Chapter 4

Digital Modulation Scheme and Channel Selection

4.1 INTRODUCTION

This chapter studies about channel simulations and the comparison between the digital modulation schemes. The wireless multipath channel model is briefed in this chapter with the wireless propagation phenomenon between the receiving and transmitting antennas. This is required to calculate the delay and this delay gives the information by which amount the FFT window should be shifted. The characteristics of the channel vary greatly with the operating frequency, and the mode of propagation, e.g., line-of-sight (LoS) radio links [66], [67], diffraction/scattering [68], and satellite links. Comparisons relating the various digital modulation schemes are given in [69] and [70].

This chapter is organized as follows: section 4.2 briefs about the various digital modulation schemes and also the simulations of BER calculations among M-PSK and M-QAM. The section 4.3 describes about the various channel simulations like AWGN, Rayleigh and Rician fading channels and BER calculations among all the channels has been carried out and followed by the section 4.4 describes about the delay spread and the coherence bandwidth and section 4.5 summarizes the chapter.

4.2 BER COMPARISON OF DIGITAL MODULATION SCHEMES

A comparison analysis has been carried out to choose best digital modulation scheme to implement the OFDMA system. Simulation was done for the BPSK and QAM digital modulation schemes. The modulation orders chosen for the simulation are 2-PSK, 64-PSK, 4-QAM and 64-QAM. The BER VS Eb/No simulation for the above mentioned schemes was carried out in MATLAB. The BER of M-PSK can be estimated by using the following equation

$$M-PSK = erfc\left(\sqrt{\frac{Es}{No}}\sin\left(\frac{\pi}{M}\right)\right) \tag{4.1}$$

The BER of M-QAM can be estimated by using the following equation

$$M-QAM=2\left(1-\frac{1}{\sqrt{M}}\right)erfc\left(\sqrt{\frac{3}{2(M-1)}\frac{Es}{No}}\right)-\left(1-\frac{2}{\sqrt{M}}+\frac{1}{M}\right)erfc^{2}\left(\sqrt{\frac{3}{2(M-1)}\frac{Es}{No}}\right) \quad (4.2)$$

The Table 4.1 shows the comparison of various digital modulation schemes. Fig 4.1 and Fig.4.2 shows the relation between the digital modulations in schematic form.

Table 4.1 Comparison of Digital Modulation Schemes

Eb/No (dB)	BER Values for			
	64-PSK	64-QAM	4-QAM	2-PSK
-5	0.9485	0.9233	0.88	0.29
0	0.93368	0.90379	0.864	0.1616
5	0.91627	0.874	0.812	0.0813
10	0.89179	0.8284	0.7241	0.0214
15	0.85929	0.7683	0.6534	0

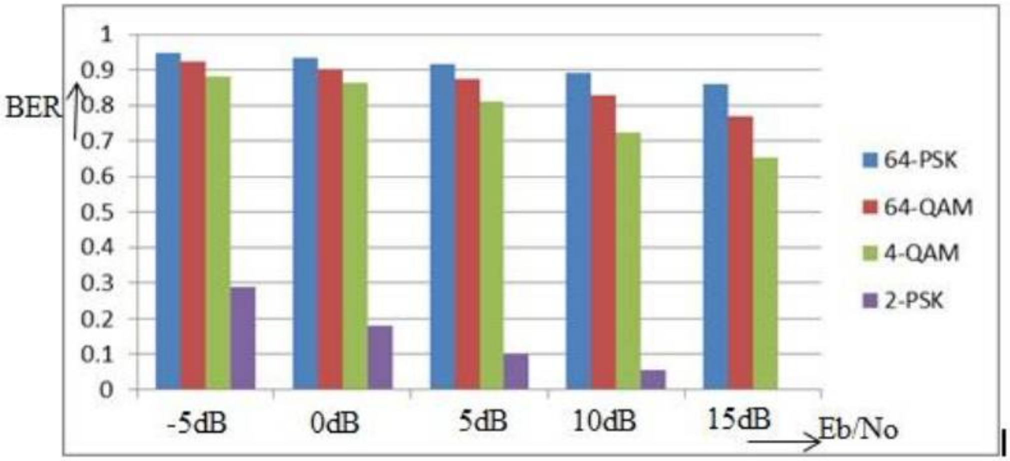

Fig.4.1. BER representation of digital modulation schemes

The comparisons show that the bit error is zero for 2-PSK at 15dB hence it has very low BER than the other digital modulation schemes, but this cannot be used for high data rate applications like OFDMA. If we observe at 64-PSK, here it has high BER when compared with the other modulation schemes. Hence it is apparent that the Quadrature Amplitude Modulation-QAM is used when compared between PSK and QAM. When compared with 4-QAM and 64-QAM, 64- QAM has more bit error but in case of high data rate applications 64-QAM is preferred.

