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Analyzing the Performance of an Equalized and Un-equalized OFDM-PON System over AWGN & Rayleigh Fading Channel by Using QPSK, BPSK, 16-QAM and 32-QAM Modulations

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Abstract: In this paper the performance analysis of OFDM architecture with and without equalization is performed by using three efficient coherent modulation techniques which are BPSK, QPSK and M-QAM modulation. Whole analysis is implemented over PON-OFDM model with Rayleigh fading channel having AWGN noise. Then the performance comparison is done with three modulations with and without equalization. Here the OFDM architecture is used to reduce noise (can be inter-symbol interference) which is the most important loss or attenuation in optical signals, thus reshaping and equalization (filtering) is performed. The simulation over BPSK, 16-QAM, 32-QAM and QPSK signals is implemented over Rayleigh and AWGN channel thus the effect of channel signal fading due to noise is observed in addition with equalization to obtain an accurate value of Bit Error Rate BER. Thus the explanatory results of BER determine the efficiency of BPSK, QPSK and M-QAM technique with respect to OFDM.

Keywords: BPSK, QPSK, M-QAM, BER, SNR, OFDM, AWGN, PON, CP, ZP, CO, ONU, OLT, ISI etc.

I. INTRODUCTION

Now these days as technology get advanced with increase in number of users we need to adopt a concept which allow us reliability to access a network that will provide fast access, high speed and flexibility with cost effectiveness. As the popularity of the Internet, IPTV, triple play, video on demand, audio and video conferencing, online gaming, fast downloading / uploading speed is increased, thus we need a network which would give dynamic bandwidth allocation instead of static bandwidth allocation. Current networks are providing dynamic bandwidth allocation.

The development of Wavelength Division Multiplexing (WDM) systems now allows multiple wavelengths to be propagated through fibres which in the past carried a single wavelength only. Although the capacity of core and metro networks have been increased greatly by making the use of WDM, a corresponding improvement in Access Networks (which provide the final connection to the end–user) has not occurred. However, such a simplistic augmentation of network speeds does not account for the ever–changing bandwidth demand patterns and as such network flexibility and re-configurability will need to be incorporated into future optical communications systems.

Due to increase in demand for higher internet speeds, driven by media-rich apps such as on–demand HDTV, Voice over IP (VoIP), video conferencing and online gaming, will require Internet Service Providers (ISPs) to upgrade their existing networks to satisfy the needs of both residential and commercial customers as current Ethernet speeds of 10 GB/s will be upgraded to 100 GB/s.

Few days back we have start using an access network in optical communication systems that simply deals with number of reflection of lights which are million in numbers. So these networks are seeking more attention.

In previous times for communication we have also used network based on copper wire but those networks was inefficient to provide high data rate, long distance/long reach data access and also have bandwidth and capacity limitations. But for high data rates and fast access we switched to an network which is based on signal transmission in form of light called an optical network.

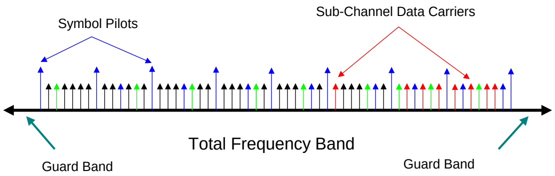

Fig-1 OFDM Subcarriers

The networks used now these days a becoming so much popular because they offer the ultimate solution for high speed.

A.PON NETWORKS

PON offers large, dynamic bandwidth which is not possible to achieve by other access methods. First-generation fibre-to-the-home (FTTH) networks are being installed in point-to-point (P2P) and point-to multipoint (P2MP) time-multiplexed passive optical network (PON) architectures.

