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Performance Analysis of Ofdm in Combating Multipath Fading

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Abstract: *Mobile Communication system has been on high rampage for high data transmission over wireless medium with various challenges caused by the transmission Channel. OFDM is been discovered in recent years to deal with this problems because of its ability to elegantly cope with multipath interference. This paper investigates the performance of different modulation schemes using M-ary Phase Shift Keying (M-PSK) and M-ary Quadrature Amplitude Modulation (M-QAM) in information transmission with OFDM technique over Ideal channel AWGN and worst channel Rayleigh Fading channel in terms of Bits Error Rate (BER). Analysis was made for different types of modulation schemes BPSK, QPSK, 4-QAM and 16-QAM gray coded bit mapping. Also, a feasibility of OFDM been used to combat multipath fading was analyzed with comparison between a single carrier technique and OFDM multicarrier technique. Variation between SNR results with respect to BER is plotted to show the trade off differences between the modulation schemes with the result showing that OFDM allows data transmission with minimal error over fading channel than a Single Carrier.*

Keywords: *OFDM, Single Carrier, AWGN, Rayleigh fading, BER, M-ary PSK, M-ary QAM*

I. Introduction

The concept of OFDM in term of parallel data transmission and frequency division multiplexing was first developed in the 50s [1, 2] and introduced in some papers in the mid 60s [3]. Although the idea of OFDM started back in 1966, it has never been widely utilized until the last decade when it “becomes the modem of choice in wireless applications” [4]. OFDM can be seen as either a modulation technique or a multiplexing technique allowing high speeds at wireless communications; its hierarchy corresponds to the physical and medium access layer. OFDM as a multicarrier technique is used to increase the robustness against frequency selective fading or narrowband interference.

In a single carrier system, a single fade or interfere can cause the entire link to fail, but in OFDM multicarrier system, only a small percentage of the subcarriers will be affected. Data to be transmitted in OFDM is typically in the form of a serial data stream and since OFDM transmits data as a set of parallel low bandwidth (100Hz – 50 kHz), hence a serial to parallel conversion is needed to divide the serial data into parallel sub carriers. OFDM provides high bandwidth efficiency because the subcarriers are orthogonal to each other. This made the carrier to be independent of each other even though their spectral overlap. The frequency spacing between the sub carriers is made to be the reciprocal of the useful symbol.

An important component in OFDM that makes its subcarrier to each other is Discrete Fourier Transform (DFT) which is been replaced by Inverse Fast Fourier Transform (IFFT) because IFFT is cost effective to implement. IFFT converts the symbols in frequency domain to time domain at the transmitter while Fast Fourier Transform (FFT) is been used at the receiver to convert back from time domain to frequency domain. High data rate systems are achieved by using a large number of carriers. Other components a basic OFDM system will contain are modulation scheme a QAM or PSK modulator or demodulator, a serial to parallel converter and a parallel to serial converter.

However, since OFDM has proved to be very effective in mitigating adverse multipath effects of a broadband wireless channel, counteracting the frequency selectivity of multipath channels by multiplexing information on different orthogonal carriers, it now becomes the underlying technology for various new applications such as digital audio broadcast (DAB) () and for Digital Video Broadcast (DVB) in Europe and Australia. Other areas of OFDM applications are wireless LAN (802.11a&g, 802.16a&b, Wimax and Hiper LAN-2), broadband wireless (MMDS, LMDS), xDSL, and home networking.

Modulation schemes in OFDM are used to cover data rates for various needs. Modulation mapping rate are dynamically adapted based on channel condition to increase the system performance in terms of Bit Error Rate (BER). Gray bit mapping is been used in different modulation schemes for the bit constellation of the transmitted bits to be rearranged thereby making every adjacent bits differ by one bit.

This paper now presents the average Bit Error Rate for different modulation schemes trying to see which is the best modulation scheme to use under an idea AWGN and worst channel Rayleigh fading channel using some forward error corrections such as Concatenated Reed Solomon and Convolutional Encoder with General interleaver.

The paper is divided into sections; section II will discuss OFDM system, Propagation Characteristics of Mobile Radio Channels, and mathematical model. In section III, simulations and results are presented. Finally, conclusion is sdrawn in the last section of this paper.

