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Performance Enhancement of WiMAX System using Adaptive Equalizer

[1]Anita Garhwal, [2]Partha Pratim Bhattacharya

[1,2] Department of Electronics and Communication Engineering, Faculty of Engineering and Technology
Mody Institute of Technology & Science (Deemed University)
Lakshmangarh, Dist. Sikar, Rajasthan, Pin – 332311, India

[1]anitagarhwal@gmail.com, [2] hereispartha@gmail.com

ABSTRACT

Mobile WiMAX is a wireless networking system which provides wireless broadband to fixed and mobile terminals. In this paper, firstly performance evaluation of WiMAX system with channel estimation is discussed. Performance evaluation with channel estimation is used because amplitude and phase shift causes error in wireless channel. Finally, Performance evaluation of WiMAX system using adaptive equalizer technique is then carried out. Bit error rate performance for different modulation schemes is then compared. Results show that by using adaptive equalization technique, bit error rate for all adaptive modulation techniques are improved. The equalizer mitigates the effect of the wireless channel and allows subsequent symbol demodulation.

Keywords: *WiMAX, OFDM, Equalizer, LMS, RLS.*

1. INTRODUCTION

WiMAX stands for Worldwide Interoperability for Microwave Access formed by WiMAX forum in 2001. It provides wireless broadband to fixed and mobile terminals in a large geographical area. The 2005 version of WiMAX provides data rate up to 40Mbits/s and 2011 version can support data rate up to 1 Gbit/s for fixed stations [1]. It is one of the latest developments and considered as a 4G (Fourth Generation) technology. Wimax supports data rate up to 75 Mbit/s which is higher than conventional cable modem and digital subscriber line (DSL) connections which are all wired access technologies. DSL has practical difficulties in providing broadband services in many urban and suburban areas because it can provide services into three miles of region. Other than this, in cable networks there does not exists any return channel and hence there is no provision for internet access. Conventional high speed internet broadband solution is difficult in remote rural areas and it does not provide good support for terminal mobility. To overcome these problems, Mobile Broadband Wireless Access (BWA) is introduced to provide flexible and cost effective solution [2]. It has many advantages as high speed, flexibility and easier to scale. It has the potential to serve customers that are unsatisfied or unserved by wired broadband services.

WiMAX is based on Wireless Metropolitan Area Network (WMAN). IEEE 802.16 group developed WMAN and it is adopted by ETSI (European Telecommunication Standard Institute) in HiperMAN group i.e. High Performance Radio Metropolitan Area Network [3]. Although the work on IEEE standard started in 1999, it was only during 2003 that the standard received wide attention when the IEEE 802.16a standard was ratified in January. Mobile WiMAX scenario is shown in Figure 1 [4].

