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Effect of Multiple Paths on BER Performance of WiMAX Physical Layer for Different Modulation Schemes

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Abstract*— In this paper, the effect of number of paths, through which the signal propagates between Base Station and Mobile User, on the BER performance of Physical layer of WiMAX communication system has been investigated using MATLAB Simulink. An end-to-end baseband model of the WiMAX physical layer over the Multipath Fading Environment is simulated for the analysis purpose. The BER response of the WiMAX system for different number of paths has been evaluated at a fixed SNR value for BPSK, QPSK, 16 QAM and 64 QAM modulation schemesover both Multipath Rician Fading and Multipath Rayleigh Fading Channels. BER is an important figure of merit for quantifying the integrity of data transmitted through any communication system.

Keywords*— WiMAX, BER, Multipath Rician Fading, Multipath Rayleigh Fading, BPSK, QPSK, 16 QAM, 64 QAM.

1. INTRODUCTION

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates with the 2011 update providing up to 1 Gb/s for fixed stations [1][2] .WiMAX is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group and adopted by both IEEE and the ETSI HIPERMAN group.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 concernfor 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 servesas a useful resource to build a simulation model for the WiMAX Physical layer [3].

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 strength 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 [4] [5].

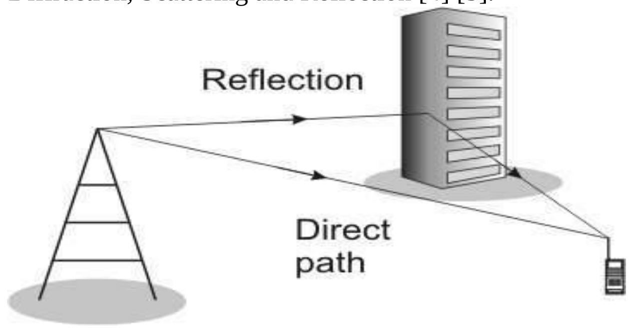

Fig. 1A Depiction of LOS (Direct Path) and NLOS (Reflected Path) [6]

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

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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] [5].

This paper is aimed at exploring BER response of WiMAX communication system with different number paths between Base Station and Mobile User, from BER perspective for differently modulated signals through Multipath Fading Environment. The noise level will be maintained for Multipath fading channel in Simulink by using Additive White Gaussian Noise Channel. BER variations with different number of paths will be noted for a fixed SNR (dB) for various modulation schemes.

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

II. MULTIPATH FADING ENVIRONMENT

In wireless mobile communications, the transmitted signal from the Base Station do not directly reach the Mobile user. There are severalenvironmental obstacles that block the LOS(line of sight path). A signal travels from transmitter to receiver over a multiple-reflection path andcauses fluctuations in the receiver signal's amplitude and phase. The sum of the signals arriving at the receiver of Mobile user can beconstructive 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 [5] [7].

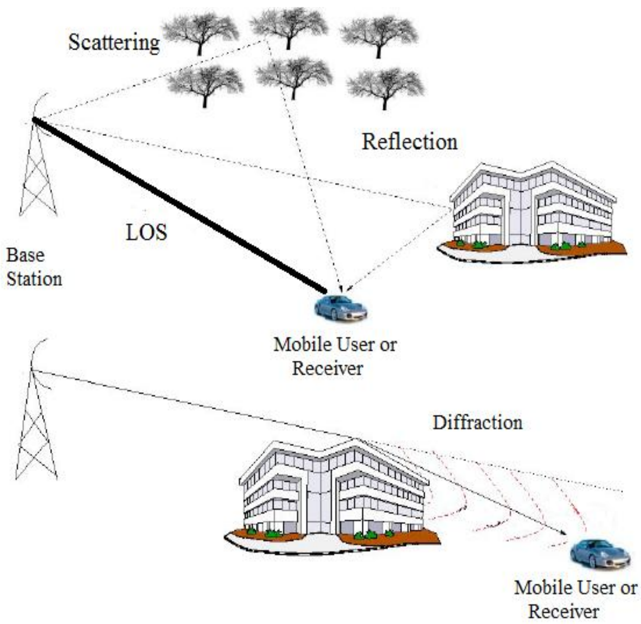

Fig. 2A Typical Fading Scenario

Rayleigh fading and Ricianfading models, employing Rayleigh distribution and Rician distribution respectively, are most widely used to model the wireless channel. Rayleigh fading and Rician fading are statisticalmodelsused to investigate the effect of a propagation environment on a radiosignal. Rayleigh fading is most applicable when there is no line of sight between the transmitterand 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] [8]. Both of these fading scenarios are briefed below in sections.

