

# Performance Evaluation of Various Cluster based OFDM Schemes

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**Abstract:** *As more and more people started using the communication equipments, the demand for high data rate increases quickly. Orthogonal Frequency Division Multiplexing (OFDM) is one of the latest modulation techniques used in order to combat the frequency-selectivity of the transmission channels, also achieves high data rate without inter-symbol interference. The basic principle of OFDM is gaining a wide spread popularity within the wireless transmission community. This paper deals with the communication system that uses BPSK, QPSK and QAM techniques to transmit information using OFDM technique over Rayleigh communication channel. In terms of Symbol Error Rate (SER), the performance of different modulation schemes using OFDM techniques in Rayleigh channel is analyzed. For different types of modulation schemes (BPSK, QPSK, 16-QAM, 64-QAM) has been used with OFDM techniques. In this paper we analyze the Bit Error Rate (BER) of Rayleigh Fading Channels in OFDM systems using BPSK, QPSK and QAM Modulation Schemes.*

**Keywords:** BPSK, QPSK, QAM, BER, SER, OFDM, Rayleigh fading channel.

## 1. Introduction

In recent years high speed wireless data communications have found many application areas like Orthogonal Frequency Division Multiplexing (OFDM) (R. D. Van Nee and R.Pras ).The principle of OFDM modulation have been used since 1960s. But in recent years, this technology has crossed the limitations into the real world of modern communication systems to combat Inter Symbol Interference (ISI) through multicarrier modulation [1,2].

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 the information on different orthogonal carriers is the key to the OFDM success. Indeed, when a cyclic prefix is inserted between successive OFDM symbols, the overall system can be viewed as composed of N parallel frequency flat channels [3, 5].

So, now it becomes the underlying technology for various new applications like digital audio broadcast (DAB), digital video broadcasting-terrestrial (DVB-T) (ETS), wireless LAN (802.11a&g, 802.16a&b and Hiper LAN-2(ETSI)), broadband wireless (MMDS, LMDS), xDSL, and home networking. Now-a-days OFDM has replaced DSSS for 802.11a and 802.11g wireless LAN application. In 802.11 and 802.16, there are several data modulation schemes that are used with OFDM, such as Binary Phase Shift Keying (BPSK), quadrature amplitude modulation (QAM) to cover data rates for different needs. The bit error rate (BER) performance of these systems evaluated in additive white Gaussian noise (AWGN) channel[6]. In this technique,

modulation, mapping rate are dynamically adapted based on channel conditions to increase the system performance in terms of Bit Error Rate (BER) and throughput (bps) in various conditions like channel mismatch, Doppler spreads, fading, etc.

By using gray bit mapping in different types of modulation schemes, bit constellation can be rearranged where every adjacent bit constellation differ by only one bit. Symbol energy and symbol error rate also get converted into bit energy and bit error rate to reduce bit error rate for different types of modulation schemes. In this paper, we are trying to figure out the way, which is Rayleigh fading channel for improving the performance of transmitting information.

## 2. System model

### 2.1 Channel Model

In a multipath environment, it is reasonably intuitive to visualize that an impulse transmitted from the transmitter will reach the receiver as a train of pulses. When there are large numbers of paths, applying Central Limit Theorem, each path can be modeled as circularly complex Gaussian random variable with time as the variable. This model is called Rayleigh fading channel model. A circularly symmetric complex Gaussian random variable is of the form,

$$Z = X + jY$$

where real and imaginary parts are zero mean independent and identically distributed Gaussian random variables. For a circularly symmetric complex Gaussian random variable  $Z$ ,

$$E[Z] = E[e^{j\theta} Z] = e^{j\theta} E[Z]$$

The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance,  $\sigma^2 = E[Z^2]$ . Now, the magnitude  $Z$  which has a probability density,

$$p(z) = \frac{z}{\sigma^3} e^{-\frac{z^2}{2\sigma^2}} \quad z \geq 0$$

is called a Rayleigh random variable. This model, called Rayleigh fading channel model, is reasonable for an environment where there are large number reflectors.