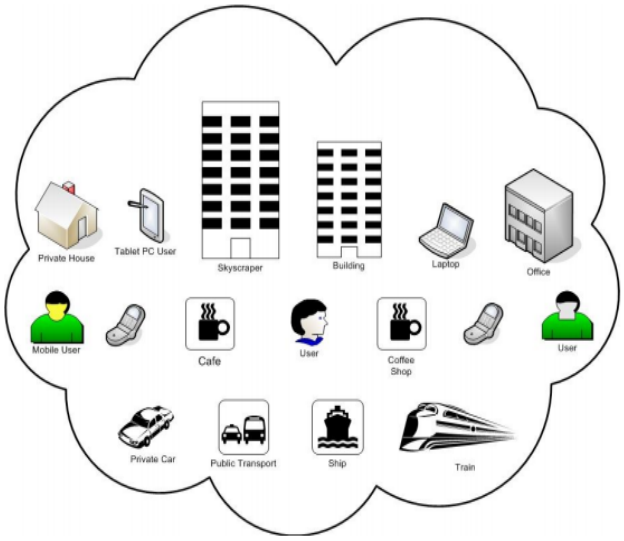

Figure 1: Mobile WiMAX scenario

WiMAX system uses OFDM in the physical layer. OFDM is based on the adaptive modulation technique in non-line-of–sight (NLOS) environments. Base stations of WiMAX can provide communication without the need of line-of-sight (LOS) connection. WiMAX base station has enough available bandwidth so at a time it can serve large number of subscribers and also cover large area range. WiMAX standard have two versions: IEEE 802.16-2004 and IEEE 802.16e. IEEE 802.16-2004 standard supports for fixed applications so it is called as fixed WiMAX or IEEE 802.16d. It supports OFDM (Orthogonal Frequency Division Multiplexing) in physical layer. It provides wireless DSL technology where broadband cables are not available. WiMAX standard 802.16e uses OFDMA (Orthogonal Frequency Division Multiplexing Access) technique. It

provides support for nomadic and mobility services so it also known as Mobile WiMAX [5]. WiMAX standards with details of frequency band, applications, modulation techniques etc are given in Table1 [6, 7].

Table1. WiMAX Standards

	802.16a	802.16d-2004	802.16e-2005
Status	Completed December 2001	Completed June 2004	Completed December 2005
Application	Fixed LOS	Fixed NLOS	Fixed and mobile NLOS
Frequency band	10GHz-66 GHz	2GHz-11GHz	2GHz-11GHz for fixed and 2GHz to 6 GHz for Mobile
Modulation	QPSK, 16QAM, 64 QAM	QPSK, 16QAM, 64 QAM	QPSK, 16QAM, 64 QAM
Gross data rate	32 Mbps-134.4 Mbps	1 Mbps-75 Mbps	1 Mbps-75 Mbps
Multi-plexing	Burst TDM/ TDMA	Burst TDM/ TDMA/ OFDMA	Burst TDM/ TDMA/ OFDMA
Duplexing	TDD and FDD	TDD and FDD	TDD and FDD
WiMAX implement-tation	None	256-OFDM	Scalable OFDM
Trans-mission scheme	Single carrier only	Single carrier only, 256 OFDM, 2048 OFDMA	Single carrier only, 256 OFDM, SODFM with 128,512, 1024,2048 multicarrier
Channel bandwidth	20MHz, 25MHZ, 28 MHz	1.75 MHz, 3.5 MHz, 7 MHz, 14 MHz, 1.25 MHz, 5 MHz, 10 MHz, 15 MHz, 8.75 MHz	1.75 MHz, 3.5 MHz, 7 MHz, 14 MHz, 1.25 MHz, 5 MHz, 10 MHz, 15 MHz, 8.75 MHz

WiMAX offers some salient features in term of services compared to other broadband services. Some features offered by WiMAX are listed below [7,8]:

- High data rate: WiMAX provides extremely high data rate up to 75 Mbps when operating with 20 MHz spectrum band.
- OFDM based physical layer: WiMAX uses OFDM in the PHY layer. It supports good resistance to interference.
- Scalability: OFDM uses FFT (Fast Fourier Transform) and so it supports scalable bandwidth and data rate.
- AMC (Adaptive Modulation and Coding): It maximizes the throughput in time varying channel. WiMAX supports several modulation and FEC (Forward Error Correction).
- OFDMA: By using OFDMA as a multiple access technique, capacity of the system is improved.
- Quality of Service (QoS): MAC layer of WiMAX is designed to support multimedia services like voice and data and QoS parameters.

Performance of WiMAX system is judged by SNR (signal to noise ratio), BER (bit error rate), and Probability of error.

2. PERFORMANCE EVALUATION OF WIMAX SYSTEM

Here, performance evaluation of WiMAX system is discussed with channel estimation in flat fading condition [5]. Modulation technique used are BPSK (Binary Phase Shift Keying), QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation) and 64 QAM.

Channel estimation based on fuzzy logic system is discussed which finds the type of channel and type of fading, e.g. slow/fast and flat/frequency selective fading channel. The speed of the mobile unit determines the channel fading rate and the Doppler spread, which is directly related to coherence time of the channel.