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:

$$p(r) = \frac{r}{\sigma^2} e^{-\left(\frac{r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right) \quad (1)$$

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:

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

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The parameter K completely specifies the Rician distribution. For K=0, the Rician distribution reduces to a Rayleigh distribution. [5]

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:

$$p(r) = \frac{re^{-(\frac{r^2}{2\sigma^2})}}{\sigma^2} \quad 0 \le r \le \infty \qquad (3)$$

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

III. WIMAX SIMULINK 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	16 QAM

Table 2. Model Parameters

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

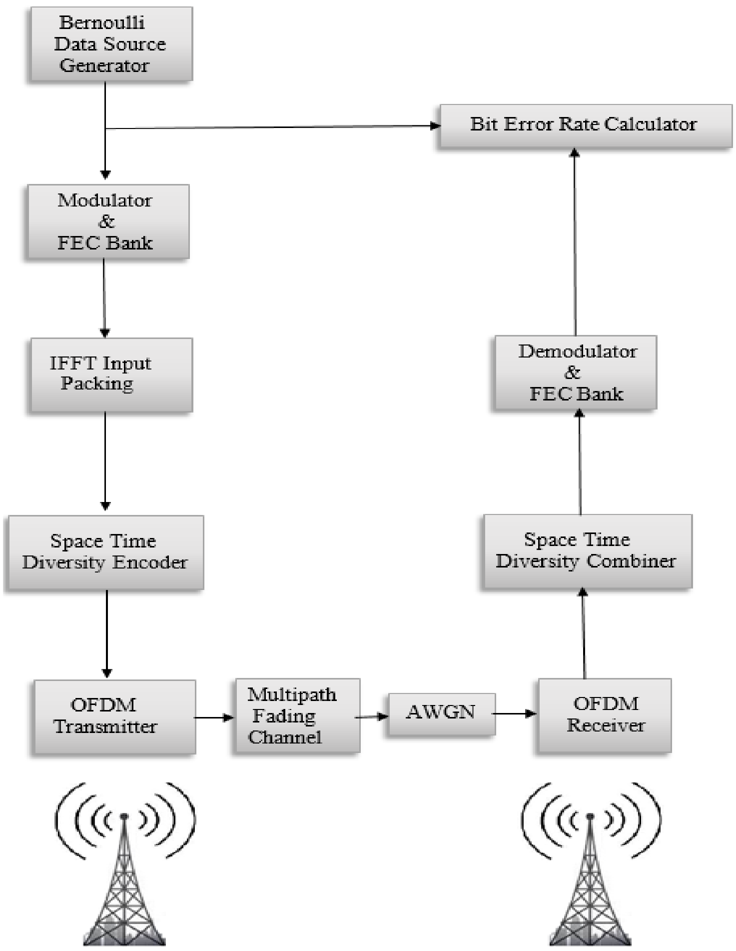

Fig. 3. WiMAX OFDM Physical Layer Link

Block wise description of WiMAX Simulink:

- Bernoulli Binary Generator: is employed to generate a vector output with 0.5 Probability of a Zero and Boolean Output data type.
- Modulator: for modulating 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.

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- Space-Time Diversity Encoder: using an Alamouti code [7]. This implementation uses the OSTBC Encoder and

Combiner blocks in the Matlab.

- OFDM: transmitter using 192 sub-carriers, 8 pilots, 256-point FFTs, and a variable cyclic prefix length.
- Multipath fading channel and AWGN: to incorporate effects of Fading and noise.
- Demodulator: to demodulate the received signal.
- BER Calculator: to evaluate the Bit error rate by comparing the received signal with the delayed version of transmitted signal.

IV. SIMULATION RESULTS

Simulation Approach: For a fixed SNR(dB) (set at AWGN block), the BER readings for different number of paths between Transmitter and Receiver have been taken. This has been done for BPSK, QPSK, 16 QAM, 64 QAM modulated signals through Multipath Rayleigh Fading Channel and Multipath Rician Fading Channel.

