A Study on the Error Rate with Different Wireless Channels and Modulation Schemes

Danish Equbal[1], Prof. Bhagwat Kakde[2], Dr. Manish Jain[3]

Research Scholar[1], Research Guide[2], HOD[3]

RKDFIST Bhopal

Abstract - Error and disturbance are the highly action degrading influence in wireless/mobile information technology. In sequence to better and certify the arrangements effective quaintness to oppose paling, modeling and simulation of comm./information technology arrangement beyond the paling way is of great significance in the Patten of comm./ information technology arrangement. For variant propagation circumstances, the characteristic of paling way is diverse and compound. Therefore, Patten of work paling structure in particular comm. circumstance is cardinal in this glance. For wireless comm./information technology arrangement., OFDM is good multi-carrier method due to help of this nature of solid retardation to disturbance and large spectra efficiency, high data rate transfer procedure. Way estimation methodologies are providing the means in sequence to estimate the outcome of propagation delay and way synchronization. Way estimation procedure can be divided into two categories: First one is blind channel or way estimation and second one is pilot-aided channel or way estimation.

Keyword –OFDM, BER, QAM, Modulation scheme.Fading Channel.

I. INTRODUCTION

The third generation (3G) wireless communication systems, mainly based on the WCDMA technology, have been confronted with a number of new challenges regarding to the design of the required wireless communication systems. The main challenges the 3G technology has been facing can be summarized as follows:

The typical delay spread observed in wireless channel puts a strong limitation on the symbol duration period if it is transmitted serially. To struggle with the time delay spread of the wireless channel, the delay spread should be smaller than the symbol period, which is not the case for high data rate serial transmission, where, in general, the delay spread is much bigger than the transmitted symbol period. It is well known that the delay spread of the channel causes Inter Symbol Interference (ISI) which can be undone often only partially by means of complex equalization procedures. In WCDMA, since the signal is transmitted serially in time it is highly challenging to increase the data rate of the transmitted signal.

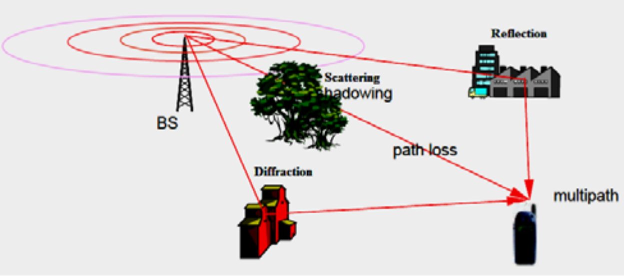


Figure 1.1 Wireless communication environments.

To contend with the above mentioned challenges and to achieve good system performance, the choice of an appropriate modulation and multiple access schemes applicable to mobile wireless communication systems is then critical. In this context, the parallel multi carriers schemes have shown their efficiency in many wireless applications. More specifically, the Orthogonal Frequency Division Multiplexing (OFDM) which is a special case of multi carrier transmission is a good choice. In OFDM, the frequency selective fading wide band channel is used as frequency multiplex of non frequency selective (flat fading) narrow band parallel sub channels. To avoid the need to separate the carriers by means of guard-bands and therefore make OFDM highly spectrally efficient, the sub channels in OFDM are overlapping and orthogonal. Initially, only analog design was considered, using banks of sinusoidal signal generators and demodulators to process the signal for multiple sub channels. The tremendous advancement in digital signal processing made the implementation of digitally designed OFDM possible and cost effective using the Discrete Fast Fourier Transform (DFFT

A. Bit-error-rate (BER)

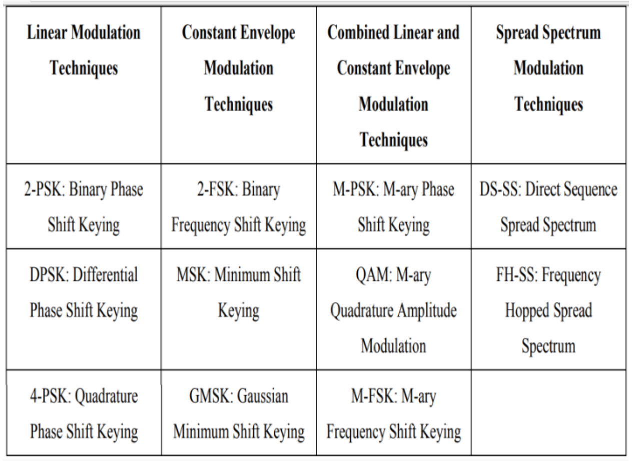
Bit-error-rate is a key factor to measure the capacity and performance of communication system. Much effort has been made to explore the characteristic and BER performance of hyper-Rayleigh fading.However, there is little work on evaluating BER performance of OFDM system under such radio propagation environment. Herein, the research exploration is focused on the investigation of OFDM system performance under various fading environment, especially hyper-Rayleigh fading. 2-D pilot-aided channel estimation, convolutional coding and cyclic prefix are also implemented in OFDM system. The performance of OFDM system can be determined by evaluating system's BER.