Bit error rate for different adaptive modulation techniques in flat fading channel without and with channel estimation are shown in Figure 2 and Figure 3 respectively.

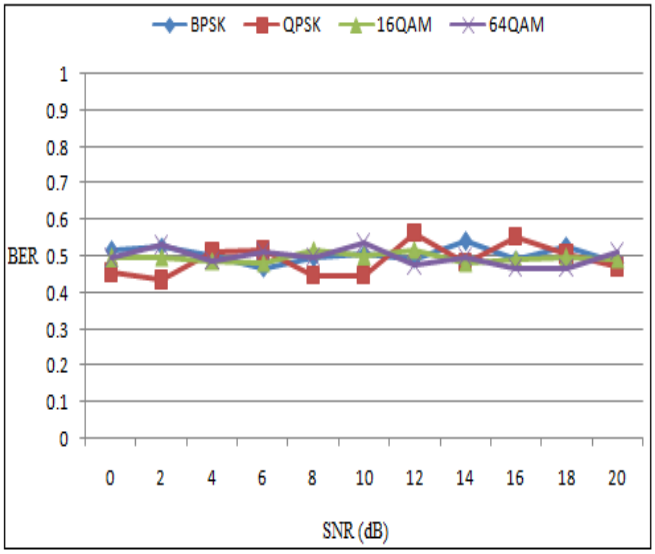

Figure 2: BER vs SNR in flat fading without channel estimation

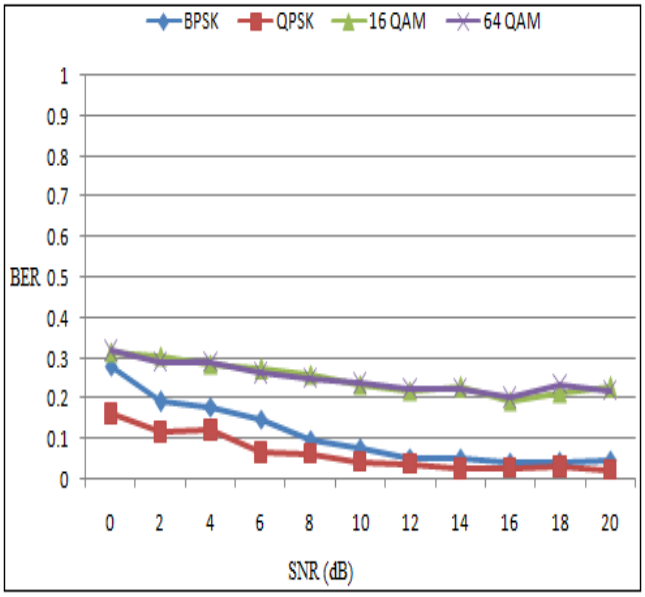

Figure 3: BER vs SNR in flat fading using channel estimation

It is clear from the Figure 2 and Figure 3 that by using the channel estimation technique BER is reduced for all adaptive modulation techniques.

3. PERFORMANCE ENHANCEMENT USING ADAPTIVE EQUALIZER

An adaptive equalizer is a time-varying filter that automatically adapts the properties of communication channel. It reduces the effect of inter-symbol-interference (ISI) in wireless channel. Different equalizer algorithms can be used. System model with adaptive equalizer is shown in Figure 4. Here, data are produced by random data generator. After the source data is produced, pilot data is inserted as the header of each source data at each coherence time. It is used to estimate the random phase shift of the fading channel. Then data is mapped from binary to complex. Modulation techniques used are BPSK, QPSK, 16QAM, 64QAM in frequency selective fading channel. Then data is trained to adjust the received signal with phase recovery. At receiver side adaptive equalizers like LMS (least mean squares) and RMS (recursive mean squares) are used to combat the effect of ISI. Finally BER for all modulation techniques are plotted.