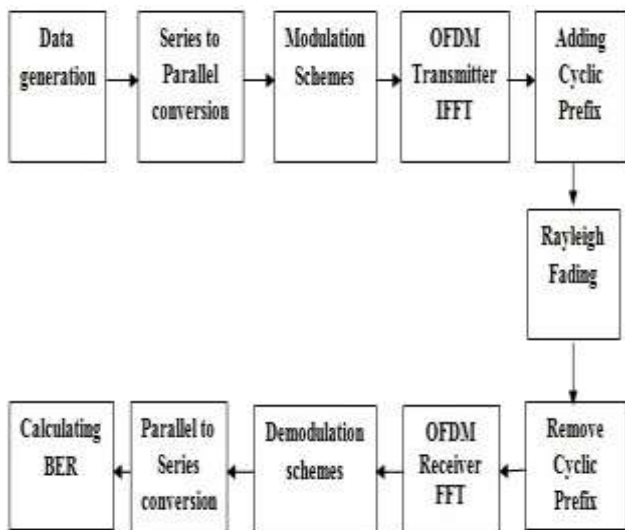
## 2.2 OFDM transceiver

Before transmitting information bit in Rayleigh fading channel through the OFDM transmitter we use different modulation schemes which are shown in Figure.1. And information data are modulated in a baseband fashion by the IFFT. Then the data is transmitted to the channel. The receiver performs the inverse process of the transmitter.

In Orthogonal Frequency Division Multiplexing, multiple sinusoidal with frequency separation  $\frac{1}{T}$  is used where  $T$  is the symbol period. The sinusoids used OFDM can be defined as (John-R-Barry et al):

$$g_k(t) = \frac{1}{\sqrt{T}} e^{j\frac{2\pi kt}{T}} w(t)$$

where  $k=0, 1, \dots, K-1$  correspond to the frequency of the sinusoidal and  $w(t) = u(t) - u(t-T)$  is a regular window over  $[0, T]$ .



**Figure.1:** Block diagram of OFDM transceiver in Rayleigh Fading channel

OFDM uses multiple sinusoidal having frequency separation  $\frac{1}{T}$  where each sinusoidal gets modulated by independent

information. The information is multiplied by the corresponding carrier signals. Mathematically, the transmit signal is,

$$s(t) = a_0 g_0(t) + a_1 g_1(t) + \dots + a_{K-1} g_{K-1}(t)$$

$$= \sum_0^{K-1} a_k g_k(t)$$

$$= \frac{1}{\sqrt{T}} \sum_0^{K-1} a_k e^{j\frac{2\pi kt}{T}} w(t)$$

The interpretation of the above Eq. (5) is as follows:

(a) Each information signal  $a_k$  multiplies the sinusoidal having frequency of  $\frac{k}{T}$ .

(b) Sum of all such modulated sinusoidal are added and the resultant signal is sent out as  $s(t)$ . The sampled version of the above equation is,

$$s(nT) = \frac{1}{\sqrt{T}} \sum_0^{K-1} a_k e^{j\frac{2\pi knT}{T}} w(nT)$$

This operation corresponds to an inverse Discrete Fourier Transform (IDFT) operation.

## 3. Rayleigh fading channel

Rayleigh fading is a statistical model for the strong influence of a propagation environment on a radio signal, used by wireless communication devices [7]. 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. For wireless communications, the envelope of the received carrier signal is Rayleigh distributed; such a type of fading is called Rayleigh fading [8]. This can be caused by multipath with or without the Doppler Effect.

Rayleigh fading is observed as a sensible model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban ambience on radio signals. Rayleigh fading is most applied in situations when there is less or no dominant propagation along a line of sight between the transmitter and receiver. Presence of a dominant line of sight indicates that Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it finally reaches the receiver. According to the central limit theorem, if there is sufficiently too much scattering, the impulse response of the channel can be modelled well as a Gaussian process, not bothering about the distribution of the individual components [9]. Absence of a dominant component to scatter clearly indicates that the process will have zero mean and phase evenly distributed between 0 and  $2\pi$  radians. The envelope of the channel response will therefore be known as a Rayleigh distributed one.