B. Digital Modulation Techniques

The basic concept behind digital modulation is to identify efficient schemes taking M different symbols in a given digital alphabet and transforming them into waveforms that can successfully transmit the data over the transmission channel. In modern digital communications systems, the modem (i.e., modulate-demodulate) has the responsibility of converting the digital data to analog signals for transmission and from analog signals to digital data for the received signal. Modulation involves changing the amplitude, frequency and/or the phase of the carrier wave traveling over the channel.

There are therefore three basic types of modulation schemes: frequency shift keying (FSK), amplitude shift keying (ASK), and phase-shift keying (PSK). The Quadrature Amplitude Modulated (QAM) signal is an expansion of the amplitude shift keying modulation types. The QAM signal transmits signals by modulating the amplitude of two sinusoidal carrier waves which are orthogonal to each other (which is what "quadrature" means: 90 degrees out of phase). The resulting signal will then exist in a bandwidth centered on the carrier frequency . Some of the most widely used digital modulation techniques are summarized in Table 1. This study will concentrate on M-FSK, 2-PSK, 4-PSK, 8-PSK, and 16-QAM, 64-QAM and 256-QAM modulation schemes. Each of these modulation types is described in more detail in the following subsections.

Table 1. Popular Digital Modulation Schemes



Linear Modulation Techniques	Constant Envelope Modulation Techniques	Combined Linear and Constant Envelope Modulation Techniques	Spread Spectrum Modulation Techniques
2-PSK: Binary Phase Shift Keying	2-FSK: Binary Frequency Shift Keying	M-PSK: M-ary Phase Shift Keying	DS-SS: Direct Sequence Spread Spectrum
DPSK: Differential Phase Shift Keying	MSK: Minimum Shift Keying	QAM: M-ary Quadrature Amplitude Modulation	FH-SS: Frequency Hopped Spread Spectrum
4-PSK: Quadrature Phase Shift Keying	GMSK: Gaussian Minimum Shift Keying	M-FSK: M-ary Frequency Shift Keying	

C. Fading Channels

When dealing with satellite and other communications systems where there is line of sight between the transmitter and receiver, the free-space propagation model gives simple theoretical explanations for propagation loss. However, with ground communications many obstructions can interfere with the transmission of a signal. Objects like mountains, buildings, densely wooded areas and rough terrain cause the signal to be reflected (i.e., bouncing off) and diffracted (i.e., bending around) these various surfaces in order to arrive at its destination. These obstacles cause signals to scatter and these delayed versions to arrive at slightly different times. This phenomenon is known as multipath propagation and causes a phenomenon in real-world communications known as fading.

D. Rayleigh Distribution

In an environment where there are reflections off multiple local objects between the transmitter and receiver, rapid variations in the signal strength can occur. The reflections off the objects cause the phase of the carrier signal to change rapidly, which can sometimes add together destructively. In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. This type of multipath fading channel is modeled with Rayleigh fading, which can be useful in modeling larger city environments where no lines of sight exist between the transmitter and receiver. Experimental work in Manhattan, New York has found near-Rayleigh fading there

Statistically, the Rayleigh distribution is related to the central chi-square distribution and probability density function is defined as:

$$P_R(r)=\frac{r}{\sigma^2}e^{-r^2/2\sigma^2}, \quad \text{if} \quad r \ge 0,$$

where r models the power of each time delayed signal generated by the multipath distortion. If we assume a unit variance, then the probability density function curve looks.