OFDM

The next generation of wireless communication, that is 4G has adopted OFDM as their physical layer because OFDM efficiently utilize multiple performance for 4G [M. Nakagami, 1960].The growing demand for modulated carriers tightly together reducing the required bandwidth but keeping the modulated signals orthogonal so that they do not interfere with each other. OFDM that is highly efficient technique shows favorable properties such as robustness to channel fading and inter symbol interference (ISI) and is immune to noise. OFDM system is capable of mitigating a frequency selective fading channel to a set of parallel flat fading.

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, many carriers, each one being modulated by a low rate data stream share the transmission bandwidth. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.

Unlike the conventional multicarrier communication scheme in which spectrum of each subcarrier is non-overlapping and band, pass filtering is used to extract the frequency of interest, in OFDM the frequency spacing between subcarriers is selected such that the subcarriers are mathematically orthogonal to each other's. The spectra of subcarriers overlap each other but individual subcarrier can be extracted by baseband processing. This overlapping property makes OFDM more spectral efficient than the conventional multicarrier communication scheme.

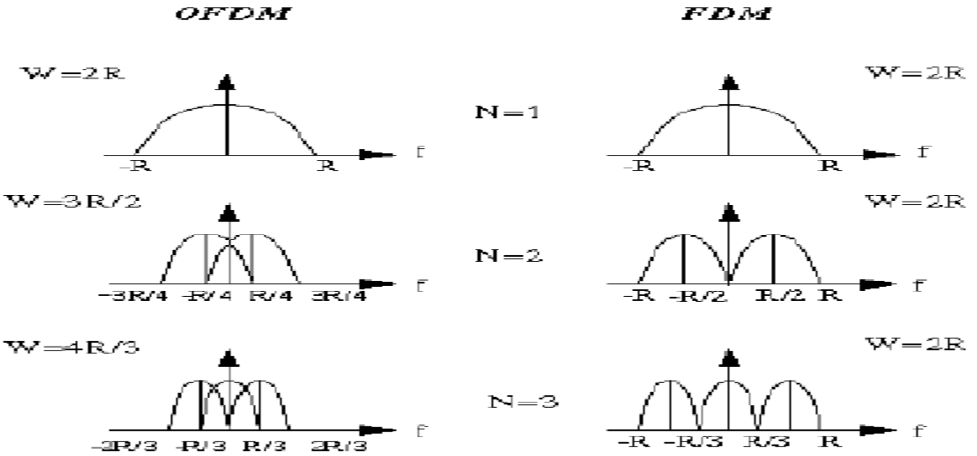

Figure 1: Concept of OFDM Signal: Orthogonal Multicarrier Technique versus Conventional Multicarrier Techniques.

Orthogonality of OFDM

The main concept in OFDM is Orthogonality of the subcarriers. Since the carriers are all sine and cosine waves, area under one period of a sine or cosine wave is Zero. Taking a sine wave of frequency m and multiplying it by a sinusoid (sine/cosine) of a frequency n, where m and n are integers, the integral or the area under this product is given by:

$$f(t) = sinm\omega t * sinn\omega t \qquad (1)$$

By the simple trigonometry relationship, this is equal to a sum of two sinusoids of frequencies (m-n) and (m+n) given as:

$$= \frac{1}{2}\cos(m-n) - \frac{1}{2} \qquad (2)$$

Equation (2) shows that the two frequencies components are sinusoids; hence integrating them over one period gives zero:

$$\int_0^{2\pi}\frac{1}{2}\cos(m-n)\omega t - \int_0^{2\pi}\frac{1}{2}\cos(m+n)\,\omega t \qquad (3)$$

$$= 0 - 0$$

Therefore, it can be concluded that when a sinusoid of a frequency n is multiplied by sinusoid of frequency m/n, the area under the product is zero. Integral for all integer n and m, sinm$x$, cosm$x$, cosn$x$, sinn$x$, are all orthogonal to each other. These frequencies are called harmonics.

In a simple way it can be put that, two periodic signals are orthogonal when the integral of their product, over one period, is equal to zero. This is true of certain sinusoids as illustrated in the equations below:
Continuous Time

$$\int_0^{\tau} \cos(2\pi n f_o t) cos(2\pi m f_o t) dt = 0 \ (n \neq m) \tag{4}$$

Discrete Time

$$\sum_0^{N-1} cos\left(\frac{2\pi kn}{N}\right) cos\left(\frac{2\pi km}{N}\right) = 0 \ (n \neq m) \tag{5}$$

The carriers of an OFDM are sinusoids that meet this requirement because each one is a multiple of frequency. Each one has an integer number of cycles in the fundamental period. If the dot product of two deterministic signals is equal to zero, these signals are said to be orthogonal to each other.