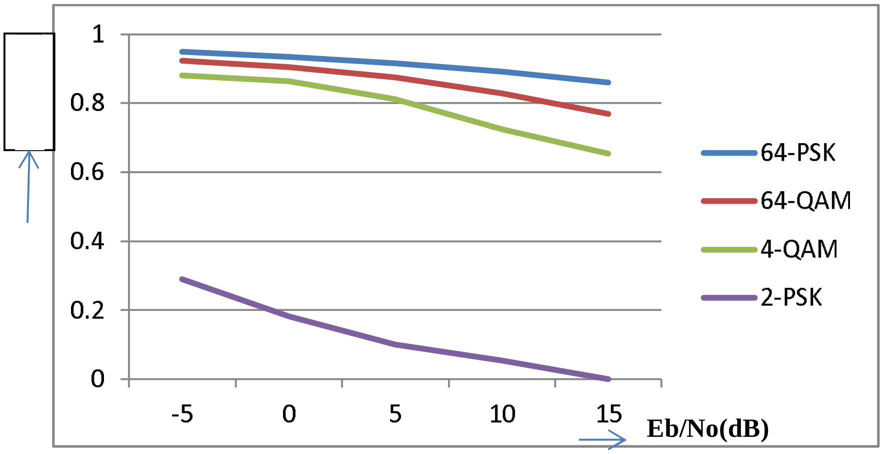

Fig.4.2. Schematic representation of M-PSK and M-QAM modulation schemes

BPSK gives the least bit error rate and with the increase in order of modulation, BER on increasing with SNR. 64-QAM has the maximum error rate. 64-QAM is capable of transmitting higher data rates because of denser constellation but it is very prone to noise and errors. Fig.4.3.shows the MATLAB simulation of digital modulation schemes.

