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BER Performance of BPSK, QPSK & 16 QAM with and without using OFDM over AWGN, Rayleigh and Rician Fading Channel

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Abstract: Wireless communications is the fastest growing segment of the communication industry. The most widely used wireless communication is mobile communication. But, there are many technical challenges that must be overcome. A signal transmitted on a wireless channel is subject to Fading, Shadowing, Interference, Propagation path loss etc. There is always a greater demand for capacity with the high quality service. In this situation, orthogonal frequency division multiplexing (OFDM) is well defined technique, which is a suitable option for high band width data transmission, by converting the wideband signal into narrow band signals for transmission. The transmission of these individual narrow band signals are executed with orthogonal carrier. In this paper, the performance of transmission mode are evaluated by Bit Error Rate versus the Signal to Noise Ratio under frequently used three channel modes, Additive White Gaussian Noise, Rayleigh Fading and Rician Fading channel. In order to investigate, first we derive the mathematical modelling for bit error rate and signal to noise ratio of OFDM over AWGN, Rayleigh and Rician fading channels then, OFDM is design and implemented. Here we have assumed AWGN channel, Rician and Rayleigh fading channel as noise channel and also built BPSK, QPSK and QAM modulation technique. OFDM transmitters and receivers are implemented here using Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) of size 64 with 52 sub carriers to convert the spectra to time domain & vice versa. The signal frequency is 8MHz and sub-carrier frequency is 0.125MHz. The performance has been concluded based on BER vs. SNR output for BPSK, QPSK and QAM using AWGN, Rayleigh & Rician channel is that BPSK is better than QPSK and QAM in all channel because over AWGN channel at SNR=4dB, BER=0.01 and same BER is achieved by QPSK at SNR=8 and give better performance over AWGN as compare to Rayleigh and Rician channel. And Rician channel is better than Rayleigh channel, BER in Rician is $1/4^{th}$ of Rayleigh for BPSK, ½ for QPSK, 5/4 for 16-QAM.

Keywords: OFDM, AWGN, Rayleigh, Rician, BER, SNR, IFFT, BPSK, QPSK and QAM.

I. INTRODUCTION

Over the past few years, there has been increasing the attention on extending the services available on wired public telecommunications networks to mobile/movable non wired telecommunications users. At present only low-bit-rate data services are available to mobile users for voice services. The demand for wireless broadband multimedia communication systems (WBMCS) are anticipated within both the public and private sectors because the wired networks are cannot support extension to wireless mobile networks due to mobile radio channels are more contaminated than wired data-transmission channels and system cannot preserve the high QoS (Quality of service) required in wired networks. The mobile radio channel is attributed to multipath reception:

- The signal which is introduced to the receiver contains not only a direct line-of-sight (LOS) radio wave but also a large number of reflected radio waves that arrive at the receiver at different times.
- Delayed signals are the result of reflections from terrain features like trees, hills, mountains, vehicles, or buildings. These delayed waves interfere with the direct wave and cause inter-symbol interference (ISI) which causes degradation of network performance.
- A wireless network should be designed to minimize adverse effects. To design broadband multimedia mobile communication systems, it is require to use high-bit-rate transmission of at least several megabits per second. If digital data is transmitted at the rate of several megabits per second, the delay time of the delayed waves should be greater than 1 symbol time. For equalization of these signals at the receiver end, the adaptive equalization techniques are used. There are practical problems in operating this equalization at several megabits per second with compact and low-cost hardware.

To overcome such a multipath-fading environment with low complexity and to achieve WBMCS, the orthogonal frequency division multiplexing (OFDM) transmission scheme is used. OFDM is one of the most popular techniques for a parallel-data-transmission scheme, which reduces the influence of multipath fading and makes complex equalizers unnecessary. OFDM is a special term for a multicarrier transmission where a single data stream is transmitted over a number of lower-data-rate subcarriers as OFDM can be seen as either a modulation technique or a multiplexing technique. The important reason to use OFDM is to increase robustness against frequency-selective fading or narrowband interference. In a single-