Calling this random variable R, it will have a probability density function

$$P_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0 \text{ where } \Omega = (R^2)$$

In the multipath case, when the dominant signal becomes weaker, such as in the non LOS case, the received signal is the sum of many components that are reflected from the surroundings. These independent scattered signal components that are reflected from the surroundings have different amplitudes and phases; then the in phase and quadrature components of the received signal can be assumed to be independent zero-mean Gaussian processes. This is derived from the central limit theorem, which states that the sum of a sufficient number of random variables approaches very closely to a normal distribution. When the mobile station moves, the frequency shift of each reflected signal component that arises from the Doppler Effect also has an influence on the fading. Very often, the gain and phase elements of a channel's distortion are represented as a complex number for mathematical convenience. Rayleigh fading channel is a small-scale effect. There will be certain properties of the environment such as path loss and shadowing upon which the fading may be superimposed. The rapidity of the channel fading will be affected by how fast the receiver and/or transmitter are in mobility. Constant motion causes Doppler shift in the received signal components.

## 4. Modulation schemes

### 4.1 Binary Phase Shift Keying (BPSK)

The BPSK digital modulation technique is referred as the simplest form of phase modulation and in this scheme the carrier phase represent only two phase states.

A Coherent BPSK system is characterized by having a one dimensional signal space with a constellation diagram consisting of two message points.

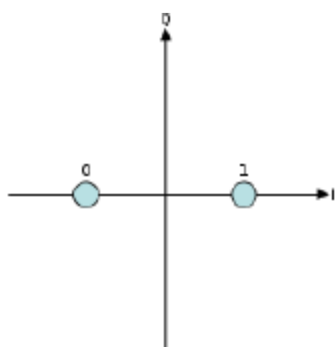


Figure.2: Constellation diagram of BPSK

The two phases which are separated by 180° and can also be termed as 2-PSK. In BPSK, a single carrier is modulated by controlling its polarity according to the binary data signal to be transmitted. The magnitude of the modulated BPSK signal is kept constant, thus increasing the maximum power to be delivered.

The BPSK modulator is basically a two positional switch, controlled by the data stream. The high level in data allows 0° phase and the low level in data permits the 180° phase introduced in the output. The prime advantage of Binary Phase Shift Keying is that it provides a suitable modulation format for downlink data transmission in inductive biomedical telemetry systems, because it achieves high data rates and power efficiencies. BPSK modulation is simple to design and less complex when compared to QPSK, which is almost double the complexity of BPSK design. The BPSK digital modulation technique is generally used in the application of high speed data transfer.

### 4.2 Quadrature Phase Shift Keying (QPSK):

In QPSK digital modulation scheme, the division of the phase of the carrier signal designed by allotting four equally spaced values for the phase angle as  $\pi/4$ ,  $3\pi/4$ ,  $5\pi/4$  and  $7\pi/4$ , thus providing a major advantage over BPSK by having the information capacity double to it.

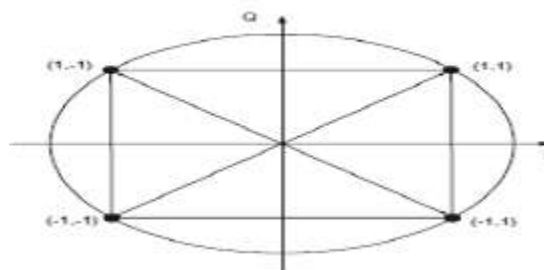


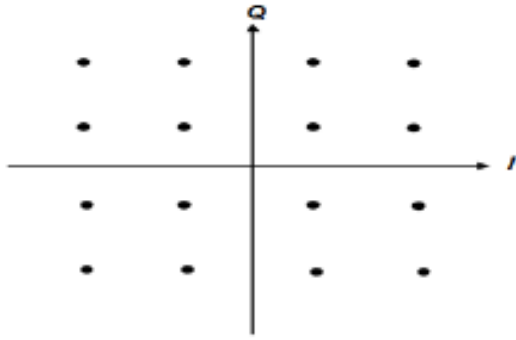
Figure.3: Constellation diagram of QPSK system

The QPSK becomes a highly bandwidth efficient digital modulation technique because in its constellation diagram, there are four message points. In QPSK the data bits to be transmitted are combined into symbol, each containing two bits each symbol can take on one of four possible values which are 00, 01, 10 or 11. In QPSK the bandwidth requisite and power requirement is less because more data can be transmitted using different phases and single carrier. QPSK technique may be used either to double the data rate compared to a BPSK modulation system while maintaining the bandwidth of the signal or to maintain the data rate of BPSK but half the bandwidth requirement. The performance of QPSK system in the presence of system impairments may be determined by its bit error rate or symbol error rate.

