International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Doppler Frequency Effect and BER Performance of FFT Based OFDM System

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Abstract: ***In the present scenario, there is a rising demand of high capacity, high performance and low Bit Error Rate (BER) in Wireless Communication systems. The Orthogonal Frequency Division Multiplexing (OFDM) is an attractive multi carrier modulation technique for wireless transmission systems. In this paper, we discuss the effect of Doppler frequency in Fast Fourier Transform (FFT) based OFDM system over Rayleigh fading channel. Multipath fading channel effect and BER on the performance of OFDM is shown in this paper. In this paper two type of modulation schemes are used. Phase Shift Key (PSK) modulation scheme is used for understanding the Doppler frequency effect on the OFDM system with RAYLEIGH Fading channel while QAM modulation scheme is used for studying the performance of BER in the OFDM system with RAYLEIGH and AWGN channel. The OFDM SYSTEM was implemented by using MATLAB.***

Keywords: AWGN channel, channel estimation, Bit Error Rate (BER), RAYLEIGH channel, FFT based OFDM system.

1. Introduction

The transmission of the data using a frequency multiplexing is very robust against the frequency selectivity of the Channel, when it is combined with a channel coding. The first techniques of frequency multiplexing with orthogonal carriers appeared in the mid 50's for military applications. In the 60's and 70's, the analog modulation and demodulation by means of the Fourier transform as been developed, but

It was prohibitive in terms of calculation load for a massive deployment of this technology. The OFDM acronym appeared in the 80's, when the evolution of the technology of semi-conductor allowed a great development of the implementation of complex algorithms, especially the ones based on FFT/IFFT of large size. This kind of modulation is now used in a large number of wired and wireless transmission standards.

The OFDM system based on IFFT/FFT algorithm which has the following major advantages

- The power amplifier (PA) can have smaller back off because of the reduced PAPR value.
- Lower the transceiver's complexity
- Low spectral re-growth
- Low sensitivity to CFO
- Power constraints of the battery driven handsets

In an OFDM system, the available bandwidth is divided into N small parts, and a block of N data symbols are modulated on N corresponding subcarriers which are orthogonal to each other. The spectra of the sub carriers are overlapped; therefore precise frequency recovery is needed. However in the mobile radio environment, the relative movement between transmitter and receiver causes Doppler frequency shifts. In addition, the carriers can never be perfectly synchronized leading to frequency offset. These random frequency errors in OFDM system distort orthogonality between the subcarriers leading to Inter Carrier Interference

This paper is organized as follows: Section 2 describes the OFDM system using FFT. Section 3explains channel estimation using pilot insertion. Section 4 describes Rayleigh and AWGN channel. Section 5 present the simulation parameters, results and analysis for FFT based OFDM system, Doppler frequency effect in RAYLEIGH channel and BER performance of AWGN and Rayleigh channel. Finally, conclusion is presented to summarize the main outcome of this paper.

2. OFDM System Using FFT

The block diagram of FFT based OFDM transceiver is shown in FIGURE 1.The input data is processed by M- ary QAM or PSK modulation.

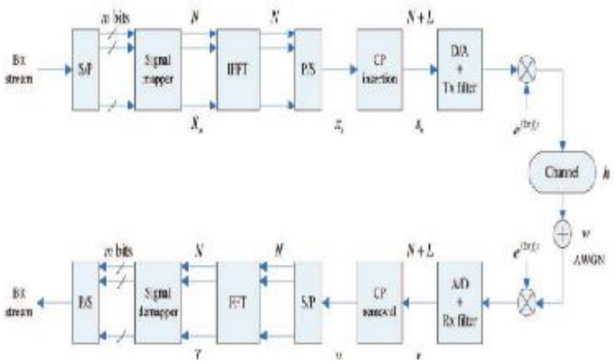

Figure 1: FFT Based OFDM System

In OFDM System data is carried on narrow band subcarriers in frequency domain. After symbol mapping it is necessary to convert the data stream into parallel form where each parallel data stream represents a sub-channel. Hence serial to parallel converter is used. The output of IFFT is the sum of the information signals in the discrete time domain as following:

$$(x)^k = \frac{1}{N}\sum_{m=0}^{N-1} x^m e^{j2\pi km/N}$$

After applying IFFT on the symbols, cyclic prefix is added and then passed through wireless communication channel. The digital data is converted to serial form and transmitted over the channel. At the receiver side the process is reversed to obtain the data after the FFT, the signal is converted back to the parallel form and demodulated to yield the transmitted signal back.

The output of the FFT is

$$(x)^m = \sum_{k=0}^{N-1} x^k e^{j2\pi km/N}$$

3. The Pilots in the OFDM Frame

The pilots, noted

$$C = \alpha e^{j\phi}$$

are subcarriers whose gain α, phase φ and arrangement in the time-frequency lattice are known by both the transmitter and the receiver. They do not carry any useful data, but are dedicated in the OFDM frame to the time and frequency synchronization, as well as the SNR and the channel estimation. In order to reduce their sensitivity to the noise, the gain is usually higher than the other subcarriers carrying useful data.