E. Quadrature Amplitude Modulation

Quadrature amplitude modulation (QAM) is generated by changing both the phase and amplitude of signal. The bits are mapped to two analogue signals by changing the amplitude and phase. The two analogue signal (sinusoid) are out of phase with each other by 90◦ , making them orthogonal. The modulated signals are summed up and the resulting waveform is the combination of both PSK and ASK. Based on structure of the constellation diagram, different types of QAM exists. QAM having a rectangular structure are denoted by rectangular-QAM, likewise circular symmetry constellations are called circular-QAM. Each constellation performs differently under different channel conditions. performance of different levels of QAM is compared with other various modulation schemes.

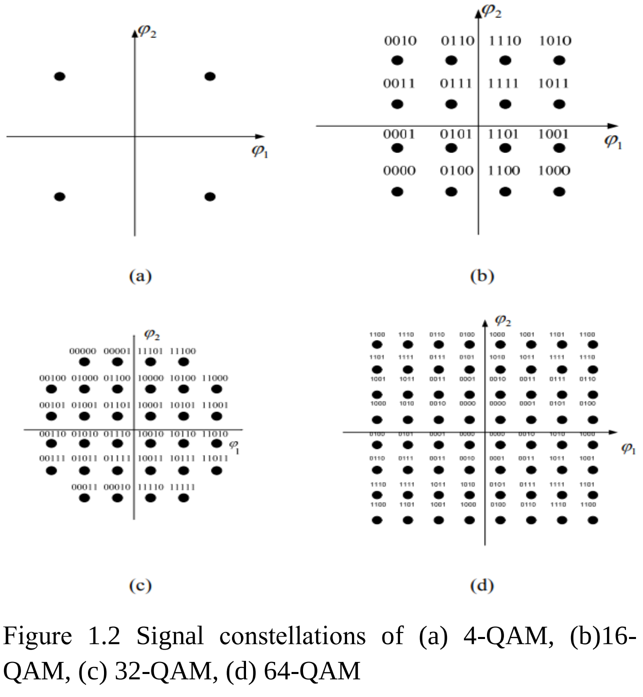
the relationship between the bandwidth and modulation scheme in an ideal case and it can be seen that with a higher modulation scheme and lower bandwidth higher data rates can be achieved. Rectangular-QAM is much easier to modulate and demodulate due to its regular structure, which is generated by amplitude modulations in phase and quadrature.

F. Design of OFDM Model Based on QAM

QAM (quadrature amplitude modulation) is a method of combining two amplitude modulated signals into a single channel, thereby doubling the effective bandwidth. QAM is used with pulse amplitude modulation in digital systems, especially in wireless applications.

In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90 degrees. One signal is called the I-signal, and the other is called the Q-signal. Mathematically, one of the signals can be represented by a sine wave, and the other by a cosine wave. The two modulated carriers are combined at the source for transmission. At the destination, the carriers are separated, the data is extracted from each, and then the data is combined into the original modulating information. The general form of M-ary QAM is as following:

$$S_i(t)=A_i\cos(2\pi f_c t+\theta_i),\ 0\le t\le T_s,\ i=1,2,\ldots,\mathrm{M}$$



(a) (b) (c) (d)

Figure 1.2 Signal constellations of (a) 4-QAM, (b)16-QAM, (c) 32-QAM, (d) 64-QAM

Where T_s is the symbol duration, Ai is the amplitude and signal in the M-ary QAM signal set. As with many digital modulation schemes, the constellation diagram is a useful representation. In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, although other configurations are possible. Since in digital telecommunications the data is usually binary, the number of points in the grid is usually a power of 2. Since QAM is usually square, some of these are rare—the most common forms are 16- QAM, 64-QAM, 128-QAM and 256-QAM

By moving to a higher-order constellation, it is possible to transmit more bits per symbol. However, if the mean energy of the constellation is to remain the same (by way of making a fair comparison), the points must be closer together and are thus more susceptible to noise and other corruption; this results in a higher bit error rate and so higher-order QAM can deliver more data less reliably than lower-order QAM, for constant mean constellation energy.

G. Applications

Quadrature amplitude modulation is implemented in a variety of modern wireless communications standards. QAM is in many radio communications and data delivery applications. However some specific variants of QAM are used in some specific applications and standards. For domestic broadcast applications for example, 64 QAM and 256 QAM are often used in digital cable television and cable modem applications. In the UK, 16 QAM and 64 QAM are currently used for digital terrestrial television using DVB - Digital Video Broadcasting. In the US, 64 QAM and 256 QAM are the mandated modulation schemes for digital cable as standardized by the SCTE in the standard ANSI/SCTE 07 2000. ln addition to this, variants of QAM are also used for many wireless and cellular technology applications.