1. Multipath Rician Fading Channel

Table 3. Rician Channel Parameters

Doppler's Shift	450Hz
SNR(dB)	15dB
Channel Bandwidth	3.5MHz
No. of OFDM symbols per burst	2
Cyclic prefix factor	1/8
Maximum Diffuse Doppler shift	450Hz
K factor	0.5

Table 4.BER variations for different no. of Paths

No. of Paths	BPSK	QPSK	QAM	QAM
3	0.0001	0.02201	0.1192	0.4835
4	0.0001	0.03031	0.1266	0.4841
5	0.0001	0.03512	0.1275	0.487
6	0.00011	0.03507	0.1279	0.486
7	0.00012	0.03546	0.1302	0.4877
8	0.00001	0.03584	0.1307	0.4855
9	0.00014	0.03532	0.1328	0.4859
10	0.00015	0.03591	0.1338	0.486
15	0.00012	0.03601	0.1368	0.4857
20	0.00011	0.0361	0.1373	0.4867
30	0.00013	0.03621	0.1395	0.4882

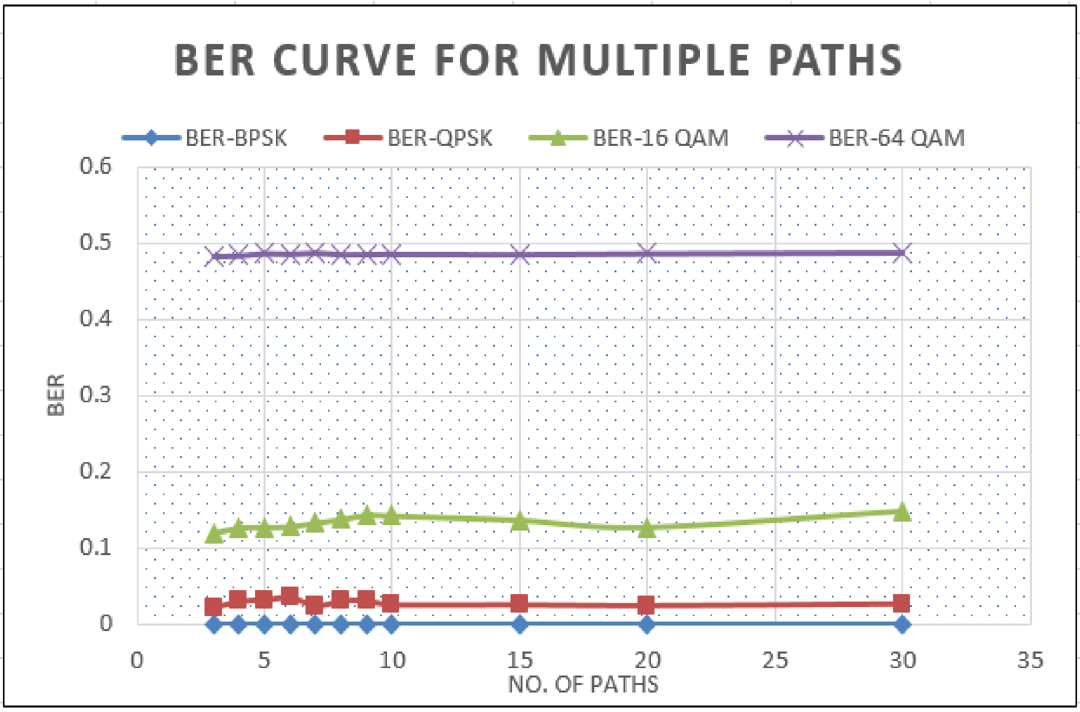

Fig. 4 BER Curve for different number of paths for Rician Channel

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2. Multipath Rayleigh Fading Channel

Table 5. Rayleigh Channel Parameters

Maximum Doppler Shift	450Hz
SNR	15dB
Channel Bandwidth	3.5MHz
Number of OFDM symbols per burst	2
Cyclic prefix factor	1/8

Table 6. Rayleigh Channel Parameters

# Paths	BPSK	QPSK	16 QAM	64 QAM
3	0.0004	0.1077	0.1964	0.485
4	0.0007	0.1236	0.2013	0.4875
5	0.0008	0.1241	0.2079	0.491
6	0.0008	0.125	0.2122	0.4891
7	0.00081	0.1251	0.2164	0.4916
8	0.00083	0.1257	0.2176	0.4913
9	0.00082	0.1292	0.2196	0.492
10	0.00084	0.1319	0.2258	0.4918
15	0.00085	0.1418	0.2288	0.4928
20	0.00087	0.1454	0.2291	0.4923
30	0.00083	0.1488	0.2301	0.4918

