0.4144
25	0.000002	0.0002	0.0008	0.3178
30	0	0.00001	0.0004	0.2687
35	0	0	0.00028	0.2518
40	0	0	0.00019	0.2464

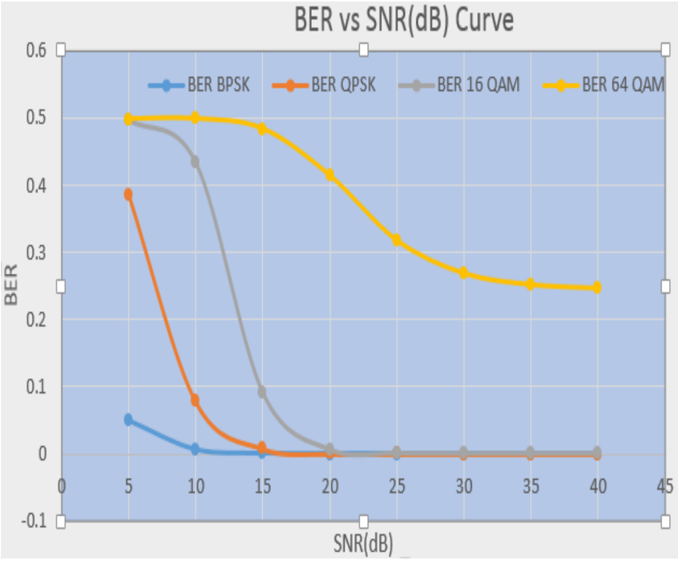

Chart -1: BER vs. SNR Curve for Multipath Rician Fading Channel

5.2 Multipath Rayleigh Fading Channel

4 NLOS and 1 LOS paths have been assumed in Channel profile.

Table -5: BER readings over the range of SNR for Multipath Rayleigh Fading Channel

SNR (dB)	BER (Bit Error Rate)			
	BPSK	**QPSK**	**16QAM**	**64QAM**
5	0.05725	0.4346	0.4995	0.4998
10	0.00222	0.1106	0.4543	0.4986
15	0.000307	0.0189	0.1896	0.486
20	0.000291	0.0061	0.0566	0.4017
25	0.000142	0.0045	0.0306	0.2834
30	0.000283	0.0042	0.0262	0.2315
35	0.000338	0.0040	0.0243	0.2151
40	0.000338	0.0039	0.0240	0.2105

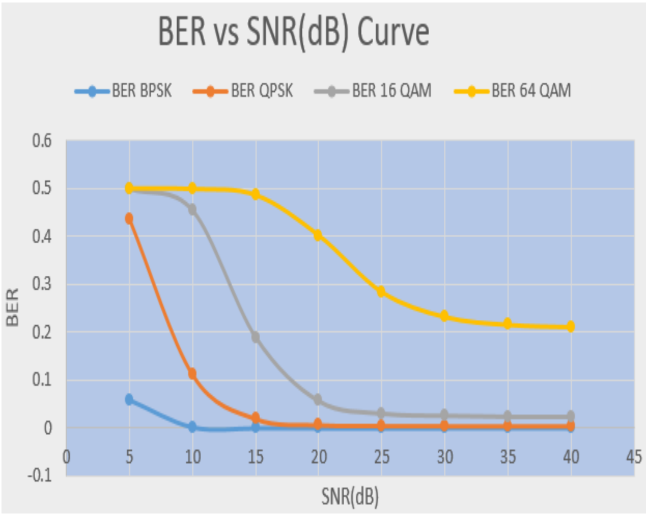

Chart -2: BER vs. SNR Curve for Multipath Rayleigh Fading Channel

5.3 Modulation Comparison

5.3.1 BPSK

Table -6: BPSK BER readings in Rayleigh Fading Channel and Rician Fading Channel

BPSK Modulation		
SNR(dB)	**BER in Rayleigh**	**BER in Rician**
5	0.05725	0.05041
10	0.00222	0.006023
15	0.000307	0.000237
20	0.000291	0.0000141
25	0.000142	0.0000023
30	0.000283	0
35	0.000338	0
40	0.000338	0

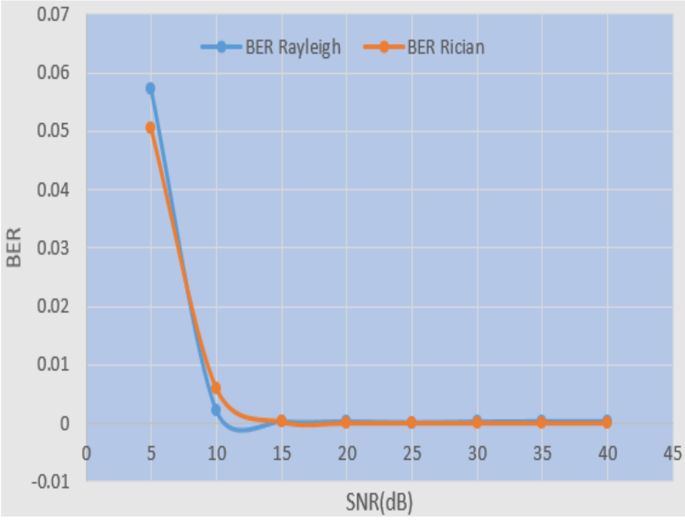

Chart -3: BER vs. SNR Curve for BPSK in Multipath Rayleigh Fading Channel and Rician Fading Channel

5.3.2 QPSK

Table -6: QPSK BER readings in Rayleigh Fading Channel and Rician Fading Channel

SNR(dB)	BER Rayleigh	BER Rician
5	0.4346	0.3848
10	0.1106	0.07803
15	0.0189831	0.008037
20	0.0060437	0.0004021
25	0.004475	0.0002037
30	0.004158	0.0000107
35	0.003974	0
40	0.003896	0

