BER Performance of OFDM System in AWGN and Rayleigh Fading Channel

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Abstract: **OFDM is being widely used in many communication systems for its ability to enhance the data rate and reduce the bandwidth. The paper gives a comparison of the performance of OFDM system using different modulation schemes under the influence of AWGN and Rayleigh fading channel. Simulations of OFDM signals are carried out with Rayleigh faded signals to understand the effect of channel fading and to obtain optimum value of Bit Error Rate (BER).**

Keywords: **OFDM, BER, AWGN channel model, Rayleigh fading channel model**

I. Introduction

The ever remaining demand of enhanced data rate along with increased reliability and reduced bandwidth in a communication system requires robustness against fast frequency selective multipath fading. Wireless communication systems widely adopted OFDM (Orthogonal Frequency Division Multiplexing) scheme for its high data rate transmission along with high bandwidth efficiency [1].

In real the transmission of data is much more complex than it seems in the block diagrams. Various factors influence the efficiency of the system like the density of users, line of sight between the transmitter and receiver, mutual movement between the transmitter and receiver etc. To consider these factors different channel models are developed like AWGN (Additive White Gaussian Noise) channel, Rayleigh fading channel, Rician fading channel etc [2]. Two such channels (AWGN and Rayleigh fading channel) are selected here to study the behavior of OFDM system.

The paper focuses upon the performance comparison of OFDM system in AWGN channel and Rayleigh fading channel. The rest of the paper is organized as follows. Section II presents a brief introduction of OFDM system. Section III gives knowledge of AWGN and Rayleigh Fading Channel in brief. Section IV presents the specifications of IEEE 802.11a. Simulation results are presented in section V and Section VI concludes the paper.

II. Orthogonal Frequency Division Multiplexing

OFDM [3] is a parallel transmission scheme, where a high-rate serial data stream is split up into a set of low-rate sub-streams, each of which is modulated on a separate sub-carrier. The bandwidth of the sub-carriers becomes small compared with the coherence bandwidth of the channel. The symbol period of the sub-streams is made long compared to the delay spread of the time-dispersive radio channel. Selecting a special set of (orthogonal) carrier frequencies high spectral efficiency can be obtained because the spectra of the sub-carrier overlaps, while mutual influence among the sub-carriers can be avoided. By introducing a guard interval (Fig. 1), the orthogonality can be maintained over a dispersive channel. OFDM scheme is advantageous because of high spectral efficiency, easy adaptability to severe channel conditions without complex time domain equalization, robustness against inter symbol interference (ISI) and fading caused by multipath propagation, efficient implementation using Fast Fourier Transform (FFT), less sensitive to time synchronization errors etc.

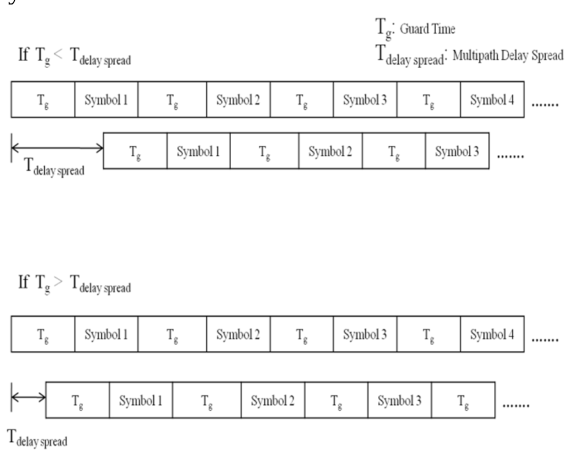

Fig.1 Effect of guard interval insertion

If T denotes the duration of OFDM symbol, f_o is the, T_g is the guard interval and Δf is the subcarrier spacing then transmitted signal can be expressed as

$s(t) = \frac{1}{\sqrt{T}} Re\{\sum_{y=1}^{K} d_y e^{j2\pi f_y t}\}$ …(1)

where $t \in [-Tg, T]$

if f_y is the y[th] subcarrier frequency and is given by

$f_y = f_o + (y-1)\Delta f$ …(2)

where f_o is the first carrier frequency

The signal at the receiver can be modeled as

$r(t) = \frac{1}{\sqrt{T}} Re\{\sum_{x=1}^{X} \sum_{y=1}^{Y} h_x(t) d_y e^{j2\pi f_y (t-\tau_x(t))}\} + z(t)$ …(3)

where $h_x(t)$ and $\tau_x(t)$ are the time varying gain and delay of x[th] path.