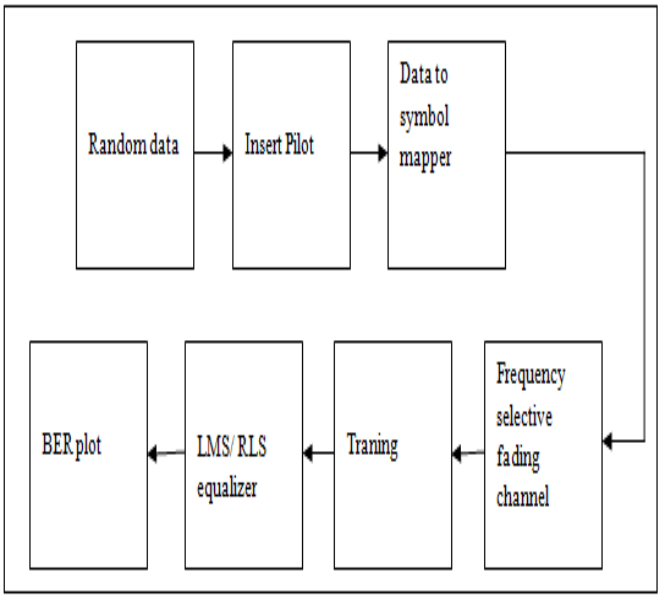

Figure 4: System model with adaptive equalizer

For simulation a model is choosen where carrier frequency is 2GHz, bandwidth of each channel is 200 KHz. For urban environment delay spread is considered to be 10µs, user is walking at a velocity of 5Km/hr. Symbol period is taken as 5µsec. Now, Coherence time may be given by equation (1) [5] –

$$T_c = \frac{9}{16\times\pi\times f_m} \qquad (1)$$

Equation (1) may be written as

$$T_c = \frac{9\times c}{16\times\pi\times f_c\times v} \qquad (2)$$

From equation (2), coherence time T_c is found to be 19.4msec. Now, it is seen that T_c>delay spread>T_s. Hence, it is a frequency selective and slow fading channel.

In system model LMS equalizer is used. Least mean square equalizer is used to find out filter coefficients. LMS produces least mean square of the error signal. Simple linear equalizer is shown in Figure5.

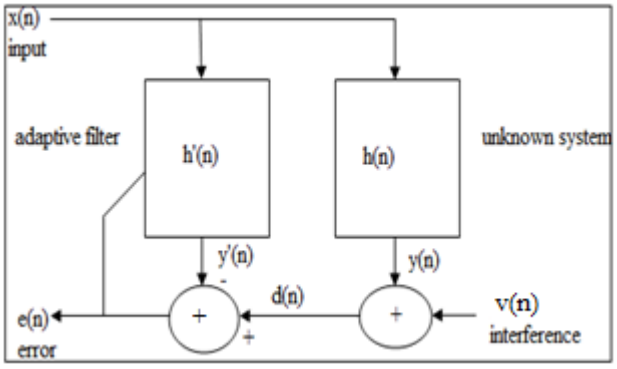

Figure 5: Linear equalizer

Equalizer output is given by: $y[n] = \sum_{k=0}^{M-1} u[n-k]w_k^*[n]$

Error is given by: $e[n] = d[n] - y[n]$

where y[n] is output, w[k] is weight of equalizer, d[n] is the estimation output, u[n-k] is the input. For linear equalizer weight is taken to be 8.

Simulation is carried out using MATLAB. Bit error rate for different adaptive modulation techniques in frequency selective fading without equalizer is shown in Figure 6.