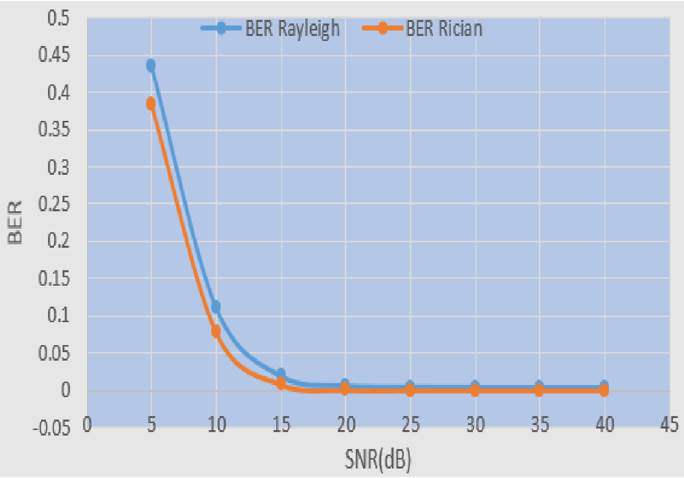

Chart -4: BER vs. SNR Curve for QPSK in Multipath Rayleigh Fading Channel and Rician Fading Channel

5.3.3 16 QAM

Table -7: 16QAM BER readings in Rayleigh Fading Channel and Rician Fading Channel

SNR(dB)	BER Rayleigh	BER Rician
5	0.4995	0.4982
10	0.4543	0.4351
15	0.1896	0.09139
20	0.0566	0.006282
25	0.03058	0.0007554
30	0.02617	0.0003521
35	0.0243	0.0002651
40	0.0245	0.000195

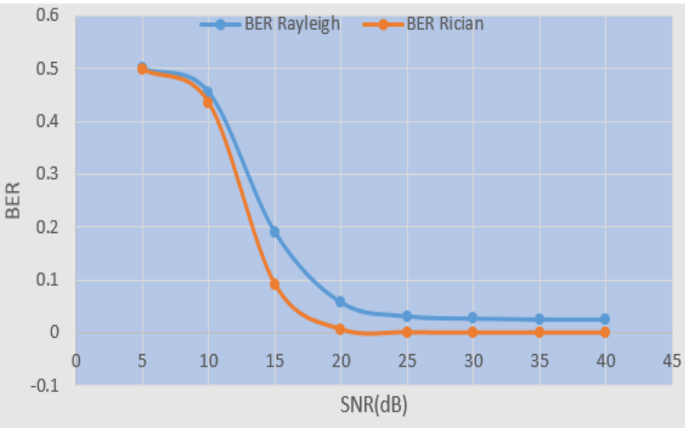

Chart -5: BER vs. SNR Curve for 16QAM in Multipath Rayleigh Fading Channel and Rician Fading Channel

5.3.4 64 QAM

Table -8: 64QAM BER readings in Rayleigh Fading Channel and Rician Fading Channel

SNR(dB)	BER Rayleigh	BER Rician
5	0.4998	0.4986
10	0.4986	0.4988
15	0.486	0.4838
20	0.4017	0.4144
25	0.2834	0.3178
30	0.23149	0.2687
35	0.2151	0.2518
40	0.2105	0.2464

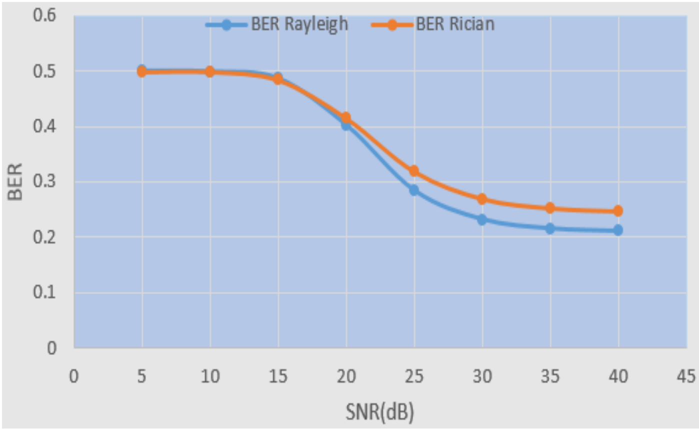

Chart -6: BER vs. SNR Curve for 64QAM in Multipath Rayleigh Fading Channel and Rician Fading Channel

6. CONCLUSIONS

Chart -1 and Chart -2 conclude that BER response of BPSK is better than that of other modulations over the SNR (dB) range whereas 64QAM has worst or highest BER during the same range. For Rician Fading channel above 20dB SNR, BPSK, QPSK, 16 QAM have approximately same BER values which are lower whereas BER for 64QAM is still higher for SNR > 20dB. For Rayleigh fading channel above 20dB, the response of modulations remain same as in Rician but in Rayleigh they have slightly higher BER.

Chart -3 concludes that up to approximately 8dB SNR, BPSK modulated signal has better BER response in Rician fading channel compared to Rayleigh fading channel. At SNR > 8dB, BER response for Rayleigh fading channel is better than that of Rician fading channel.

Chart -4 concludes that for the entire SNR (dB) range considered, QPSK modulated signal has better BER response in Rician fading channel than that in Rayleigh fading channel.

Chart -5 concludes that for the entire SNR (dB) range considered, 16QAM modulated signal has better BER response in Rician fading channel than that in Rayleigh fading channel.

Chart -6 concludes that 64 QAM modulate signal has better BER response in Rayleigh fading channel than that in Rician fading channel over the entire SNR (dB) range.

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