### 4.3 Quadrature Amplitude Modulation (QAM):

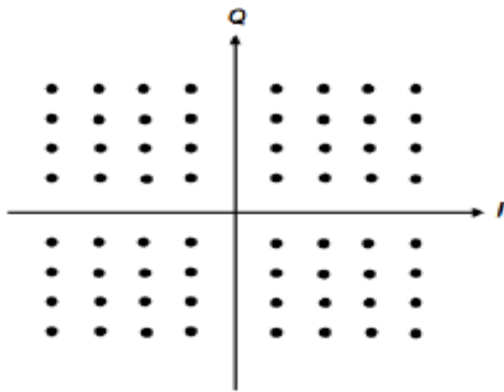
The QAM is a modulation scheme where its amplitude is allowed to vary with phase. This technique can be viewed as a combination of ASK as well as PSK.

QAM is widely used in many digital data communication applications, where data rates beyond 8-PSK are needed by a radio communication system then QAM modulation scheme is extensively used because QAM achieves a greater distance between adjacent points in the I-Q plane by distributing the points are more distinct and data errors are reduced. The QAM modulation is more useful and efficient than the others and is almost applicable for all the progressive modems.



**Figure.4:** Constellation diagram of 16-QAM

In the 16-QAM, the four different magnitude levels are used. The combined stream would be of  $4 \times 4 = 16$  states. In this scheme, each symbol represents four bits.



**Figure.5:** Constellation diagram for 64-QAM

This is same as 16-QAM except that it has 64 states where each symbol represents six bits. It is a complex modulation technique but with a greater efficiency. The mobile Wi-Max technology uses this higher modulation technique when the link condition is high.

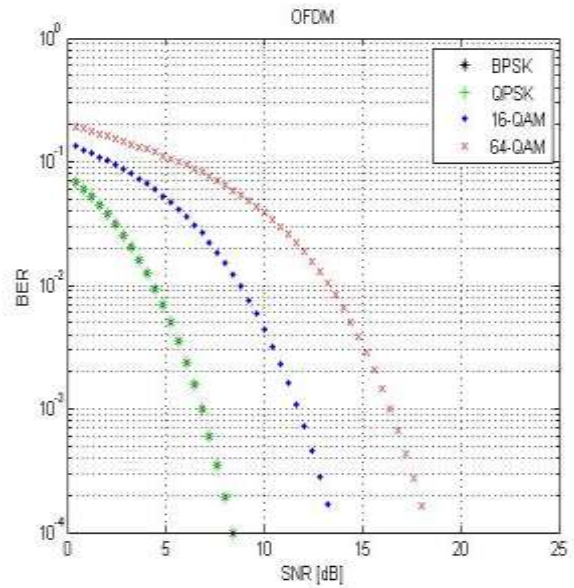
### 5. Simulation results & discussion

Simulation parameters chosen are listed in Table 1.

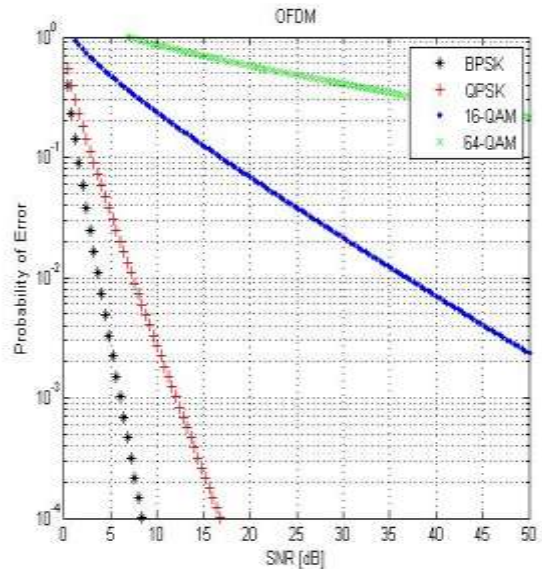
Parameter	Value
Modulation	BPSK/QPSK/16-QAM/64-QAM
FFT size. nFFT	512
Number of used subcarriers. nDSC	512
FFT Sampling frequency	10 MHz
Cyclic prefix duration, T <sub>cp</sub>	0.8μs
Data symbol duration, T <sub>d</sub>	3.2μs
Total Symbol duration, T <sub>s</sub>	4μs