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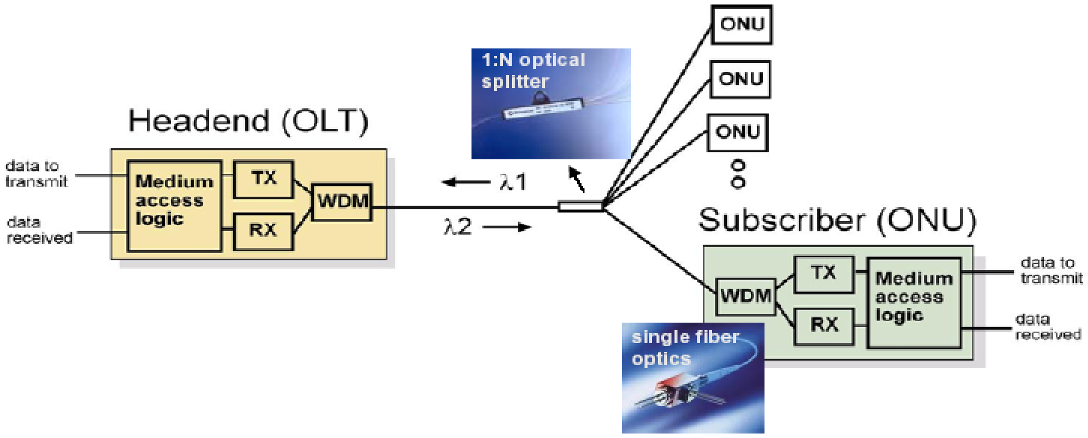

Fig-2 PON Architecture

For long reach applications, PON is best suited in long-haul and backbone networks. PON technology is rapidly becoming the first choice in LAN Local Area Networks, MAN (Metropolitan Area Networks). PON used to transmit data to all FFTX networks where X refers to any building, home, business, any organisation, curbs or any node / terminal shared among the number of users, the PON's maintenance costs relay beyond the certain reach and number of users, but it requires a well-tailored medium access control protocol for fair sharing of the capacity among them. The major part of any infrastructure is architecture that may offer lower installation thus OFDM is better choice. Data transmissions through PON network consist of three blocks are:

- Optical Line Terminal (OLT) / Central Office (CO)
- Optical Splitter
- Optical Network Unit (ONU)

B.OPTICAL LINE TERMINAL

It is the main element placed in the Local Exchange. It is a network element with PON line card, basically an aggregation switch. It is the central office or we can say main exchange/control room where all modulations, digital or analog conversions and other active elements exist.

C.OPTICAL SPLITTER

It is a passive device with single input and multiple outputs and can be placed anywhere in between the CO. Optical power at input is split between all outputs and signal travels from input to different outputs and also travels from the output to the input. This splitter device is use to split an optical signal into number of light power frequencies.

We generally have two types of networks first is AON (Active Optics Network) and second is PON (Passive Optics Networks). Active networks always work with input power supply and they are noisy also. To maintain AON is also costly and due to scarcity of active units in optical communication the PON architecture is the best, most convenient, simple, cost-effective network and gain more attention in the era of fast communication.

It is simply a subscriber's premises, building, curb, home, office or any college building, curb, organization and college. PON is a single, shared optical fiber network that uses passive devices such as passive optical splitter.

II. OFDM

OFDM is an Orthogonal Frequency Division Multiplexing which is a Multi-Carrier Modulation technique. This technique converts a single high data rate stream of bits into multiple low rate data streams of bits. OFDM is similar to FDM (Frequency Division Multiplexing) but differs with respect to the guard insertion and number of subcarriers. OFDM provide large number of sub-carriers as compare to FDM. OFDM is provided with a special feature which is not in FDM is orthogonality.

In this all subcarriers are orthogonal to each other which minimises the danger of ICI i.e. inter carrier interference and gaurd-band insertion with CP (cyclic prefix) minimises the danger of ISI (inter symbol interference). In OFDM the dot product of each carrier with each other is zero or also we can say that the integral multiple of each carrier over an interval is zero defines that subcarriers are orthogonal to each other. All carriers transmitted with time and frequency in synchronized form.

In OFDM carriers referred to as 'subcarriers' defines the RF carrier mixing the signal from base band. OFDM and PON which is less complex. OFDM is modulation + multiplexing technique. PON is passive because except CO there will be no active elements exist within the network and therefore we can say that PON is become best option for user as well as for service providers. PON can be any building and curb etc.

The main advantages of OFDM system are that, it can provide efficient spectral usage and has multi-path spread delay tolerance. In OFDM Modulation and demodulation can be done by using method of inverse fast fourier transform (IFFT) and another one is fast fourier transform (FFT) operations, which are computationally efficient. OFDM is symbol based, thus data transmission becomes more easier as compare to previous networks.