II. SYSTEM MODEL

Orthogonal Frequency Division Multiplexing (OFDM), which is also referred to as Discrete Multi-tone Modulation (DMT), is a multi-carrier transmission technique, is widely applied to wireless communications, such as digital audio broadcasting, digital video broadcasting and wireless local area network (WLAN). OFDM is also regarded as one of the most promising technologies for the fourth generation (4G) mobile communication system. OFDM technology has distinctive advantages on high data transmission, anti-interference and low equipment complexity.

A. Principle of OFDM system

The idea of OFDM is to divide the original data steam into several parallel narrowband low-rate streams modulated on corresponding orthogonal sub-carriers [7]. To be specific, each sub-carrier has integer periods in OFDM symbol duration. Neighboring sub-carriers have one period difference to maintain orthogonality. This orthogonality characteristic of OFDM system can also be understood in the view of frequency domain. As shown in Figure 2-1, all sub-carriers are controlled to maintainorthogonality by making the peak of each sub-carrier signal coincide with the nulls of other signals.

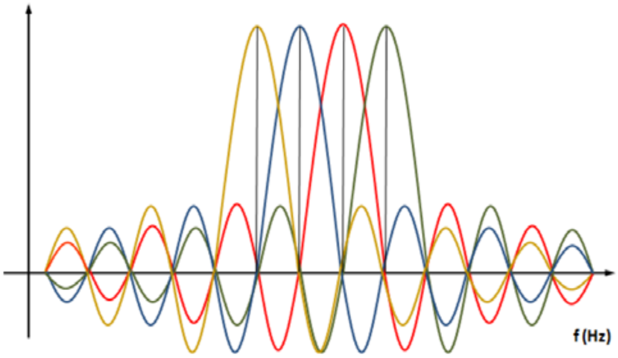


Figure 2.1 Frequency spectrums of OFDM sub carriers.

The orthogonal characteristics of sub-carriers enable OFDM system to have higher spectral efficiency than conventional multi-carrier technique. For conventional multi-carrier techniques, guard intervals are inserted between sub-carriers so that sub-carrier signal can be separated from other signal by corresponding filter at the receiver. In the case of OFDM system, however, sub-carriers overlap each other and can be demodulated without guard interval.

B. Model of OFDM System

OFDM system is presented in figure 2.2, where some significant functions are analyzed. Coding and modulation schemes are essential in developing a feasible OFDM communication system. Moreover, cyclic prefix is considered as an indispensible part of OFDM system to combat inter-carrier interference (ICI), since OFDM system is particularly vulnerable to ICI.