III. AWGN vs. Rayleigh Fading Channel

AWGN channel model is widely used in studying OFDM. In this model there is only linear addition of white noise with a constant spectral density and Gaussian distribution of amplitude. The model does not consider fading, frequency selectivity, interference etc. Although it is not much suitable for most of the terrestrial links yet being used for providing simple and controlled mathematical models to study the basic behavior of a system in the absence of the above mentioned factors.

In contrast to AWGN channel, in a multipath channel the transmitted signal reaches the receiver as a train of impulses. A multipath Rayleigh Fading channel considers the fading effects similar to an actual terrestrial channel [4-5]. It is best suitable for tropospheric and ionospheric signal propagation and for signal propagation in urban environments in short when there is no line of sight between transmitter and receiver. When there is a relative motion between transmitter and receiver there occurs Doppler shifts in signal frequency (fig 2).

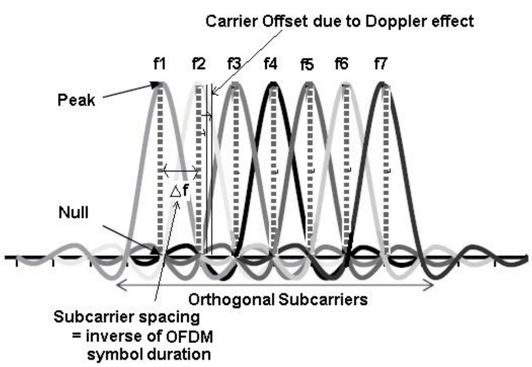

Fig 2. Effect of doppler shift

Since a multipath channel reflects signals at multiple places, a transmitted signal travels to the receiver through several paths that may have different lengths and hence different associated time delays. Fading occurs when these signals travelling through different paths interfere with each other.

IV. IEEE 802.11a System Specifications

The IEEE 802.11a standard specifies an OFDM physical layer that splits an information signal across 52 separate subcarriers. 4 subcarriers are pilot subcarriers and remaining 48 subcarriers provide separate wireless pathways for sending the information in a parallel manner. The resulting subcarrier spacing is 0.3125 MHz (for a 20 MHz bandwidth with 64 possible frequency slots). The basic parameters for OFDM systems as per IEEE 802.11a standard are given in Table 1.

Parameter	Value
FFT Size	64
No. of Subcarriers	52
FFT Sampling frequency	20 MHz
Subcarrier Spacing	312.5 KHz
Subcarrier Index	-26 to -1 and 1 to 26
Data Symbol Duration	3.2 µsec
Cyclic Prefix Duration	0.8 µsec
Total Symbol Duration	4 µsec
Modulation Schemes	BPSK, QPSK, 16-QAM, 64-QAM

Table 1. OFDM System Specification

V. Simulation Results

The OFDM system is developed, simulated and analyzed in MATLAB version 7.

Bit Error Rate is calculated for different modulation schemes under AWGN and Rayleigh Fading channel model.

The symbol to noise ratio can be calculated using

$\frac{E_s}{N_o} dB = \frac{E_b}{N_o} dB + 10log_{10}\left(\frac{No.of\ data\ Subcarries}{No.of\ FFT\ Symbols}\right) + 10log_{10}\left(\frac{Data\ Symbol\ Duration}{Total\ Symbol\ Duration}\right)$ …(4)

The mathematical model for calculating the impulse response of a n tap Rayleigh fading channel is give as

$h(t) = \frac{1}{\sqrt{n}}(h_1(t-t_1) + \cdots + h_n(t-t_n))$ …(5)

for this simulation n is taken as 10.

The BER performance of BPSK, QPSK and 16 & 64 QAM for OFDM system in AWGN system is shown in Fig.3