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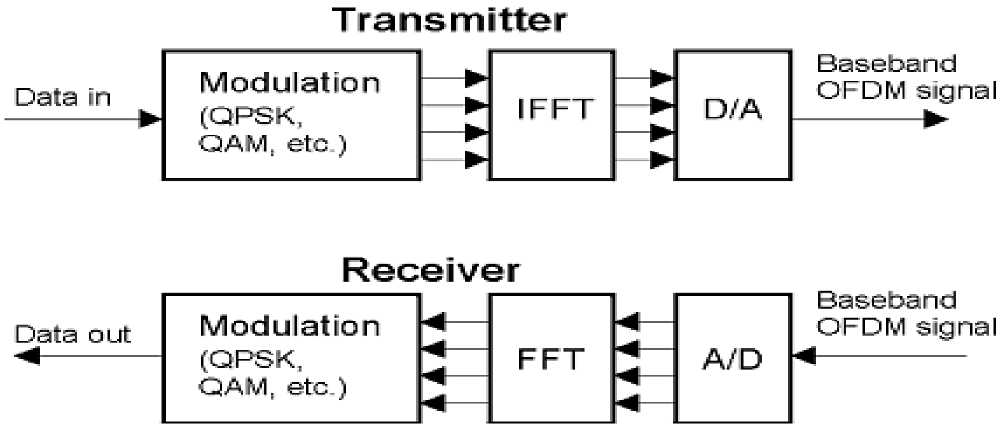

Fig-3 OFDM Transmitter and receiver

III. OFDM SYSTEM MODEL

This section will consist of three blocks which are transmitter, channel and receiver section.

A.TRANSMITTER

OFDM transmitter contain data generator which produce random data.

- Random Data Generator

Random data generator create a serial bit stream of 0's and 1's binary data. The bit stream is a stream of raw and un-modulated data which is transmitted further through the channel. The data is feed to OFDM transmitter.

- S/P Converter

As name indicates it is serial to parallel converter device which converts the serial data stream into parallel stream. Before converted to parallel the serial data is framed into a word and these words are further modulated and transmitted.

- Data To Symbol Mapper

This will do BPSK,QPSK and M-QAM modulation. Each symbol with data is get mapped with a corresponding phase. Each phase is mapped with bits in unique pattern.

- IFFT

IFFT is Inverse fast fourier transform. It converts the signal from frequency domain to time domain .IFFT window size is same as that of FFT window size. It is more easier to analyze the signal in time domain than in frequency domain also the spectral representation of data into time domain is more easy to understand and used in all practical systems.

- Cyclic Prefix

To prevent our signal from ISI we use gaurd interval insertion in between the symbols or words. This can be done with two methods first one is Zero Padding ZP, in this the number of zeros are inserted in between the symbols but not used so much because it sometimes destroy the orthogonality of subcarriers and also do bandwidth wastage because its size taken is 5 times the total symbol size.

Thus programmer switched to (Cyclic Prefix) CP insertion because its size taken is only1/4 of the symbol size. Results in less wastage of bandwidth and do not damage orthogonality of subcarriers.

B.CHANNEL

In this we have taken Rayleigh channel with AWGN noise which is Additive white Gaussian Noise also called as thermal noise /Johnson-Nyquist noise/shot noise and considered as Gaussian distribution of amplitude in a signal. It is a kind of noise with the linear summation of wideband Gaussian noise generated from various natural conditions such as, black body radiation from warm objects and also from earth, celestial bodies e.g. sun, thermal vibrations of atoms (due to movement of charge carrier whether electrons or holes) e.g. in conductors. AWGN has nothing to do with interference fading or flat fading occur due to band limited channel, frequency selectivity, nonlinearity intermodal dispersion in PON. Rayleigh fading channel contain fading of signal due to multipath propagation of light.

C.EQUALIZERS

Equalization is a digital filtering technique that provides an inverse of frequency response use to mitigate the effects of ISI by decreasing the probability of error. We have different types of equalizers.

1).Adaptive Equalization:
This equalizer used with coherent modulation techniques like PSK (phase shift keying) automatically adapts to time-varying properties of the communication channel.
Another form of equalization is work upon finding mean between the terms given below.

2).Maximum-likelihood sequence Estimation (MLSE):
It is maximum-likelihood sequence estimation (MLSE) implemented by means of the "Viterbi" algorithm based on "hadamard" algorithm based on finding the hidden states in between input and output .Let transmitted signal is {x(t)} and observed signal is {r(t)}. The signal r and x are the related signals using a nonlinear transformation. The problem is solved by using the observations {r(t)} to

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Vol. 4, Issue 7, July 2015

create a good estimate of {x(t)}. MLSE is use to solve this problem and the provide the estimate of {x(t)} is defined as a sequence of values which maximize the functional L(x) = p(r | x), Where p(r|x) is conditional joint probability density function of r and x signals.