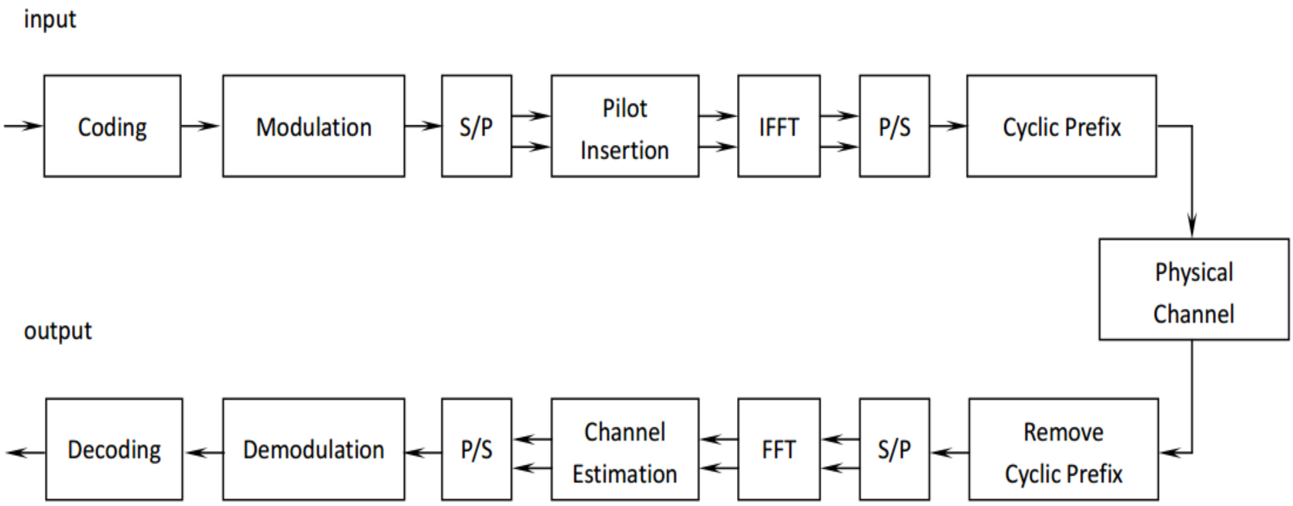


Figure 2.2 System model of OFDM.

C. Modulation Scheme

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique (QPSK). After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel - to - serial converter. In order to avoid ISI we provide a cyclic prefix to the signal.

D. Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial - to - parallel converter. A demodulator is used, to get back the original signal.

The bit error rate and the signal - to - noise ratio is calculated by taking into consideration the un - modulated signal data and the data at the receiving end.

E. Bit Rate and Symbol Rate

The signal bandwidth for the communications channel depends on the symbol rate or also known as band rate.

$$Symbolrate = \frac{Bitrate}{Numberofbittrsnmittedpersymbol} \dots.(1)$$

Bit rate is the sampling frequency multiplied by the number of bits per sample. For example, a radio with an 8-bit sampler is sampled at 10 kHz for voice. The bit rate, the basic bit stream rate in the radio, would be 8 bits multiplied by 10k samples per second giving 80 kbps.

- Bit Error Rate (BER)

BER is a performance measurement that specifies the number of bit corrupted or destroyed as they are transmitted from its source to its destination. Several factors that affect BER include bandwidth, SNR, transmission speed and transmission medium.

- Signal-to-Noise Ratio (SNR)

SNR is defined as the ratio of a signal power to noise power and it is normally expressed in decibel (dB). The mathematical expression of SNR is

$$SNR = 10log_{10}\frac{SignalPowe}{NoisePower}dB \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

III. PREVIOUS WORK

M. Raju and K. A. Reddy,[1] The concert of wireless communication systems depends on wireless channel environment. By properly analyzing the wireless channels, we can develop an efficient wireless communication system. M-QAM modulation schemes are preferred because in this scheme more than one bit can be grouped and transmit at a time, which is very effective for band limited channels. M-QAM (M-Quadrature Amplitude Modulation) is the most effective digital modulation technique as it is more power efficient for larger values of M. In this research work, we analyze OFDM system inimitability in AWGN (additive White Gaussian Noise) and Rayleigh fading channel using M-QAM modulation schemes. Rayleigh fading channel is describe by Clarke and Gans model. The performance measured in terms of bit error rate (BER) is evaluated for M = 4, 8 and 16 modulation schemes of M-QAM numerically and verified our analytical results by computer simulation. It has been demonstrated that the BER increases as the modulation order increases.

J. A. Sheikh, Uzma, S. A. Parah and G. M. Bhat,[2] The work in the field of wireless communication these days is directed towards the efficient usage of the available spectrum as the spectrum scarcity keeps haunting people in general and communication engineers in particular. This puts an upper limit on the development of new spectrum hungry applications. Spectral efficiency has thus given new direction to the researchers to look for the available option for better utilization of spectrum and to develop techniques that will be compatible with the existing technology. The work presented in this research work is also an attempt towards this direction. The idea is to use the Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) for transmission of image data with improved Bit Error Rate (BER) and Pixel Error Rate (PER) as the performance of most of the communication systems developed is measured, in the most common parlance, in terms of BER. The bit error has been improved using bit level scrambling in addition to the convolutional coding. A MATLAB program has been developed to model the MIMO-OFDM system. The model under consideration prompts the user for various inputs and then produces the results in terms of various plots and graphs. The results confirm the significant improvement in the BER and PER of the system.