1.3 Mathematical Model of OFDM System.

The basic idea of OFDM is to divide the available spectrum into several sub channels (subcarriers) by making all sub channels narrowband, they experience almost flat fading, which makes equalization very simple or may not require equalization. To obtain a high spectral efficiency the frequency response of the sub-channels are overlapping and orthogonal, hence the name OFDM. This orthogonality can be completely maintained, even though the signal passes through a time dispersive channel, by introducing a cyclic prefix [6]. There are several versions of OFDM, [7, 8, 9] but this research focus on systems using such a cyclic prefix [10]. A cyclic prefix is a copy of the last part of the OFDM symbol, which is presented to the transmitted symbol. This makes the transmitted signal periodic, which plays a decisive role in avoiding intersymbol and intercarrier interference [7].

Starting with the waveforms used in the transmitter and proceeding all the way to the receiver, the description goes thus:

Transmitter

Assuming an OFDM system with N subcarriers, a bandwidth of Q Hz and symbol length of T seconds, of which Tcp seconds is the length of the cyclic prefix, the transmitter uses the following waveforms:

$$\phi_\kappa(t) = \begin{cases} \frac{1}{\sqrt{T - T_{cp}}} e^{j2\pi \frac{\omega}{N} k(t - T_{cp})} & \text{if t} \in [0 \quad \text{T}] \\ 0 & otherwise \end{cases} \tag{6}$$

Where $T = \frac{N}{W} + T_{cp.}$ Note that $\emptyset_t(t) = \emptyset_k\left(t + \frac{N}{W}\right)$, where T is within the cyclic prefix $[0, \quad T_{cp}]$ since $\emptyset_k(t)$ is the rectangular pulse modulated on the carrier frequency $\frac{KW}{N}$, the common interpretation of OFDM is that it uses N subcarriers, each carrying a low-bit rate. Now the transmitted baseband signal for OFDM symbol number *l* is:

$$s_t(t) = \sum_{k=0}^{N-1} x_k \, , \ell^{\emptyset_k(t - \ell T)} \tag{7}$$

Where $x_0, \ell, x_1, \ell \ldots \ldots \ldots \ldots x_{N-1}$ are complex symbols from the set of signal constellation points. When an infinite sequence of OFDM symbols is transmitted, the output from the transmitter is a juxtaposition of individual OFDM symbols:

$$s(t) = \sum_{\ell=-\infty}^{\infty} s_\ell(t) = \sum_{\ell=-\infty}^{+\infty} \sum_{k=0}^{N-1} x_{k,\ell\emptyset_k}(t - \ell T) \tag{8}$$

Physical Channel

An assumption that the support of possibly time variant impulse response g(τ;t) of the physical channel is restricted to the interval $\tau \in [0, T_{cp}]$ i.e to the length of the cyclic prefix. The received signal becomes:

$$r(t) = g(\tau, t) * s(t) + n(t) = \int_0^{T_{cp}} g(\tau; t) s(t - \tau) d\tau + \dot{n}(t) \tag{9}$$

Where $\dot{n}(t)$ is additive white, complex Gaussian channel noise.

Receiver

In an OFDM receiver, a filter bank is matched to the last part $[T_{cp}, T]$ of the transmitter waveforms $\emptyset_k(t), i.e$

$$\psi_k(t) = \begin{cases} \phi^*(T-t) & if\ t \,\epsilon\, [0, T-T_{cp}] \\ 0 & otherwise \end{cases} \qquad (10)$$

From the equation above, it is been observed that the cyclic prefix is removed at the receiver. Since the cyclic prefix contains all ISI from the previous symbol, the sampled output from the reciver filter bank contains no ISI. Therefore, the time index ℓ when calculating the sampled output at the *kth* matched filter.

When we consider equations, we arrive at

$$y_k \;=\; \int_{T_{cp}}^{T} \Big(\int_0^{T_{cp}} g(\tau;t) \left[\sum_{k'=0}^{N-1} x_{k'} \emptyset_{k'}(t-\tau)\right] d\tau\, \emptyset_k^*(t)\, dt + \int_{T_{cp}}^{T} \hbar(T-t)\, \emptyset_k^*(t)\, dt\Big] \qquad (11)$$