3).Blind equalization:

This minimizes the error between actual output and desired output. Filtering allows the transmitted bandwidth to be significantly reduced without losing the content ofthe digital data. This improves the spectral efficiency of the signal. Filtering can also create Inter-Symbol Interference (ISI).

4).Minimum Mean Square Error Equalizer (MMSE):

Consider error Y in terms of three other random variables as
Y'=a1X1+a2X2+a3X3
Similarly Ə\ Əa2 and Ə\ Əa3
Yield Collectivity.
E {€ X1} =0
E {€ X2} =0
E {€ X3} =0
€=Y-Y'
Min E {€2} =E ((Y-Y') 2)
a1>a2>a3
Ə\ Əa1 {E {(Y-a1X1-a2X2-a3X3)2}}
=E {Ə\ Əa1 (Y-a1X1-a2X2-a3X3)2}
=E {2(Y-a1X1-a2X2-a3X3) (-X1)} =0
(Y-a1X1-a2X2-a3X3)= €

Shows that error € is orthogonal to data X1>X2>X3 are the data used to estimate signal Y where Y' is observed signal. Thus it is used to find out minimum error in between the symbols.
This occurs when the signal is filtered enough so that the symbols blur together and each symbol affects those around it. This is determined by the time domain response or impulse response of the filter. Thus equalization is get used in our OFDM system model. It is implanted generally in our receiver section and with filtering reshaping is also done.

D.RECEIVER
It works opposite to transmitter. Here firstly demodulation then removal of CP and FFT is done.

III.MODULATION

In this paper we use two modulation techniques which are QPSK and BPSK. Both techniques are coherent in nature.

A.BPSK
BPSK is Binary Phase Shift Keying or also known as phase reversal keying (PSK) or 2PSK. It is able to modulate 1bit/symbol and not suited for high data rate applications. BPSK is functionally equivalent to 2QAM modulation. As name indicates BPSK uses two phases separated by 180 degree. Among all PSK's it is the most robust technique because it takes distortion and noise of higher level force the demodulator to take an incorrect decision.

B. QPSK
It is quadrature phase shift keying and also known as quadric-phase PSK, 4PSK or 4QAM. The resulting waveforms of QPSK and 4-QAM are exactly same but the concept is different. QPSK contain four points in the constellation diagram shows the data points.
The advantage of QPSK over BPSK is that over the same BER the QPSK can transmits twice the data rate in a given bandwidth compared to BPSK. It can encode only two bits per symbol to minimize the bit error.

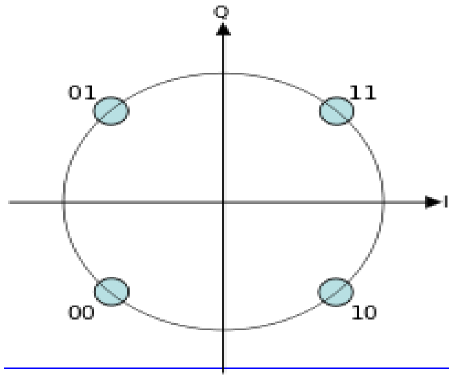

Fig-4 Constellation Diagram Of QPSK

Phase -shift keying (PSK) is a digital modulation scheme that conveys data by modulating or changing the phase of the carrier wave. In the QPSK the odd (even) bits are used to modulate the Quadrature phase component and the even (odd) bits interpretation is used to modulate the in phase component of the carrier.

C.QAM
It is M array quadrature amplitude modulation technique have many different orders like 4, 8, 16, 32, 64, 128 so on. In QAM the two waves are orthogonal to each other and out of phase each other by 90 degree. In QAM the constellation points with equal vertical and horizontal spacing are arranged in a square grid. QAM is combination of amplitude and phase shift keying. In this amplitude and phase both are changed at the same time. QAM conveys data by modulating the amplitude of two carrier waves. In QAM the resulting waveform is the combinations of both ASK and PSK techniques.