R. Yoshizawa and H. Ochiai [3] Active constellation extension (ACE) has been proposed for a peak-to-average power (PAPR) reduction of orthogonal frequency- division multiplexing (OFDM) signals, which projects the clipping noise generated by iterative clipping and filtering (CAF) onto the outside region of the constellation such that its minimum Euclidean distance (MED) is not reduced. Due to this arrangement, some amount of average power increase is introduced, but ACE can achieve better trade-off between uncoded bit-error rate (BER) and power amplifier (PA) efficiency compared to simple CAF. However, the coded BER of ACE has not been analyzed so far, where the degradation of signal-to-noise power ratio (SNR) due to the average power increase may have dominant effect on the performance. Moreover, in order to perform effective error correction, the statistical property of the clipping noise imposed by ACE should be developed. This research work empirically models the clipping noise distribution after ACE such that soft decoding can be employed at its receiver, and investigates its performance in terms of mutual information and coded BER employing near optimal channel coding. It is revealed that the simple CAF may outperform the ACE in terms of both PA efficiency and BER performance when both are protected by practical channel coding.

Y. Goto et al.[4] Light-emitting diode (LED) transmitters based optical wireless communication (OWC) systems offer the potential for new generation communication systems. Particularly, an image sensor based OWC systems consist of the LED transmitters and camera receivers are expected to contribute to intelligent transport system (ITS) for driving supports. For high achievable data rates, orthogonal frequency division multiplexing (OFDM) based OWC systems have attracted a great deal of attention. Despite attractive features of optical OFDM, only few attempts have so far been made to adopt it as a modulation scheme of an image sensor based OWC system. There remains a need for an evaluation of adopting an optical OFDM to the image sensor based OWC systems. Another important issue needs to be addressed is the performance degradation due to a frequency response of an actual image sensor device, especially a signal attenuation loss in higher frequency. In addition to such loss, a narrow band noise generated by its circuits also degrades the performance. The purpose of this research work is to investigate BER performances of the optical-OFDM using an actual image sensor device, the optical communication image sensor (OCI). From simulation results, it is found that the frequency response and the narrowband noise at 12MHz of the OCI lead to the significant reduction of BER performances. Additionally, the results shows that ACO-OFDM shows a little better performance compared to DCO-OFDM with the same bandwidth efficiency.

M. Thanigasalam and P. Dananjayan,[5] Orthogonal Frequency Division Multiplexing is a highly flexible multicarrier modulation technique adapted in frequency selective and time variant wireless channels. In spite of its many advantages, OFDM suffers from high PAPR. Many methods of PAPR reduction techniques have been proposed. Of these, PTS is a distortion-less method of PAPR reduction. But PTS involves more computational complexity with increase in subblocks. To address the issue of high computational complexity, Modified PTS is used. Modified PTS is based on neighbourhood search algorithm, wherein a threshold PAPR is assumed to search the optimum set of phase factors. The optimum set of phase factors are then used to obtain OFDM signal with low PAPR. By combining Modified PTS and interleaving, a further reduction in PAPR is achieved. In this research work, the performance of OFDM receiver is analyzed using MMSE channel estimation. The parameters MSE and BER are used to evaluate the performance of MMSE OFDM receiver. Simulation results show that BER performance improves with reduction in PAPR.

S. R. Chaudhary and M. P. Thombre,[6] In recent years, wireless broadband communication has gained attention due to ever growing demands of multimedia and internet services. The major challenges faced by wireless communication are availability of resources like bandwidth and transmission power. Also the wireless channel suffers from impairments like fading and interference. Technologies that achieved above requirements are Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM). Channel impairments must be mitigated at the receiver by using equalization techniques. In this research work, BER performance improvements of MIMO-OFDM systems using different equalization techniques such as Zero forcing (ZF), Minimum mean square error (MMSE) and Maximum likelihood (ML) are shown and compared. Simulations are carried out under Rayleigh frequency flat channels.

H.S. Abdel-Ghaffar and S. Pasupathy[7] This paper presents a general framework for computing the asymptotic error probability (i.e., at high average SNRs) of M-ary and binary signaling schemes over Rician and Rayleigh fading diversity channels. A general theorem (Theorem 1) relates the asymptotic error rate of multipath and multichannel receivers (over AWGN, ISI free channels) to the multidimensional integral of the conditional error probability. Two other theorems are presented for the particular cases where the conditional error probability is a function of the sum of received SNRs (Theorem 2) or received amplitudes (Theorem 3). Theorems 2 and 3 are related for linear coherent systems, and closed form expressions are obtained for equal gain combining systems. Detection structures for typical diversity schemes (coherent/noncoherent maximal ratio and equal gain combining, and quadratic noncoherent combining) are considered. We analyze the asymptotic error rates of some M-ary signaling schemes (MPSK/MPAM with Kth order diversity and orthogonal signals with K=1 and with coherent and noncoherent detection). Binary signaling is also considered in our study.