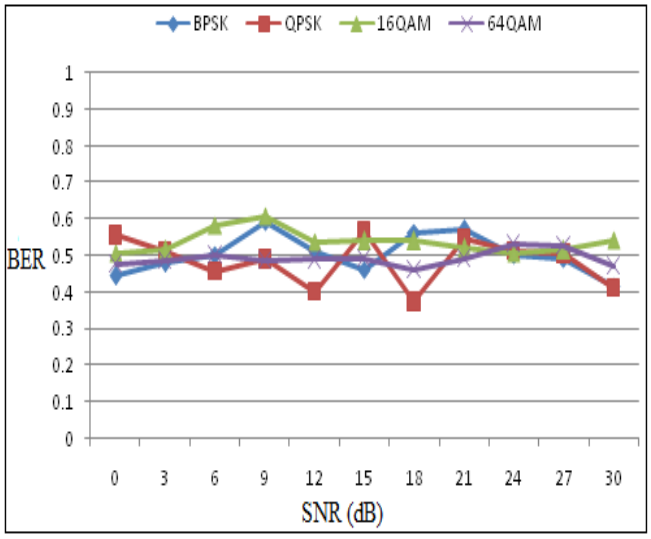

Figure 6: BER vs SNR in frequency selective fading without equalizer

4. RESULTS AND DISCUSSION

BER values for BPSK, QPSK, 16QAM and 64QAM are shown in Figure 7, Figure 8, Figure 9 and Figure 10 respectively. With adaptive equalizer BER is improved for all modulation techniques in frequency selective fading channel.