Above 8 PSK, QAM modulation is used. The most common forms of QAM are 16, 64, 128 QAM and 256 QAM. With increase in order, the possibility of transmission more bits per symbol increases. But with this noise get increased. This results in higher bit error rate (BER). So the higher order QAM delivers data with high rate but less reliably 64-QAM and 256-QAM are often used in digital cable television and cable modem applications. The BER depends on the bit to symbol mapping, but for Eb/No >>1 we assume that each symbol causes only one bit error.

1).ADVANTAGES

(a) For the long distance communication
(b) Can carry high data rate and capacity

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Vol. 4, Issue 7, July 2015

(c) Less BER
(d) Increased system performance.

With following figure we can see the constellation diagrams of different orders QAM obtained when 1024 bits with 128 samples are modulated and demodulated over Rayleigh channel with AWGN noise. We use CP of 0.0625us and 10 GHz frequency band. The constellation diagram obtained with same input but with 64, 256 and 32-QAM orders determine the data points.

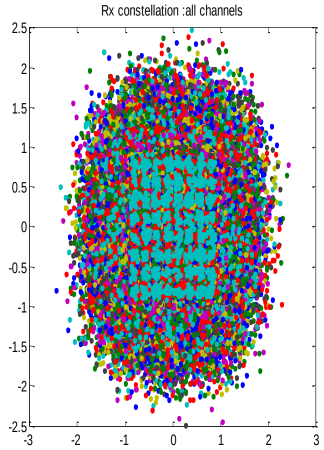

Fig-5 Constellation diagram of 64-QAM

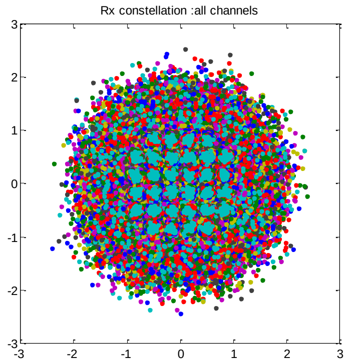

Fig-6 Constellation diagram of 32-QAM

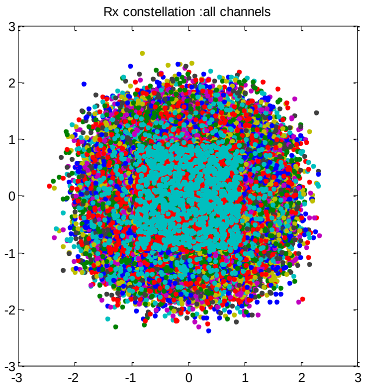

Fig-7 Constellation diagram of 256-QAM

IV.RELATED WORK

C. W. Chow, Member, IEEE, C. H. Yeh, C. H. Wang, Student Member, IEEE, F. Y. Shih, Student Member, IEEE, and S. Chi et.al[1] concluded that 4 Gb/s of 16-quadrature amplitude modulation (QAM)-OFDM signal can be transmitted over the LR-PON (Long Reach-PON) utilizing the bandwidth of 1 GHz. Thus transmission over100-km is obtained without any dispersion compensation mechanism and also the possibility of signal re-modulation over the channel is proved. At splitter the splitting-ratio of 256 was achieved and also analyzed the possibility of using more higher level of QAM, such as 256-QAM .

Mr. Sumit Dalal /M.Tech Scholar and Mr Pulkit Berwal et.al [2]concluded the BER performance over Rayleigh fading channel by using MMSE (minimum mean square error equalization) and MLSE (maximum- likelihood sequence estimation) equalization techniques with BPSK, QPSK, 4 and 16-QAM. BER for all modulations using CP (cyclic prefix) is calculated to reduce Inter symbol Interference (ISI), therefore to reduce the effect of ISI equalization is done at receiver, but it cannot be diminished completely in MMSE and MLSE equalizer and results are calculated with equalization and without equalization.

Results obtained are average value of BER of around 0.4 in BPSK QPSK, 4QAM, 16QAM without equalization and BER reduced by using MLSE equalization and become constant at value of 0.0015 in BPSK and 0.02 in QPSK, 0.12 in 16QAM, 0.0003 in 4QAM.