M. Raju and K. A. Reddy [8]The concert of wireless communication systems depends on wireless channel environment. By properly analyzing the wireless channels, we can develop an efficient wireless communication system. M-QAM modulation schemes are preferred because in this scheme more than one bit can be grouped and transmit at a time, which is very effective for band limited channels. M-QAM (M-Quadrature Amplitude Modulation) is the most effective digital modulation technique as it is more power efficient for larger values of M. In this paper, we analyze OFDM system inimitability in AWGN (additive White Gaussian Noise) and Rayleigh fading channel using M-QAM modulation schemes. Rayleigh fading channel is describe by Clarke and Gans model. The performance measured in terms of bit error rate (BER) is evaluated for M = 4, 8 and 16 modulation schemes of M-QAM numerically and verified our analytical results by computer simulation. It has been demonstrated that the BER increases as the modulation order increases.

M. Srivastava and B. Singh, [9]" In this paper analysis of Digital audio broadcasting on its four different modes have been performed. All the possible four modes have been executed and simulated on SIMULINK platform under different types of modulation schemes and channels. This paper is trying to develop a novel scheme of low cost, complexity wise reduced communication model for open air performance analysis. Thus the paper implements a novel method for the purpose of quality improvement in the communication equipment improvement using DAB. The results that have been performed on different types of channels are additive white Gaussian noise, Rayleigh and Rician fading channels. Similarly different modulation schemes in the model for example BPSK, QPSK, 16 QAM on different channels has been done. Of all the different types of channels in MATLAB & SIMULINK software for which a complete detailed table analysis has been done has found that of all the possible four modes the fourth mode has outperformed with good level of BER performance ranging between 20% to 22%. This paper has shown that with QPSK and AWGN Rayleigh channel mode 4 has proved to be the best working mode**.**

Xiaoyi Tang, M. S. Alouini and A. J. Goldsmith,[10] We determine the bit-error rate (BER) of multilevel quadrature amplitude modulation (M-QAM) in flat Rayleigh fading with imperfect channel estimates, Despite its high spectral efficiency, M-QAM is not commonly used over fading channels because of the channel amplitude and phase variation. Since the decision regions of the demodulator depend on the channel fading, estimation error of the channel variation can severely degrade the demodulator performance. Among the various fading estimation techniques, pilot symbol assisted modulation (PSAM) proves to be an effective choice. We first characterize the distribution of the amplitude and phase estimates using PSAM. We then use this distribution to obtain the BER of M-QAM as a function of the PSAM and channel parameters. By using a change of variables, our exact BER expression has a particularly simple form that involves just a few finite-range integrals. This approach can be used to compute the BER for any value of M. We compute the BER for 16-QAM and 64-QAM numerically and verify our analytical results by computer simulation. We show that for these modulations, amplitude estimation error leads to a 1-dB degradation in average signal-to-noise ratio and combined amplitude-phase estimation error leads to 2.5-dB degradation for the parameters we consider.

J. Kim, G. L. Stuber and Y. G. Li, [11]" An iterative pilot-symbol aided modulation (PSAM) channel estimation approach is proposed for vertical Bell Laboratories layered space-time (V-BLAST) orthogonal frequency division multiplexing systems operating on frequency-selective fading channels. Since the signals at the receive antennas are the superposition of signals from multiple transmit antennas, accurate channel estimates are crucial for good error performance. Furthermore, the time selectivity of the fading channels leads to inter-carrier interference (ICI). While ICI can be ignored for slow fading channels, it should be mitigated for fast fading channels. This paper proposes an ICI mitigation scheme for time-varying channels. We also propose an iterative channel estimator with low-complexity. Simulation results demonstrate the usefulness of the proposed algorithm on frequency-selective fading channels.

IV. PROBLEM STATEMENT

The error rate in Rayleigh fading channel is also higher than the AWGN channel for same signal. So to provide a reliable communication along with the high data rate, there should be a tradeoff between modulation order and signal power.Bit error rate is major issue in wireless communication system due to fading of the signal and the other impacts are discussed.