Considering the channel to be fixed over the OFDM symbol interval is denoted by $g(\tau)$, which gives

$$y_k = \sum_{k'=0}^{N-1} x_{k'} \int_{T_{cp}}^{T} \Big(\int_0^{T_{cp}} g(\tau)\, \emptyset_{k'}(t-\tau)\Big] d\tau\, \emptyset_k^*(t)\, dt + \int_{T_{cp}}^{T} \hbar(T-t)\, \emptyset_k^*(t) dt \qquad (12)$$

The integration intervals are $T_{cp} < t < T$ and $0 < \tau < T_{cp}$ which implies that $0 < t - \tau < T$ and the inner integral can be written as:

$$\int_{T_{cp}}^{T} \Big(\int_0^{T_{cp}} g(\tau)\, \emptyset_{k'}(t-\tau)\Big] d\tau = \int_0^{T_{cp}} g(\tau) \frac{e^{j2\pi k'(t-\tau-T_{cp})\frac{W}{N}}}{\sqrt{T-T_{cp}}} d\tau = \frac{e^{j2\pi k'(t-\tau-T_{cp})\frac{W}{N}}}{\sqrt{T-T_{cp}}} \int_0^{T_{cp}} g(\tau)\, e^{-j2\pi k'\frac{W}{N} d\tau,}\; T_{cp} < t < T \qquad (13)$$

The latter part of this expression is the sampled frequency response of the channel at frequency $f = k'\frac{W}{N}$, *i. e.,* at the k'th subcarrier frequency:

$$h_{k'} = G\left(k'\frac{W}{N}\right) = \int_0^{T_{cp}} g(\tau)\, e^{-j2\pi k'\frac{W}{N} d\tau,} \qquad (14)$$

Where $G(f)$ is the fourier transform of $g(\tau)$. Using this notation the output from the reciver filter bank can be smplified to

$$\begin{aligned} y_k &= \sum_{k'=0}^{N-1} x_{k'} \int_{T_{cp}}^{T} \frac{e^{j2\pi k'(t-T_{cp})\frac{W}{N}}}{\sqrt{T-T_{cp}}}\, h_{k'}\, \emptyset_k^*(t) dt + \int_{T_{cp}}^{T} \hbar\,(T-t)\, h_{k'}\, \emptyset_k^*(t) dt \\ &= \sum_{k'=0}^{N-1} x_{k'} h_{k'} \int_{T_{cp}}^{T} \emptyset_{k'(t)}\;\; \emptyset_k^*(t) dt + \; n_k \end{aligned} \qquad (15)$$

Where

$$n_k = \int_{T_{cp}}^{T} \tilde{n}(T-t)\;\; \emptyset_k^*(t) d(t)$$

Since the transmitter filters $\emptyset_k(t)$ are orthogonal,

$$\int_{T_{cp}}^{T} \emptyset_{k'(t)}\;\; \emptyset_k^*(t) dt = \int_{T_{cp}}^{T} \frac{e^{j2\pi k'(t-T_{cp})\frac{W}{N}}}{\sqrt{T-T_{cp}}}\; \frac{e^{-j2\pi k'(t-T_{cp})\frac{W}{N}}}{\sqrt{T-T_{cp}}}\, dt = \delta[k-k'] \qquad (16)$$

Where $\delta[k]$ is the Kronecker delta function (Oppenheim and Schafer, 1989), equation (15) can be simplified to obtain

$$y_k = h_k x_k + \; n_k \qquad (17)$$

Where n_k is the additive white Gaussian noise (AWGN).

The benefit of cyclic prefix is to avoid ISI since it acts as a guard interval and ICI because it maintains the orthogonality of the sub carriers.

Discrete-time model

In discrete time model, as compared to continuous time model, an inverse DFT (IDFT) and a DFT respectively replace the modulation and demodulation, and the channel is a discrete time convolution. The cyclic prefix operates in the same fashion and the calculations can be performed in essentially the same way. The main difference is that all integrals are replaced by sums. From the receiver's point of view, the use of a cyclic prefix longer than the channel will transform the linear convolution in the channel to a cyclic convolution. Denoting cyclic convolution by'$\otimes$' the whole OFDM system can be written as:

$$\begin{aligned} y_l &= DFT(IDFT(x_1) \;\otimes g_l + \tilde{n}_l) \\ &= \;DFT(IDFT(x_1) \;\otimes\; g_l + n_l) \end{aligned}$$

(18)