Amol Kumbhare, Smita Jolania, DR Rajesh Bodade et.al [3] concluded that for high data rate and high performance in different channels MIMO-OFDM technology is best suited. In MIMO Space time block coding scheme is used because of its decoding is simpler. In this paper the performance comparison of different equalizers such as zero forcing equalizer, minimum mean square error, maximum likelihood sequence estimation and space time block coding is
done. The BER performance, spectral efficiency and capacity are calculated. Therefore the combination of zero forcing with MLSE or MMSE + MLSE provided an extra advantage in equalization that zero forcing equalizer improves the performance of BER and further improved by finding maximum likelihood sequence.

Hindumathi, V. et al. (2012) [4] presented the analysis of OFDM architecture with QAM and QPSK. To avoid ISI in single carrier system the symbol period should be taken greater the delay used in between the symbols. According to the results it is analysed that if we increase the order of PSK modulation then the BER get also increases as BER depends on modulation type. Therefore to obtain reduced BER the high SNR is required with higher order modulation scheme. QAM is mostly used in comparison to QPSK and higher order PSK because in QAM if signal get destroyed or corrupted can be reconstructed by varying

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IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

amplitude or by phase. Therefore with QAM SNR will improve and BER can be reduced as compared to QPSK.

M. Divya et.al [5] concluded the performance of BPSK with OFDM over AWGN and Rayleigh fading. The results show the improved results in BPSK over Rayleigh fading channel is compared over

AWGN channel. It is analyzed that the graphical results of simulated BER of BPSK is same as theoretical BER of BPSK and can further reduced by using channel estimation. The results are calculated over input parameters are number of subcarriers are 52 with sampling frequency of 20 MHz. The CP used is of 0.8us with symbol duration of 4us. FFT and IFFT window size is 64.

Jonathan M. Buset, Student Member, Ziad A. El-Sahn, and David V. Plant IEEE et.al [6] concluded a 10 Gb/s bidirectional subcarrier multiplexed (SCM) wavelength-division multiplexed PON. In this square-root raised cosine pulse shaping techniques and digital signal processing is used to generate M-QAM for downlink and BPSK for uplink transmissions. Then as a result 10 Gb/s transmission over a 20 km single feeder PON with powers from 1 to 9 dBm is obtained.

Megha Gupta, Prof. Rajesh Nema, Dr. Ravi Shankar Mishra, Dr. Puran Gour et.al [7] concluded that MLSE (maximum likelihood sequence estimation) can reduce inter symbol interference (ISI) over Rayleigh fading. In this work the comparison of the performance of un equalized systems with the equalized system is done. Hence the BER is improved by using modulations are BPSK, QPSK, 4QAM, 16QAM. The input parameters are sub carriers = 52, IFFT/FFT size=64 with CP=16us. The channel is Rayleigh channel with subcarrier frequency = 20MHz and symbol rate= 52/3.2 usec or 16 Mb. Results in improved BER with equalized system and represented graphically.

A.Sangeetha and Y.Kavven Rajaet.al[8] presented the OFDM with MMSE equalization and heterodyne detection. OFDM provide robustness against narrow band co-channel interference and heterodyne Detection we can optimize channels of different frequencies to a same frequency range. In this paper 2 channels each of 12Gbps modulated with 4-QAM.

OFDM signal transmitted over 60 km fiber over downstream and re-modulated using On-Off keying (OOK) as a upstream signal of bit rate 2.5Gbps with the MMSE equalization technique is proposed in-order to avoid ISI. With filter type the BER of Bessel filter is1.42757e+010 and with adaptive filter using MMSE BER obtained is 1.37405e-022.

V.RESULTS AND SIMULATIONS

To obtain the results we have used following input values with MMSE equalization shown in table1. This input table is only for one transmitter and receiver.

Table1 Input Parameters

S.NO	PARAMETERS	VALUES
1.	IFFT/FFT Window Size	64
2.	Number Of Data Subcarriers	52
3.	Bits Per OFDM Symbol	52
4.	Number Of Total Bits	10^4
5.	Type Of channel	Rayleigh and AWGNChannel
6.	Multipath Channel	10