V. CONCLUSION

To write a review number of literatures are studied in this brief its investigated the various impact of channel fading on bit error rate in OFDM channel different modulation approaches are passed down to active the Bit error rate and loss o signal and execution enhancement. Due to the limited time, issue of Synchronization is not included in the research exploration, which is, however, an essential issue in developing OFDM system. Accurate synchronization is necessary for OFDM system, since sub-carriers need to be kept strictly orthogonal. The characteristic and applicability of three-wave with diffuse power model has gained more and more attention, which may probably better represent the propagation situation of aggressive/hyper-Rayleigh paling/fading.

REFERENCES

[1] M. Raju and K. A. Reddy, "Evaluation of BER for AWGN, Rayleigh fading channels under M-QAM modulation scheme," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 3081-3086.

[2] J. A. Sheikh, Uzma, S. A. Parah and G. M. Bhat, "Bit Error Rate (BER) improvement of Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) system using bit level scrambling," 2015 Annual IEEE India Conference (INDICON), New Delhi, 2015, pp. 1-6.

[3] R. Yoshizawa and H. Ochiai, "Mutual Information and Coded BER Analysis of PAPR Reduced OFDM System with Active Constellation Extension," 2015 IEEE Global Communications Conference (GLOBECOM), San Diego, CA, 2015, pp. 1-6.

[4] Y. Goto et al., "BER characteristic of optical-OFDM using OCI," 2014 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS), Ishigaki, 2014, pp. 328-331.

[5] M. Thanigasalam and P. Dananjayan, "BER analysis of OFDM receiver using MMSE channel estimation and modified PTS combined with interleaving," 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies, Ramanathapuram, 2014, pp. 662-666.

[6] S. R. Chaudhary and M. P. Thombre, "BER performance analysis of MIMO-OFDM system using different equalization techniques," 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies, Ramanathapuram, 2014, pp. 673-677.

[7] Theodore S.Rappaport, “Wireless Communication Principles and Practice”, Pearson Press, Second edition, 2010.

[8] Proakis. John G., "Digital Communications", McGraw-Hill, 4th edition, 2001.

[9] S.Coleri, M.Ergen, A.Puri and A.Bahai, "Channel estimation techniques based on pilot arrangemtn in OFDM systems", IEEE Transaction on Broadcasing, vol.48, no.3m pp.223-229, 2002.

[10] Ye(Geoffrey) Li, “Pilot-symbol-aided channel estimation for OFDM in wireless systems”, IEEE Transaction on Vehicular Technology, Vol.49, no.4, pp.1207-1215, 2000.

[11] J.LiandM.Kavehrad, “Effects of time selective multipath fading on OFDM systems for broadband mobile applications,” IEEE Communication. Letter., vol. 3, no. 12, pp. 332-334, 1999.

[12] M. Raju and K. A. Reddy, "Evaluation of BER for AWGN, Rayleigh fading channels under M-QAM modulation scheme," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 3081-3086.

[13] M. Srivastava and B. Singh, "Detailed performance analysis of digital audio broadcasting under different modulation schemes and channels," 2016 International Conference on Control, Computing, Communication and Materials (ICCCCM), Allahbad, 2016, pp. 1-6.

[14] MarvinK.Simon, Mohamed-Slim Alouini, “Digital Communication over Fading Channels”, A Unified Approach to Performance Analysis”, John Wiley & Sons, Inc.,2012, Print ISBN :0-471-31779-9, Electronic ISBN: 0¬471-20069-7.

[15] Digham, F.F., Hasna, M.O., “Performance of OFDM with M-QAMmodulation and optimal loading over Rayleigh fading channels”, IEEE Conference on Vehicular Technology, Vol.1, pp.479-483 2004,DOI:10.11.09/VETECF-2004.

[16] Xiaoyi Tang, Mohamed-Slim Alouini and Andrea J.Goldsmith, “Effect of Channel Estimation Error on M-QAM BER Performance in Rayleigh Fading”, IEEE Transaction on Communications, Vol.47, n0.12, 1999.

[17] Abdel-Ghaffar, H.S., Pasupathy.S., “Asympototical performance of M-ary and binary signals over multipath/multichannel Rayleigh and Rician fading”, IEEE Transactions on Communications, Vol.43, no.1, pp.2721¬2731, 1995.