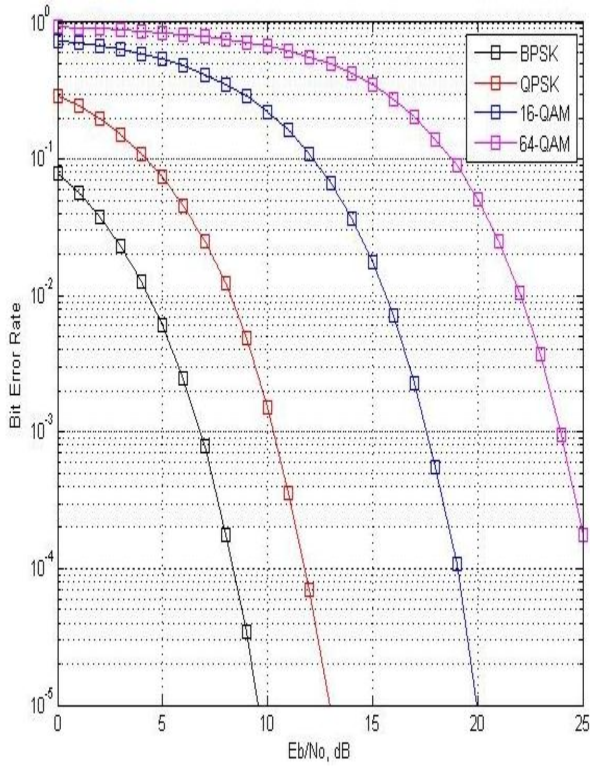

Fig.3 Performance comparison in AWGN channel

From the figure it can be observed that 64-QAM technique performs better than others in OFDM system for AWGN channel.
Fig.4 shows the BER comparison of BPSK, QPSK, 16QAM and 64QAM for OFDM system in multipath Rayleigh Fading channel.

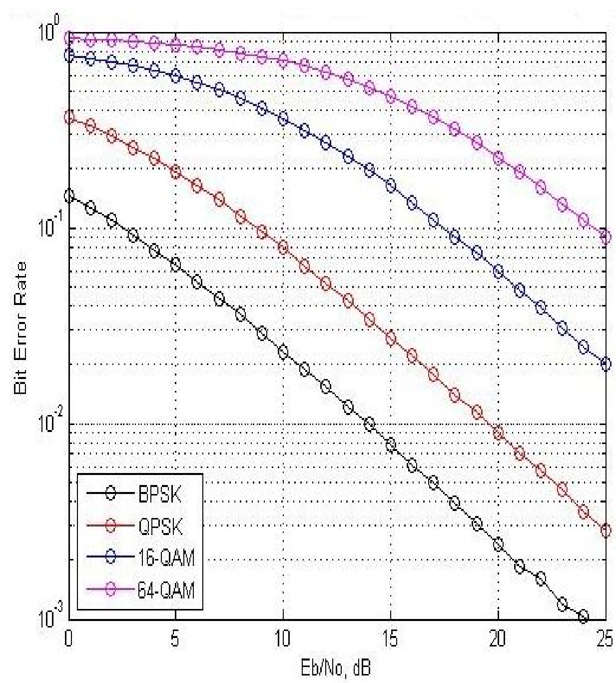

Fig.4 BER comparison in Rayleigh Fading channel

Fig.5 presents a comparison of the BER curves in AWGN and Rayleigh Fading channel.

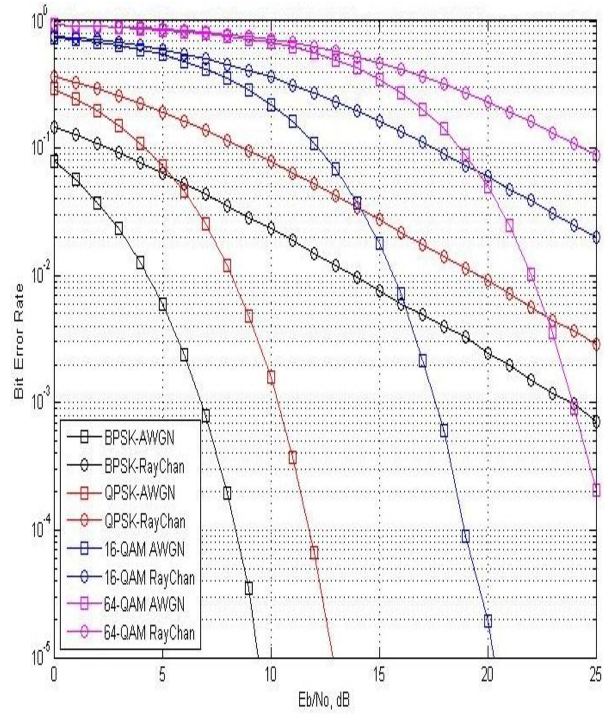

Fig.5 BER curves under AWGN and Rayleigh Fading channel

VI. Conclusion

The results presented shows that 64-QAM performs better for both channels but it also increases the complexity of the system. Also the result shows the performance improvement of the four modulation techniques in a 10 tap Rayleigh fading channel in comparison to their performance in AWGN channel. The reported BER can be further improved by using ICI reduction techniques.

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