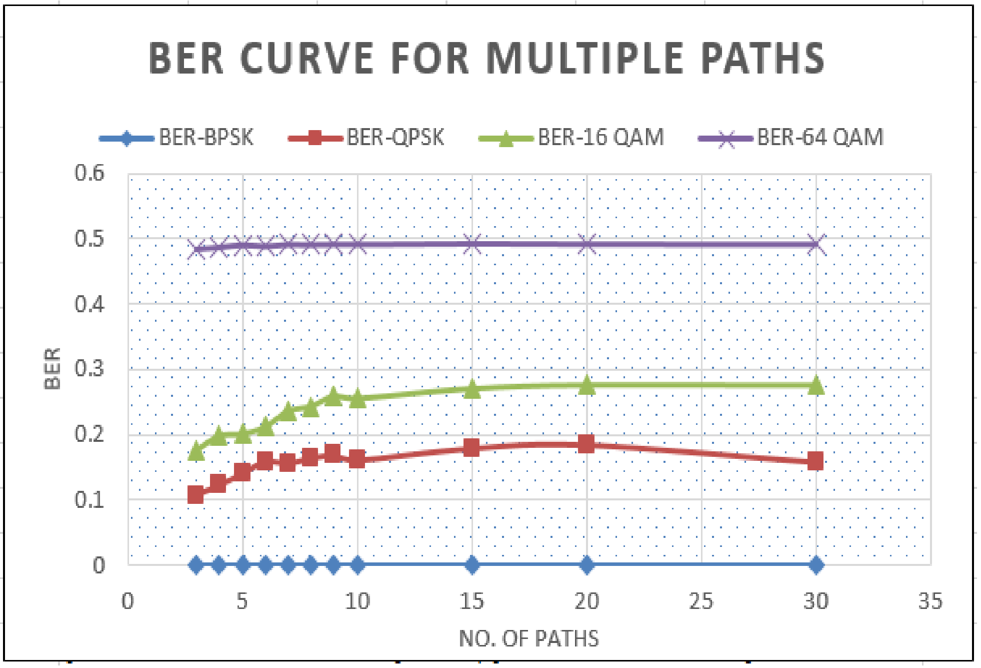

Fig. 5 BER Curve for different number of paths for Rayleigh Channel

V. CONCLUSION

It is observed from Table 4 and Fig. 4 that for Multipath Rician fading channel, the BER response of the WiMAX system remains approximately constant throughout the changing number of paths for all the modulation schemes. For BPSK, BER is approximately closer to 0, throughout the range of number of paths. For QPSK, BER varies within the range 0.01 to 0.015. The BER curve for QPSK is higher than that of BPSK, but lower than 16 QAM and 64 QAM BER curves. For 16QAM, BER varies within the range 0.10 to 0.15. The BER curve 16QAM is higher than BPSK and QPSK BER curves, but lower than 64 QAM BER curve. For 64 QAM, BER varies within the range 0.48 to 0.49. The BER curve 64 QAM is higher than BER curves of BPSK, QPSK and 16QAM.

It is observed from Table 6 and Fig. 5 that for Multipath Rayleigh fading channel, the BER response of the WiMAX system remains approximately the same for the changing number of paths for all the modulation schemes. For BPSK, BER is approximately closer to 0, throughout the range of varying number of paths. For QPSK, BER varies within the range 0.10 to 0.15. The BER curve for QPSK is higher than that of BPSK, but lower than the BER curves of 16QAM and 64QAM. For 16QAM, BER varies within the range 0.19 to 0.24. The BER curve for 16QAM is higher than that the BER curves of BPSK and QPSK, but lower than that of 64 QAM BER curve. For 64 QAM, BER varies within the range 0.48 to 0.49. The BER curve for 64 QAM is higher than the BER curves of BPSK, QPSK and 16 QAM.

It can be concluded that for both Multipath Rayleigh Fading Channel and Multipath Rician Fading Channel, the number of paths for the signal propagation between transmitter and receiver affects the BER of a particularly modulated signal, marginally and the main factors affecting BER performance of the system are Dopplers Shift and Noise (SNR) [5] [6].

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