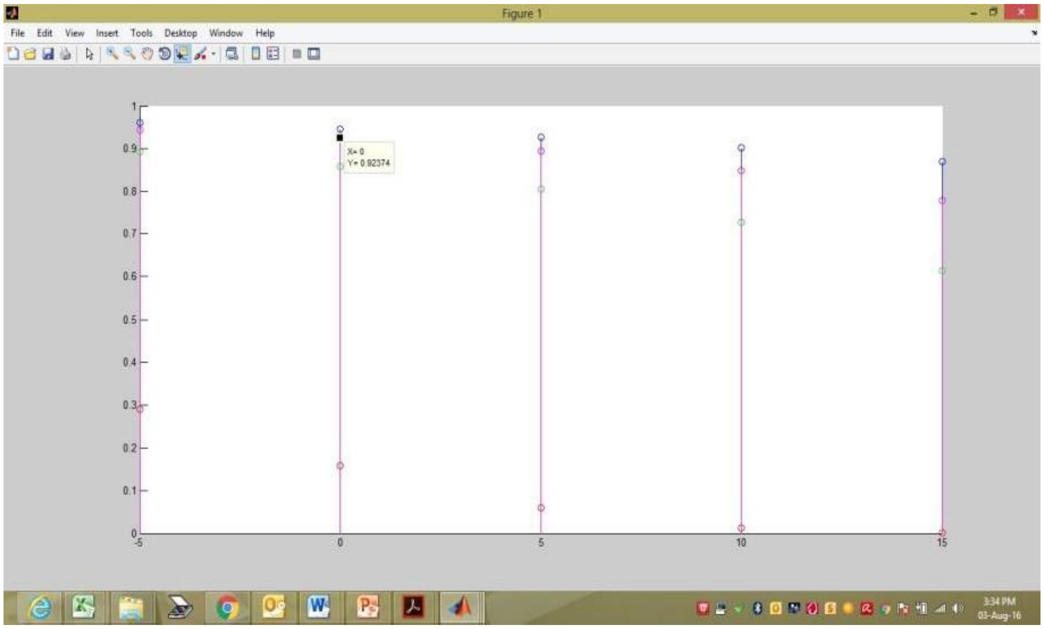

Fig. 4.3 Simulation of digital Modulation schemes

4.3 CHANNEL SIMULATION

A comparison analysis has been carried out to choose best channel implementation for the OFDMA system. The channels were simulated and BER was calculated for the AWGN, Rayleigh and Rician fading channels. The Rayleigh fading channel was also simulated by increasing the number of OFDM frames. Table 4.3 shows the BER values for Channels

Table 4.2 BER VS Eb/No values for AWGN, Rayleigh and Rician fading channels

Eb/No (dB)	BER Values for		
	Rician fading Channel	Rayleigh fading channel	AWGN fading channel
-5	0.309	0.33	0.45
0	0.2041	0.3	0.44

5	0.103	0.153	0.42
10	0.023	0.05	0.4
15	0.004	0.03	0

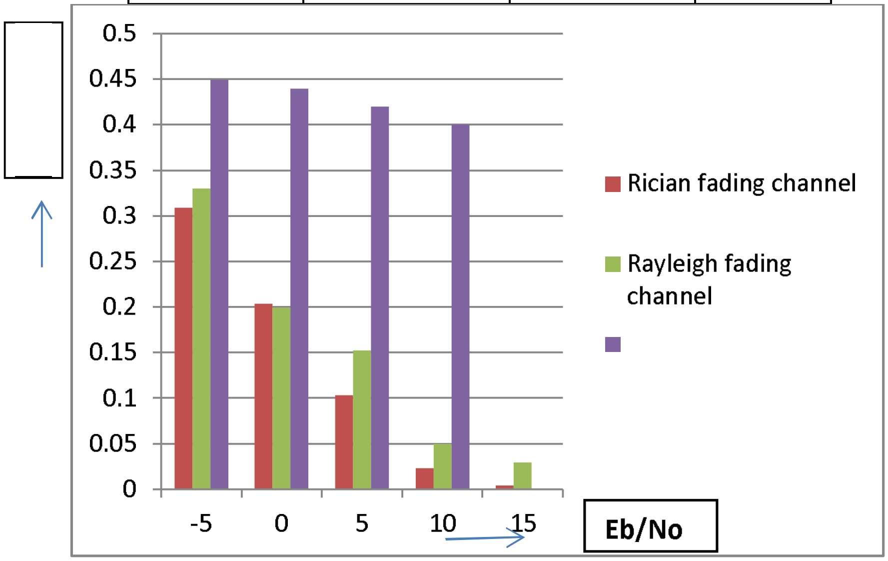

Fig.4.4 SNR VS BER Comparison of AWGN, Rayleigh and Rician Fading channels

The comparison between the AWGN, Rayleigh and Rician fading channels have been carried out and it shows that the AWGN channel has highest BER of 0.45 from -5dB to 10dB and then suddenly falls to zero. But in high data rate applications where the modulation order 64-QAM is applied to systems like OFDMA the signal interference will be more and hence it is better to use Rayleigh fading channel which gives the BER 0.3 at -5dB and 0.004 at 15 dB. Fig.4.6 gives the BER comparison between all the channels in MATLAB.