Where y_l contains *N* received data points, s_l the *N* transmitted constellation points, g_l the impulse response of the channel (padded with zero to obtain a length of *N*), and $\tilde{n}_l$ the channel noise. Since the channel noise is assumed white and Gaussian, the term $\tilde{n}_l$= *DFT* ($\tilde{n}_l$) represents the uncorrelated Gaussian noise. Further, we use that the DFT of two cyclically convolved signals is equivalent to the product of their individual DFTs. Denoting element-by-element multiplication by (.), the above expression can be written

$$y_l = x_l.DFT(g_l) + n_l = x_l.h_l + n_l,$$

(19)

Where $h_l =$ *DFT* (g_l) is the frequency response of the channel. Thus, we have obtained the same type of parallel Gaussian channels as for the continuous-time model. The only difference is the channel attenuations h_l are given by the *N* point DFT of the discrete time channel, instead of the sampled frequency response as in Equation (17).

1.4 Propagation Characteristics of Mobile Radio Channels

Channel Fading Techniques

The physical medium between the transmitter and receiver is known as channel. Radio channel is the link between the transmitter and the receiver that carries information bearing signal in the form of electromagnetic waves. Scatters (local to the receiver) and reflectors (local to the transmitter) commonly characterize the radio channel. Small-scale fading, or simply fading, is used to describe the rapid fluctuations of the amplitude of a radio signal over a short period or travel distance, so that large-scale path loss effects may be ignored.

This channel results in random delay (random phase shift) with total a factor. Channels may be three types as tabulated below

Type	**Descriptions**	**Example**
Simplex	One way only	FM radio, television
Half duplex	Two way, only one at a time	Police Radio
Full duplex	Two way, both at the same time	Mobile systems

Table1. Types of Channels with examples.

Attenuation

Attenuation can be described as the drop in the signal power when signal is been transmitted from one point to another. Transmission path length, obstructions in the signal path, and multipath effects are the major factors causing attenuation. Any objects, which obstruct the line of sight signal from the transmitter to the receiver, can cause attenuation. The most important environmental attenuation factor generally caused by buildings and hills is Shadowing. Shadowing of the signal can occur whenever there is an obstruction between the transmitter and receiver, especially in heavily built up areas with much building shadows.

Diffraction is the bending of a radio signal towards a solid obstruction. Radio signals diffract off the boundaries of obstruction, thus preventing total shadowing of the signals behind hills and buildings. Hills can cause a large problem due to the large shadow they produce. However, the amount of diffraction is dependent on the radio frequency used, with low frequencies diffracting more than high frequency signals. Hence, for adequate signal strength, Ultra High Frequencies (UHF), and microwave signals require line of sight. More so, to overcome the problem of shadowing, transmitters are usually elevated as high as possible to minimize the number of obstruction. The typical amounts of variation in attenuation due to shadowing are shown in the table 2 below [11].

Description	**Typical Attenuation due to Shadowing**
Heavy built-up urban center	20dB variation from street to street
Sub-urban area (fewer large buildings)	10dB greater signal power then built-up urban center
Open rural area	20dB greater signal power then sub-areas
Terrain irregularities and tree foliage	3-12dB signal power variation.

Table 2: Typical Attenuation in Radio Channel [11]

Multipath Effects.

In mobile communications, the signal is degraded by terrestrial multipath fading in the lower atmosphere known as troposphere [12].This troposphere is between altitude of 0 and 70 km and consists of many objects such as buildings, mountains, trees, moving cars, sign posts at the ground surface and natural phenomena like temperature, humidity, rainfall, etc at above the ground surface. These artificial and natural phenomena obstruct the transmitted signal, hindered the signal to reflect, refract, diffract and scatter, and move in different paths called multipath propagation causing the received signal to be degraded. The different paths add up constructively when the received signal paths are in phase and destructively under unfavourable phase conditions. The effects of terrestrial multipath propagation are signal fading, delay spread which is very dominant in urban environment leading to intersymbol interference (ISI) distortion, and lastly the doppler spread which occurs when there is relative motion in terrestrial environment. Therefore, these result in signal fluctuation at the receiver [13]. In wireless channel, the medium is the free space. In this case, there is no specified or particular path for signal transmission. The transmitted signal may be reflected from many things like hills, trees, etc before being received at the destined receiver. This can give rise to multiple transmission paths up to the receiver. The relative phase of the multiple reflected signals causes destructive or constructive interference at the receiver. This is normally experienced for very short distances (typically at half of the wavelength distances), thus is given the term - *fast fading*. This variation can vary from10 to 30dB [over short distances [14].