The choice of the pilot pattern depends on the selectivity of the channel, which is characterized by Bc and Tc. The block-type arrangement (a), also called time preamble, is adapted to quasi-static channels with high frequency selectivity. On the contrary, the comb-type arrangement (b) is used when the channel is time selective and with a low frequency selectivity. In the case of time and frequency selective channels, the rectangular (c) or staggered rows (d) patterns can be used. Consequently, an interpolation will be needed to estimate the channel frequency response over the time-frequency plan. The literature describes some other arrangements such as the hexagonal pattern or even an irregular distribution.

(a) Least Square Method of Channel Estimation

The least square criterion aims at minimizing the cost function J defined as the square norm of an error vector. This vector is the difference between the vector of the received signal U and the product of the transmitted signal vector C by a diagonal matrix D whose coefficients have to be optimized. We then get the estimation

$$\hat{\mathbf{H}}^{LS} = \underline{\mathbf{D}}_{opt}.$$

The cost function is first expressed as

$$J_{LS} = |\mathbf{U} - \underline{\mathbf{D}}\mathbf{C}|^2,$$

$$J_{LS} = \sum_{m=0}^{M-1} |U_m - D_m C_m|^2.$$

Minimizing J_{LS} amounts to solve $\nabla_{\underline{\mathbf{D}}} J_{LS} = 0$ with

$$\nabla_{\underline{\mathbf{D}}} J_{LS} = \begin{pmatrix} \frac{\partial}{\partial D_0}(|U_0 - D_{0,opt}C_0|^2) \\ \vdots \\ \frac{\partial}{\partial D_m}(|U_m - D_{m,opt}C_m|^2) \\ \vdots \\ \frac{\partial}{\partial D_{M-1}}(|U_{M-1} - D_{M-1,opt}C_{M-1}|^2) \end{pmatrix}.$$

For all $m = 0, 1, .., M-1$, we simply get

$$-2C_m(U_m - D_{m,opt}C_m) = 0,$$

and from $\hat{\underline{\mathbf{H}}}^{LS} = \underline{\mathbf{D}}_{opt}$ we deduce

$$\hat{H}_m^{LS} = \frac{U_m}{C_m} = H_m + \frac{W_m}{C_m}.$$

We notice that the LS estimation can be performed on each carrier individually. It can then be applied in the case of sparse pilot carriers in the OFDM frame. In the case of a pilot preamble, from we give the vectorial form of the expression.

$$\hat{\mathbf{H}}^{LS} = \mathbf{U}\underline{\mathbf{C}}^{-1} = \mathbf{H} + \mathbf{W}\underline{\mathbf{C}}^{-1}.$$

4. Rayleigh and AWGN Fading Channels

Rayleigh fading is a statistical model for the strong influence of a propagation environment on a radio signal, used by wireless communication devices. Rayleigh fading models consider that the magnitude of a signal that has passed through a transmission channel or medium will vary often and in a random manner, or fade, according to a Rayleigh distribution- the radial component of the addition of two uncorrelated Gaussian random variables. For wireless communications, the envelope of the received carrier signal is Rayleigh distributed; such a type of fading is called Rayleigh fading. This can be caused by multipath with or without the Doppler Effect. Rayleigh fading is a reasonable model where many objects in the environment scatter the radio signal before it arrives at the receiver. If there is no dominant component to the scatter, then such process will have zero mean and phase evenly distributed 0 and 2 pi radians. Calling this random variable R, it will have a probability density function.

$$P_R(r) = 2\pi/\Omega e^{-r^2/\Omega},\ r \geq 0$$

Where $\Omega = E(R^2)$

ADDITIVE WHITE GAUSSIAN noise (AWGN) channel is a universal channel model for analyzing modulation schemes. In this model, the channel does nothing but add a white Gaussian noise to the signal passing through it. This implies that the channel's amplitude frequency response is flat(thus with unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signal pass through it without any amplitude loss and phase distortion of frequency components. AWGN channel is a theoretical channel used for analysis purpose only.

The received signal in the interval of 0≤t≤T may be expressed as-

R(t)=S(t)+n(t)

Where n(t) denotes the sample function of additive white Gaussian noise channel(AWGN) process with power spectral density.