A.RESULTS

The results over different modulations with MMSE equalizations are compared

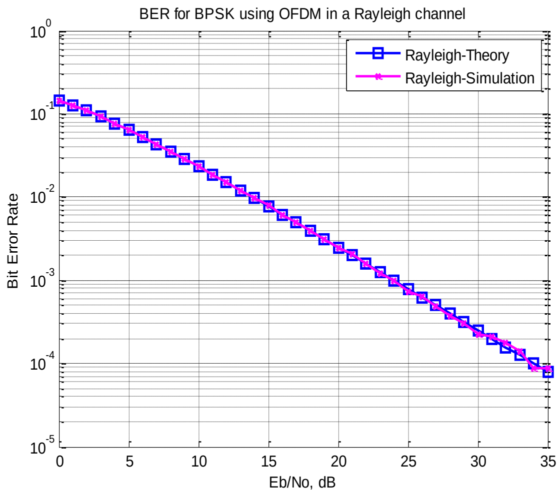

Fig-8 Graph of BER by using BPSK

Figure-8 represent the BER value with respect to input parameters and MMSE equalization and results shows that both theory and simulated results over Rayleigh channel are same with (E_b/No) bit to noise ratio of 35dB over 0.01 bits.

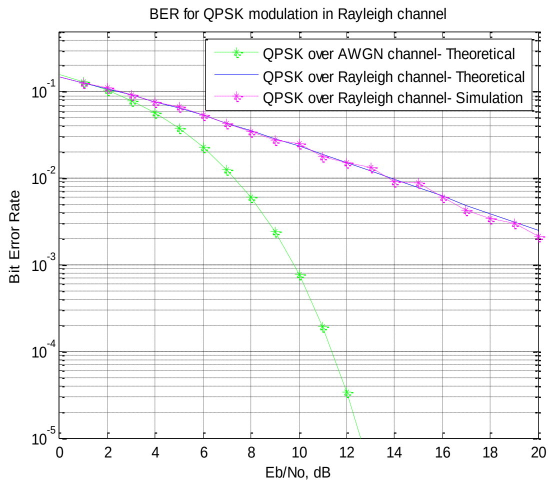

Fig-9 Graph Of BER By Using QPSK

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

Figure-9 represent the BER value with respect to input parameters and MMSE equalization and results are shown on QPSK simulated and theory values and also on AWGN channel. Both theory and simulated results over Rayleigh channel are same with bit to noise ratio of 20dB over 0.01 bits but in AWGN results are 12 dB bit to noise ratio which is less over sme no of bits.

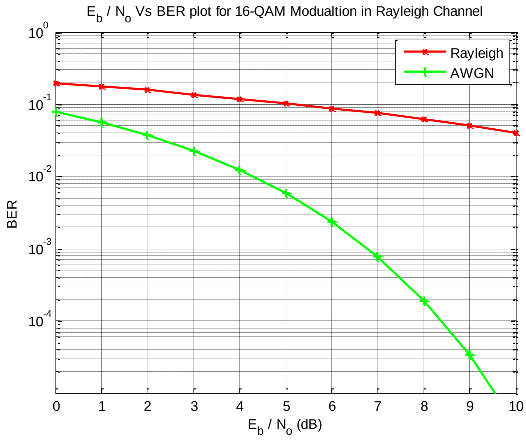

Fig-10 BER for 16 QAM

Figure-10 represent the BER value with respect to input parameters and MMSE equalization and results shows that both on Rayleigh and AWGN channel. On AWGN we get better results as compare to Rayleigh channel with bit to noise ratio of 10 dB over 0.01 bits, but these results are better than QPSK and BPSK. Now following are the results obtained when no equalization is done.

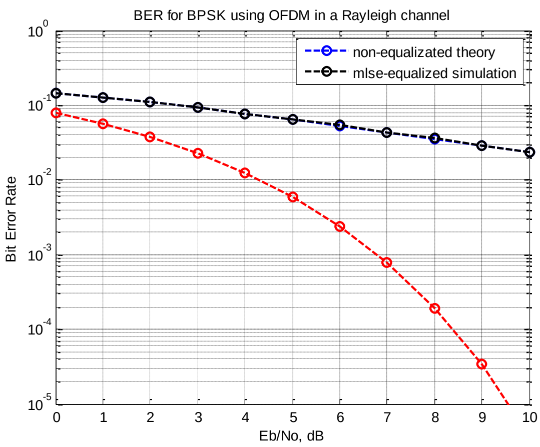

Fig-11 BPSK BER over Rayleigh channel without equalization

The above figure shows the equalized and un-equalized result of BPSK over Rayleigh channel.

The above figure is obtained when equalization is used over Rayleigh channel with MMSE and compare when no equalization is used with QPSK over Rayleigh channel. As a result equalized results are better.