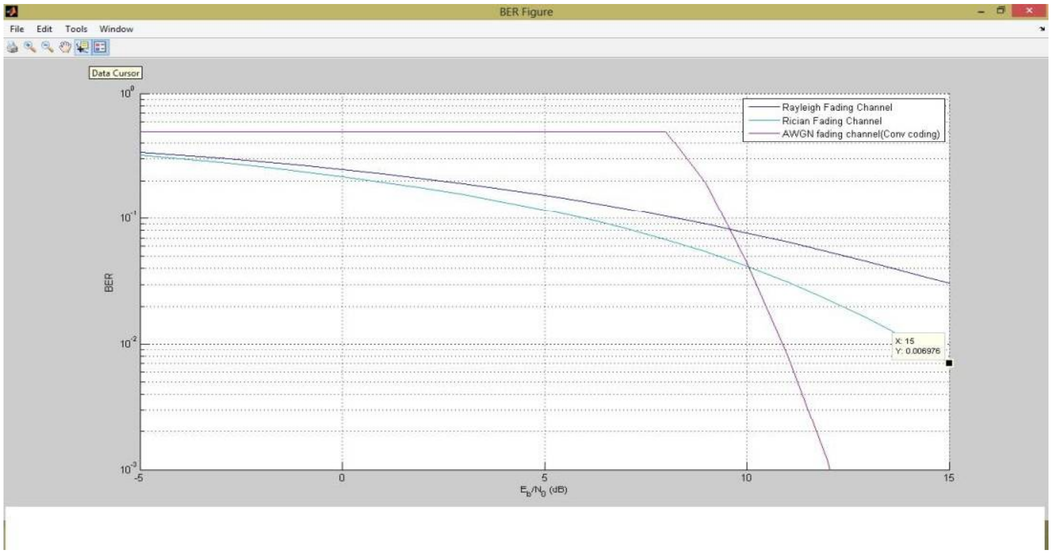

Fig 4.5.MATLAB simulation of AWGN, Rayleigh and Rician channels.

The Rayleigh channel was also simulated with increasing the number of OFDM frames. It has been observed that with the increase in the number of OFDM frames the BER also increases accordingly. The BER for 10 OFDM frames at 15 dB gives zero BER but in practical OFDMA the size of the OFDM frames lies in between 1000 to 10,000 OFDM frames and hence in the BER range 0.0229 to 0.0299 at 15 dB.

Table 4.3 BER of Rayleigh fading channel with various OFDM frames

Eb / No	BER Values for					
	10^4 OFDM Frames	10^3 OFDM Frames	500 OFDM Frames	100 OFDM Frames	50 OFDM Frames	10 OFDM Frames
-5	0.6577	0.6572	0.6559	0.6403	0.6103	0.6092
0	0.4029	0.4027	0.4010	0.399	0.3905	0.39
5	0.1792	0.1783	0.1737	0.1559	0.131	0.0758
10	0.0644	0.062	0.0595	0.048	0.0545	0.0033
15	0.0299	0.0229	0.0127	0.0092	0.0082	0

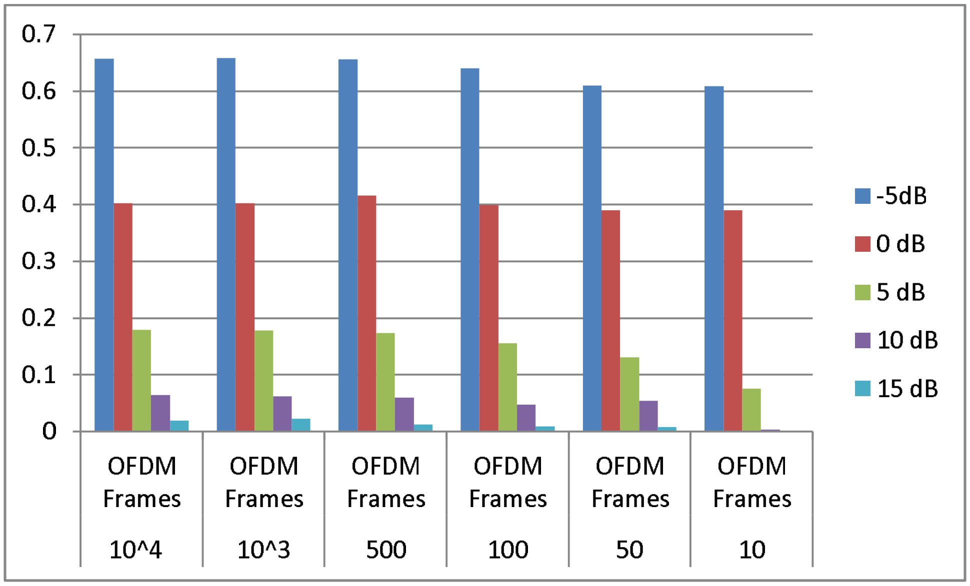

Fig .4.6 BER of Rayleigh fading channel with various OFDM frames

4.4 DELAY SPREAD CALCULATION

The radio waves will be propagating via reflections, diffraction and scattering to the receiver. At the mobile station, signal arrives from many different directions and with different delays, as shown in Fig.4.9. This property is called multipath propagation. The multiple plane waves get combined at the receiver antenna of the mobile to produce a composite received signal [71].