Fading Statistics in Radio Channel

In communications systems, fading occurs due to the multipath propagation. As a result, signals reaching the receiver from several different paths that may have different lengths corresponding to different time delays and gains. Time delay causes additional phase shifts to the main signal component. Therefore, the signal reaching the receiver is the sum of some copies of the original signal with different delays and gains. With this explanation, the channel impulse response can be modelled as described in [15] with the equation given below:

$$h_c(t) = \sum_{K=0}^{K-1} \alpha_k \delta(t - \tau k) \qquad (20)$$

Where:

$\alpha_k =$ Complex path gain

$k =$ Number of paths

$\tau_k =$ Path delay

Fading can be classified into two different scales:

Small Scale fading**:** small-scale fading happens in very short time duration, is caused by reflectors**,** and scatters that change the amplitude, phase and angle of the arriving signal. Rayleigh distribution and Rician distribution are often used to define small scale fading.

Large Scale fading: Large-scale fading is due to shadowing and the mobile station should move over a large distance to overcome the effects of shadowing. Log-normal distribution is often used to define large-scale fading.

Fast Fading

In a fast fading channel, the rate of change of the channel is higher than the signal symbol period and hence the channel changes over one period. In other words, the channel coherence time T_c, is smaller than the symbol periodT_s. T_c is related to the Doppler spread,f_d, as:

$$T_c=0.423/f_d \qquad (21)$$

From this relation it is clear that a high Doppler spread results in a smaller channel coherence time. The coherence time of 0.423ms corresponding to a f_d of 1 kHz is clear.

1.4.6 Slow Fading

As the name suggests, in a slow fading channel, the channel coherence time is larger than the symbol period and hence the channel remains approximately static over a symbol or multiple symbols. From the above equation it is clear that slow fading is usually expected with low Doppler spread values; i.e. with slower moving obstacles and receiver/transmitter. Multipath delay spread based and Doppler spread based fades are completely independent of each other and hence is quite possible to have a flat, fast fading channel or a flat, slow fading channel; and so on.

Additive White Gaussian Noise

Zero-mean white Gaussian Noise (WGN) has the same power spectral density AWGN (f) for all frequencies. The adjective ‘white’ is used in the sense that white light contains equal amounts of all frequencies within the visible band of electromagnetic radiation. The autocorrelation function of WGN is given by the inverse Fourier transform of the noise power spectral density GWGN (f): The autocorrelation function RaWGN (t) is zero for t≠0. This means that any two different samples of WGN, no matter how close together in time they are taken, are uncorrelated. The noise signal WGN (t) is totally decorrelated from its time-shifted version for any t≠0.

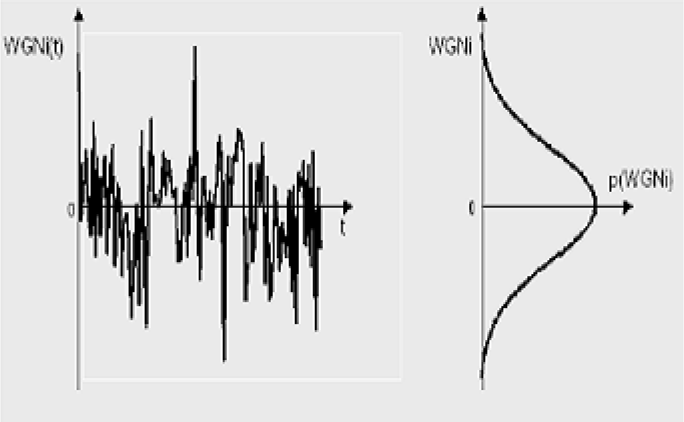

Fig 2. Signal with AWGN Noise

The amplitude of ‘integrated’ (bandwidth) WGN has a Gaussian probability density distribution P (WGNi).Noise exists in all communications systems operating over an analog physical channel, such as radio. The main sources are thermal background noise, electrical noise in the receiver amplifiers, & inter-cellular interference.

Rayleigh Fading Distribution

Rayleigh distributions are defined for fading of a channel when all the received signals are reflected signals and there is no dominant component. The Rayleigh distribution has a Probability Density Functions (PDF) given as: [18].

$$p(r) = \begin{cases} \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right) & (0 \le r) \\ 0 & (r \le 0) \end{cases} \qquad (22)$$

Where σ is the Root Mean Square (RMS) value of voltage in a received signal and σ^2 is the time-average power of the received signal. The Cumulative Distribution Function (CDF) is defined to specify the probability that the received signal does not exceed a specific threshold R. The CDF is given by [16]

$$P(R) = P(r \le R) = \int_0^R p(r)dr = 1 - \exp\left(-\frac{R^2}{2\sigma^2}\right) \qquad (23)$$

The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received signal power. It describes the probability of the signal level being received due to fading.