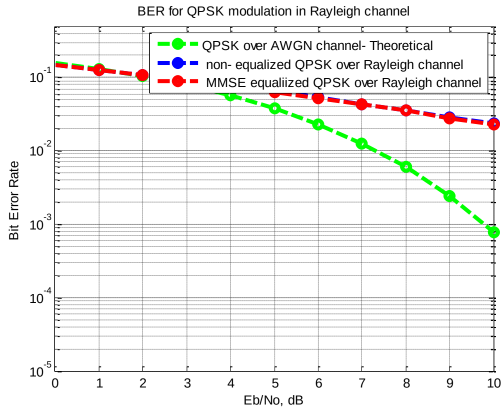

Fig-12 QPSK BER over Rayleigh channel without equalization

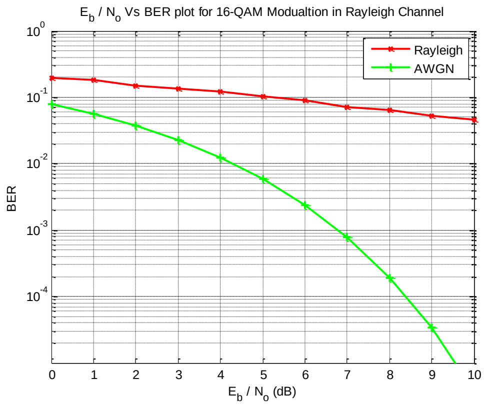

Fig-13 16-QAM BER over Rayleigh channel without equalization

This is result obtained when no equalization is done over 16-QAM.

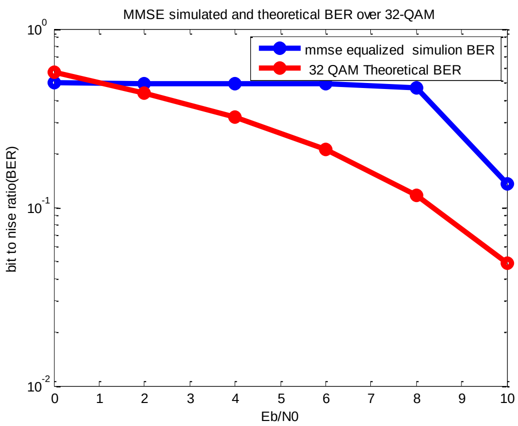

Fig-14 BER over Rayleigh channel with 32-qam having MMSE equalization

This above result is obtained with MMSE equalizer is used showed by blue and when no equalization is used by re color over 32-QAM.

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 7, July 2015

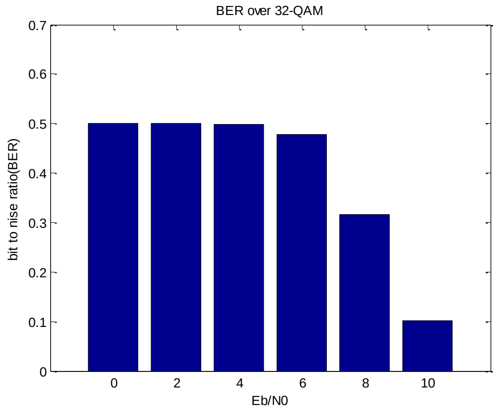

Fig-15 BER of 32-QAM without equalization

Above figure shows the bit error rate performance when no equalization is used.

VI.CONCLUSION

In this paper we analysed the MMSE equalised OFDM system over QPSK, BPSK and over 16-QAM and 32-QAM. Here our equalizer performs linearly because we use only one transmitter and receiver model. After simulation on "Matlab" we obtain that QAM performs better than QPSK and BPSK. Data transmission and reception is better over AWGN than Rayleigh channel by providing less bit to noise ratio. And best results are obtained over 32-QAM with MMSE equalizer. Whether equalizer performs linearly but it improves with higher order of QAM. AWGN is best suited channel but its thermal noise can be reduced by using efficient methods. And study over Rayleigh channel improves the possibility of data accessing over multipath fading channel. And more study on Rayleigh channel will generate more methods for data access with high data rate and with less attenuation.

VII.FUTURE SCOPE

After whole work it is clear that if we use QAM with MMSE over AWGN channel, we wil get better results. In future we can also use higher order of QAM to get more better results with respect to BER. And if BER is reduced than data access can be done more efficiently.

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