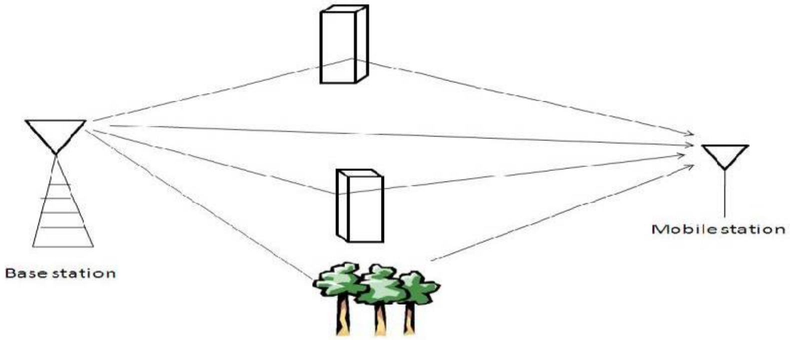

Fig. 4.7 Multipath propagation between transmitter and receiver antennas

The wavelength of the carrier used in Ultra High Frequency (UHF) mobile radio applications typically ranges from 15 to 60 cm. Therefore, even the small change in the differential propagation delay due to MS mobility will cause large changes in the phases of the individually arriving plane waves at the receiver. Hence, the arriving plane waves arriving at the mobile station and base station antennas will experience constructive and destructive addition of noise depending on the location of the mobile station. Especially the signal fading is more if the mobile station is moving or there are changes in the scattering environment [72].

4.4.1 Characteristics of Mobile Multipath Channels

Delay spread, Doppler spread, Coherence Time and Coherence Bandwidth are the main parameters on which the characteristics of multi-path channels depend. These multipath channel parameters are derived from the power delay profile of the received signal. The power delay profiles are calculated by taking the average instantaneous power delay profile measurements over a local area which determines an average small scale power delay profile. Delay spread and Doppler spread parameters are used to quantify and compare different channels [73]. The time dispersive natures of the channel in local area are described by the parameters Delay spread and coherence bandwidths [74], [75]. The time dispersive properties of wide band multipath channels are most commonly calculated by their mean excess delay ($\overline{\tau}$) and RMS delay spread (σ_τ). The mean excess delay is given by:

$$\overline{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \tag{4.3}$$

Where the absolute power is level of received signal is given by $P(\tau_k)$ and τ_k is delay of the kth detectable signal arriving at the receiver.

The RMS delay spread is defined as:

$$\sigma_\tau = \sqrt{\overline{\tau^2} - \overline{\tau}^2} \tag{4.4}$$

The Mean excess delay and the RMS delay spread delays are measured relative to the first detectable signal arriving at the receiver at $\tau_0 = 0$. If the Coherence Bandwidth is given a relaxation so that the relation between RMS delay spread and the coherence bandwidth is approximately:

$$B_C \approx \frac{1}{5\sigma_\tau} \tag{4.5}$$

If the value of coherence bandwidth is greater than the signal bandwidth or delay spread is less than the symbol period, then this fading is called "flat fading". If coherence bandwidth is less than the signal bandwidth then the fading is "frequency selective fading"[76], [77]. And also Exact Matched Filter Bound for Two-Beam Rayleigh Fading and Frequency-domain simulation and analysis of the frequency-selective Rician fading radio channel are given in [78] and [79].

4.5 SUMMARY

In this chapter the simulations were carried to choose the best digital modulation scheme and the channel to apply for the high data rate application like OFDMA. The simulations for the digital modulation schemes were carried out between M-PSK and M-QAM out of which though the 2-PSK has less BER, QAM-64 was selected in order to apply for the high data rate system. and also simulations among AWGN, Rayleigh and Rician fading channels were carried out and the results showed the various comparisons among them and it tells that the Rayleigh channel has moderate BER. Theoretical and practical simulations were also done to evaluate the performances. The comparison of BER for Rayleigh fading channel with different OFDM frames was also carried out to verify the variation in the BER.