The central limit theorem will give the channel the statistical characteristics of a Rayleigh Distribution.

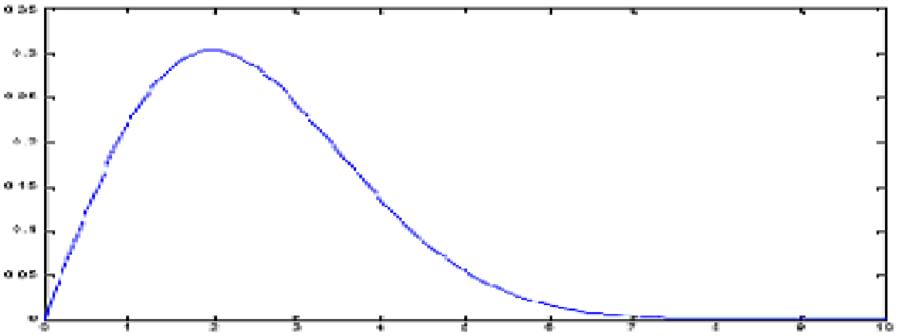

Fig. 3: Rayleigh distribution

II. Simulation Results And Discurssion

In this paper, analysis of the performance of different modulation schemes with gray coded bit mapping over AWGN and Rayleigh fading Channel with OFDM technique is performed using MATLAB SIMULINK. The diagram below shows the typical block diagram of an OFDM system.

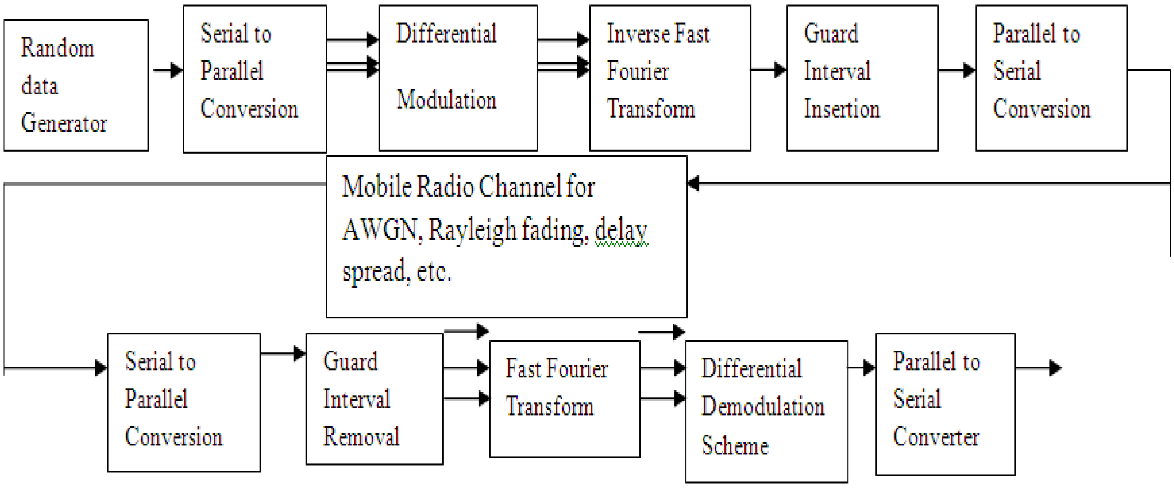

Fig 4: The OFDM Model block diagram.

1.	Required Bandwidth	20 MHz
2.	Sampling Frequency	20 MHz
3.	Carrier Modulation Used	BPSK, QPSK, 4QAM, 16QAM.
4.	Number of FFT size (N_{fft})	256
5.	Number of data subcarrier (N_{SD})	200
6.	Number of pilot subcarrier (N_{SP})	28

Table 3 the Simulation Parameters for OFDM Transceiver

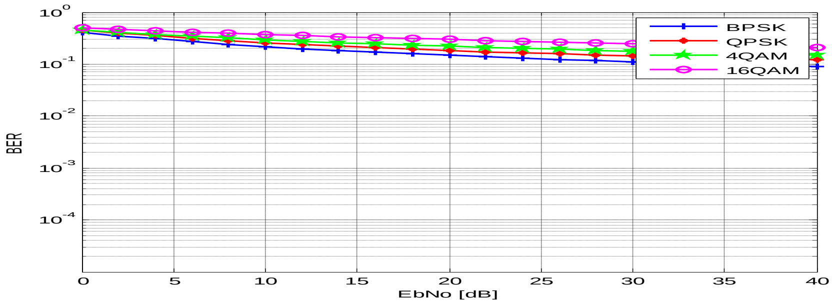

Fig 5: Single Carrier Modulation Schemes over Multipath Rayleigh Fading Channel.