5. Simulation Results

(A) Simulation

FFT based OFDM system are implemented using MATLAB and graphical result are found showing the bit error rate (BER) of the system

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

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

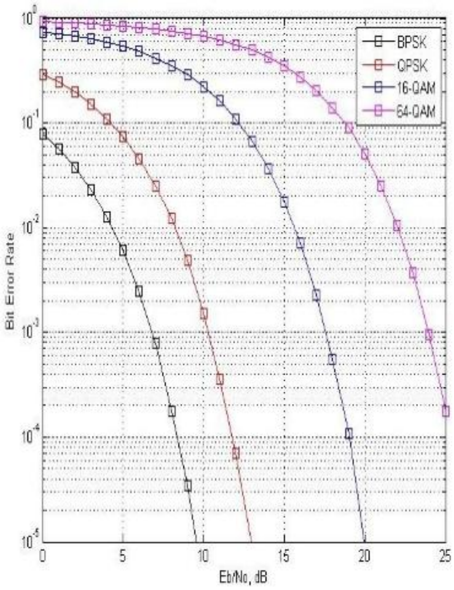

Figure 2: Performance comparison in AWGN channel

From the figure it can be observed that 64 QAM techniques perform better than others in OFDM system for AWGN channel.

Figure 3 shows the BER comparison of BPSK, QPSK, 16QAM and 64QAM for OFDM system in multipath Rayleigh Fading channel.

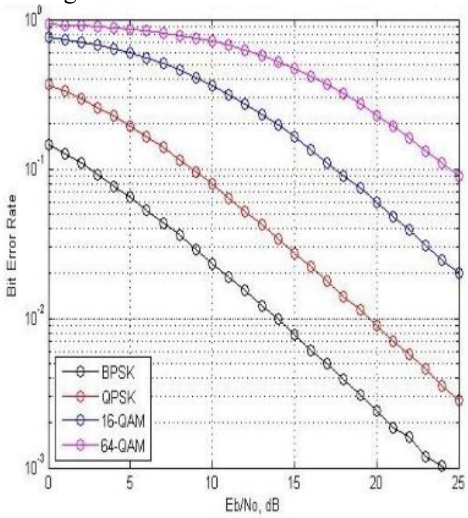

Figure 3: Performance comparison in Rayleigh fading channel

(B) Simulation:

When Doppler frequency Fd=0, implies that there is no mobility in the user. It is considered as the RAYLEIGH flat fading. For Fd=0Hz

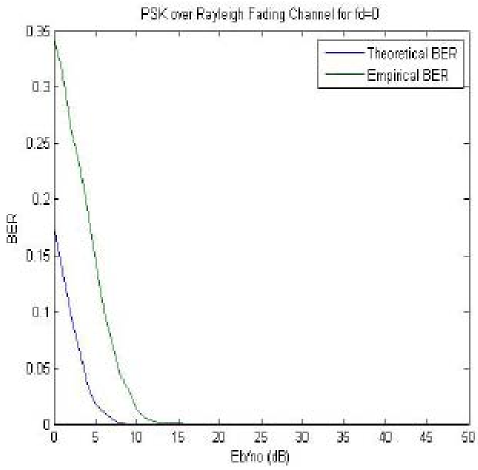

Figure 4: Doppler frequency is equal to zero

In figure 4, the result is bit far away from the theoretical. This is because of the removal of cyclic.

Prefix and the pilot symbol, causing overall reduction in transmitted power.

When the Fd = 50 Hz:-

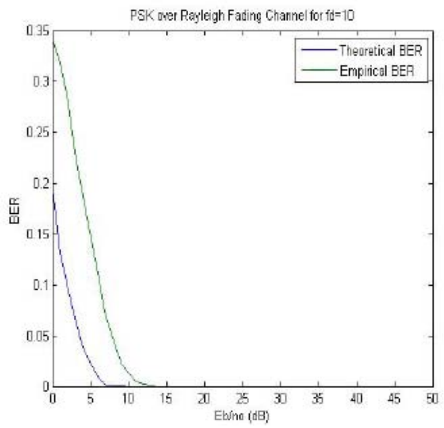

Figure 5: Doppler frequency is 10Hz over the RAYLEIGH fading channel.

In the comparison between the figure 4 and figure 5 there is less difference in the BER

When the Fd = 50 Hz:-

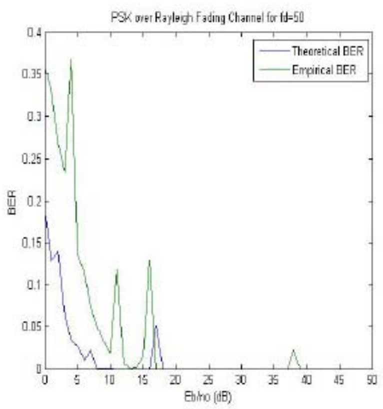

Figure 6: Doppler frequency is 50Hz over the RAYLEIGH fading channel

Figure 6 shows the effect represented by change in Doppler frequency causing the system performance to degrade.

6. Conclusion

The BER performance of the FFT based OFDM system can be found over AWGN and RAYLEIGH fading channel using the QAM and PSK modulation schemes. From the performance of both the channels it is found that QAM modulation is better than other modulation schemes because it is more bandwidth efficient. From the figure4 to figure 6 it represented that the as the Doppler frequency increases the BER is highly effected and it reduces the system performance.

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