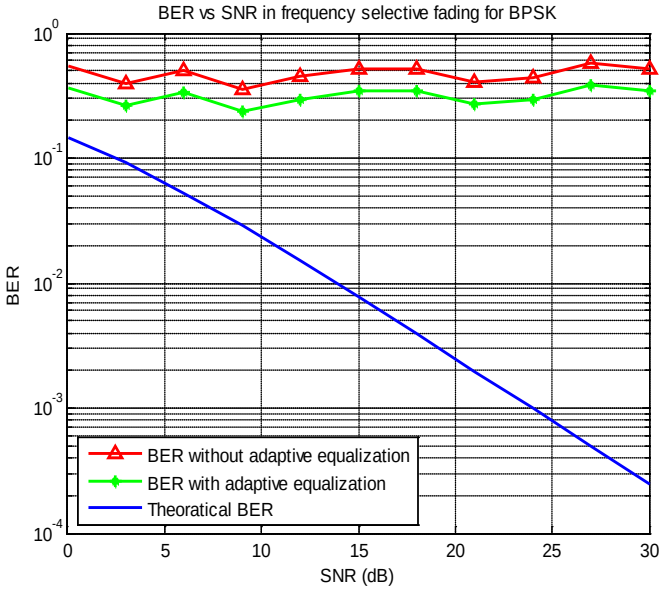

Figure 7: BER vs SNR in frequency selective fading for BPSK

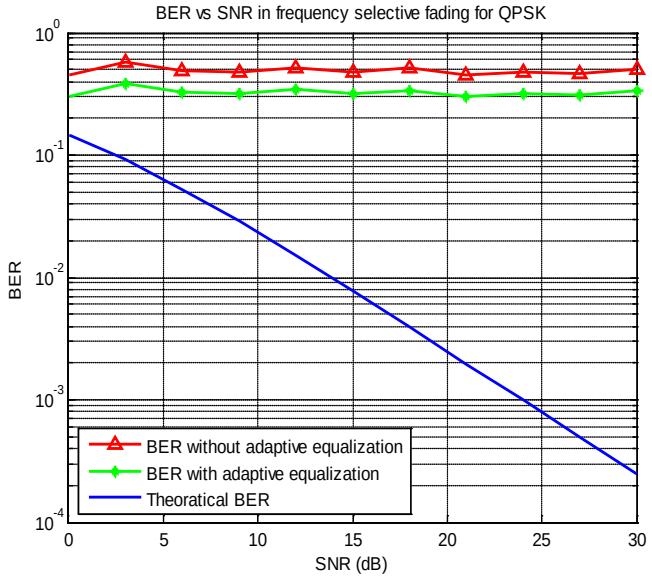

Figure 8: BER vs SNR in frequency selective fading for QPSK

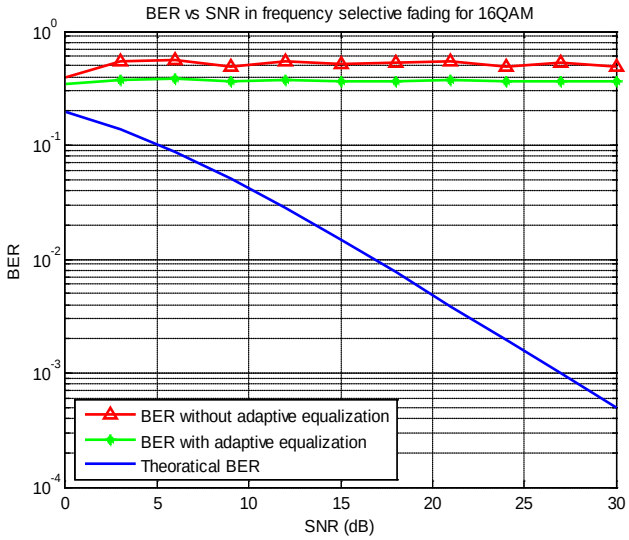

Figure 9: BER vs SNR in frequency selective fading for 16QAM

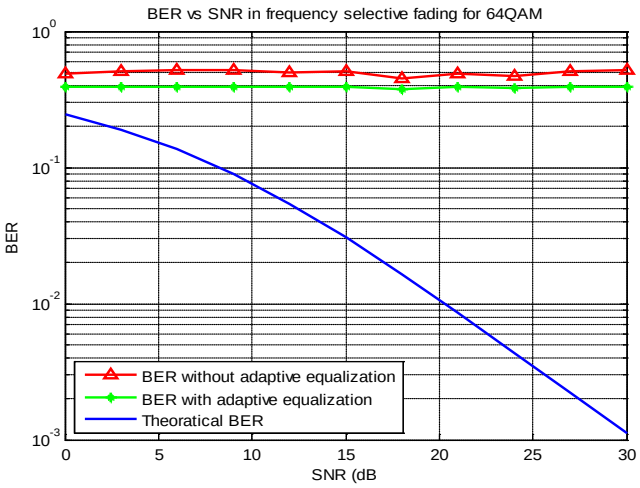

Figure 10: BER vs SNR in frequency selective fading for 64QAM

In Figure11 BER vs SNR with for all adaptive modulation techniques are compared

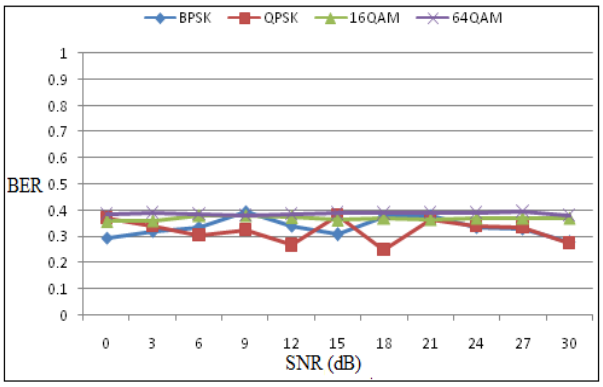

Figure11: BER vs SNR with adaptive equalizer

It is clear from Figure11 that using adaptive equalizer technique bit error rate for all adaptive modulation techniques are improved. Here 16QAM or 64 QAM show highest BER than QPSK and BPSK.

5. CONCLUSION

In this paper, performance enhancement of WiMAX system is done with adaptive equalizer. Firstly, BER for different adaptive modulation techniques are evaluated in slow frequency selective fading channel. In frequency selective fading, channel is affected by more ISI and noise then in flat fading. Finally, performance of WiMAX system is evaluated using adaptive equalizer. Using adaptive equalizer technique bit error rate is improved.

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