Table 1: Selected Simulation Parameters

To analyze the performance of different modulation schemes with OFDM techniques in Rayleigh fading channel, we perform simulations using MATLAB and obtained the following results

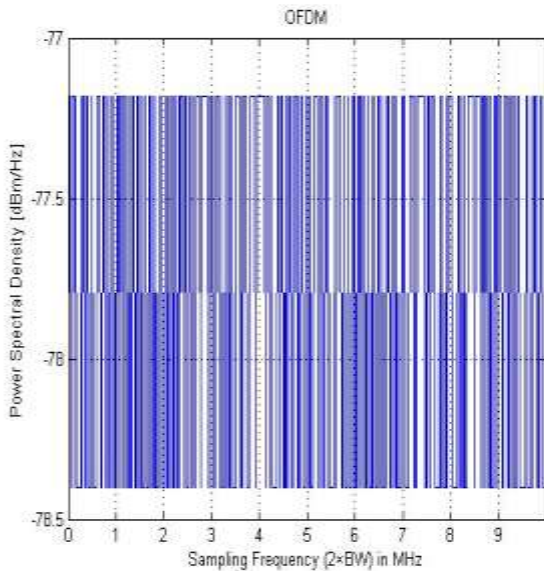


**Figure.6:** SNR vs BER Plot



**Figure.7:** Error probability curve





**Figure.8:** Spectrum of OFDM transmission.

The bit error rate or bit error ratio (BER) is defined as the rate at which errors occur in a transmission system during a studied time interval. BER is a unit less quantity, often expressed as a percentage or 10 to the negative power. The SNR is the ratio of the received signal power over the noise power in the frequency range of the process. SNR is inversely related to BER, that is high BER causes low SNR. High BER causes an increase in packet loss, enhance in delay and decrease throughput.

Figure.6 shows the SNR vs BER Plot under different modulation schemes in a Rayleigh Fading Channel for OFDM System. From Figure, it is observed that since the bit error rate for BPSK and QPSK is similar thus it by using QPSK we can transmit twice amount of data on the same channel with the same bandwidth. If we extend the modulation using 16-QAM and 64-QAM then we can achieve higher data rate on little increase in Bit error rate as compare to BPSK and QPSK. The signal to noise ratio for BPSK is very low means that it provides high immunity to noise as compare to the signal floating through the medium. The analysis is on matlab with BPSK, QPSK, 16-QAM and 64-QAM and it is seen that the by using QAM or higher order QAM, we can achieve high SNR. Thus we can be sure of less noise in the channel during transmission.

Figure.7 shows the Error probability curve for different modulation schemes in a Rayleigh Fading Channel for OFDM System. From Figure, it is clear that the performance of QAM is better than BPSK and QPSK. QAM has several advantages over BPSK and QPSK. It has higher data rate than in PSK while bandwidth occupancy remains the same. Noise immunity of QAM is very high. It is best suitable for high bit rates. Low error probability. Baud rate is half the bit rate therefore more effective utilization of the available bandwidth of the transmission channel. The QAM techniques are exclusively used for Microwave Digital radio, Digital video and broadband set top boxes and in Modems.

Figure 8 shows the power spectral density of an OFDM signal.

## 6. Conclusion

In this paper, we have designed an OFDM technique, using different modulation schemes viz BPSK, QPSK, 16 QAM & 64QAM. The performance of the modulation techniques on various performance parameters have been simulated and analyzed. Higher order modulation schemes (e.g. 64QAM) that are able to carry higher data rates are not as robust in the presence of noise. Lower order modulation formats (e.g. BPSK, QPSK, etc.) offer lower data rates but are more robust.

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