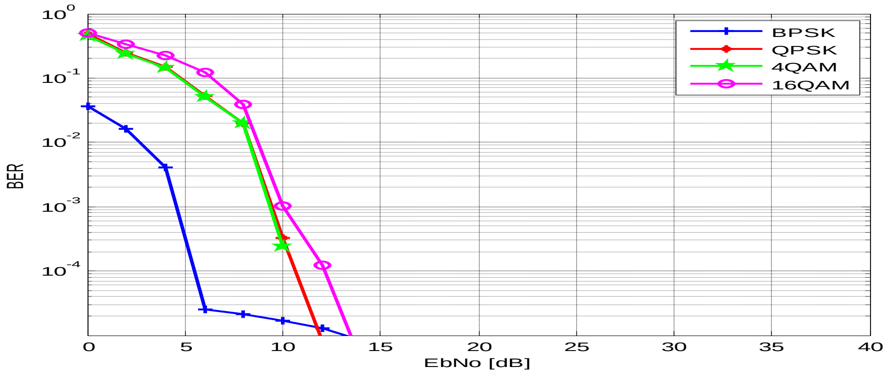

Fig 6: Single Carrier Modulation Schemes over AWGN Channel.

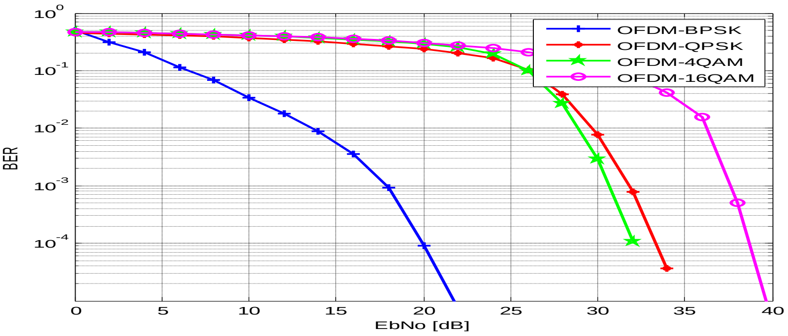

Fig 7: BER versus SNR Curve for OFDM technique in Multipath Rayleigh fading Channel with different modulation Schemes.

Fig 5 and Fig 7 above show the effect of multipath fading channel on data transmission and the feasibility of using OFDM Schemes to combat the effect of fading. A single fade or interferer in a single carrier system of fig 5 can cause the entire link to fail hence not making the graph to converge due to much attenuation and loss of transmitted bits that occur at the multipath channel. Hence, the BER is high in a Single Carrier System. Fig 6 shows Single carrier converges easily over the AWGN Channel because it is an idea Channel with noise and no delay spread. This establishes the fact that OFDM is used in combating frequency selective fading channel and not AWGN.

However, the effect of Multipath Rayleigh Fading channel to the performance of the OFDM system for four modulation techniques namely BPSK, QPSK, 4-QAM and 16-QAM are shown in the figure 6. It can be observed from the above figure that, to achieve a BER of 10^{-5}, the OFDM model system with BPSK modulation needs at least a SNR of 20dB, the OFDM system when using QPSK modulation needs at least 34dB, the OFDM system with 4-QAM modulation needs at least SNR around 32dB and the OFDM system for 16-QAM modulation needs at least SNR around 38dB.

III. Conclusion

Analysis was made on a Single Carrier technique and OFDM multicarrier technique. It has been shown that OFDM allows data transmission with minimal error over fading channel than a Single Carrier. In addition, performances of different modulation scheme for BPSK, QPSK, 4-QAM, and 16-QAM has been analyzed. It can be deduced hence that in a channel with high interference, a small modulation scheme like BPSK is favourable since it requires a low signal to noise ratio (SNR) in the receiver but with low data rate. However, in an interference free channel, a larger constellation modulation scheme (16-QAM) is more beneficial due to the higher bit rate.

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