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carrier system a single interference can cause the whole link to fail but in a multicarrier system only a small percentage of the subcarriers will be damaged. These few failures can be corrected by an Error-correction coding methods. The concept of using parallel-data transmission and frequency-division multiplexing (FDM) was developed in the mid-1960s. In parallel-data system the total signal frequency band is divided into N non overlapping frequency sub channels. Every sub channel is modulated with a separate symbol and then the N sub channels are multiplexed. It seems acceptable to avoid spectral overlap of channels to reduce inter-channel interference but it leads to inefficient use of the available spectrum. To face with this inefficiency the idea was proposed in the mid-1960s to use parallel data and FDM with overlapping sub channels in which each carrying a signalling rate b which is spaced by b in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion as well as to use the whole available bandwidth. Figure 1 illustrates the difference between the conventional non overlapping multicarrier technique and the overlapping multicarrier modulation technique. Almost 50% of bandwidth can be preserved by using overlapping multicarrier modulation technique. To realize this technique there is a need to reduce cross talk between subcarriers which means there is a need of Orthogonality between the different modulated carriers. The word “orthogonal” shows that there is a mathematical relationship between the frequencies of the carriers in the system. In a FDM system many carriers are spaced apart in such a way that the signals can be received by using conventional filters and demodulators. In such receivers there is a need of guard bands between the different carriers and in the frequency domain which results in a lowering of spectrum efficiency. It is possible to arrange the carriers in an OFDM signal so that the sidebands of the individual carriers overlap and the signals are still received without adjacent carrier interference. For this the carriers must be mathematically orthogonal with the resulting signal integrated over a symbol period to recover the original data. If the other carriers all beat down the frequencies that in the time domain have a whole number of cycles in the symbol period T then the integration process results in zero contribution from all of these other carriers. If the carrier spacing is a multiple of 1/T then the carriers are nearly independent (i.e., orthogonal). Much of the research focuses on the highly efficient multicarrier transmission scheme based on “orthogonal frequency”. The introduction of the discrete Fourier transform (DFT) to parallel-data-transmission systems as part of the modulation and demodulation process was given by Weinstein and Ebert in 1971. Fig. 2 shows the spectrum of the individual data of the sub channel. The OFDM signal multiplexed in the individual spectra with a frequency spacing b equal to the transmission speed of each subcarrier. Therefore DFT is used at the receiver and calculate correlation values with the centre of frequency of each subcarrier to recover the transmitted data with no cross talk.

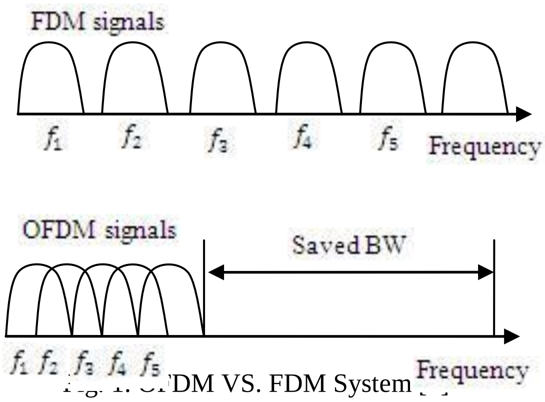

Fig. 1. OFDM VS. FDM System

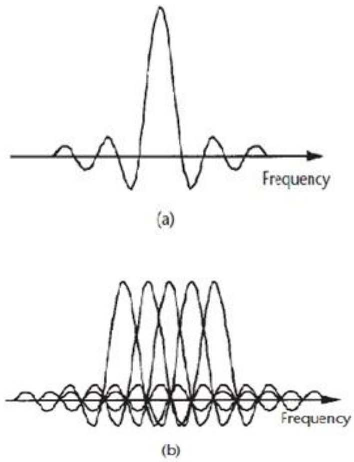

Fig. 2. Spectra of (a) an OFDM sub channel, and (b) an OFDM signal [1]

Over the many advantages of OFDM technique, it has some drawbacks also: OFDM system is more sensitive to frequency offset and phase noise. The most important weak point of OFDM is high- peak-to-average-power ratio which tends to reduce the power efficiency of the radio frequency (RF) amplifier.

A. OFDM SIGNAL MATHEMATICAL REPRESENTATION

An OFDM signal consists of N_c subcarrier spaced by the frequency distanceΔf. Thus, the total system bandwidth W is divided into N_c equidistance subchannels. Every subcarrier is commonly orthogonal with a time interval of length$T_s = 1/\Delta f$. This serves two purposes, efficient use of spectrum and N_c streams transmitted with different carriers orthogonal to each other reducing effect of ICI and ISI simultaneously. The Kth subcarrier signal is described analytically by the function $g_k(t)$:

$$g_k(t) = \begin{cases} e^{j2\pi k\Delta ft} & 0 < t < T_s, k = 0, \dots\dots, N_c - 1 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Since the OFDM system bandwidth W is subdivided into N_c narrowband subchannels (subcarrier bandwidth), the OFDM duration T_s is N_c times large compared to a single-carrier transmission system covering the same bandwidthW. For a given system bandwidth, the number of subcarriers is chosen such that the symbol duration is larger compared to the maximum delay of the channel.

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This subcarrier signal $g_k(t)$ is extended by a cyclic prefix (guard interval to avoid ISI) with the length T_g yielding the signal:

$$g_k(t) = \begin{cases} e^{j2\pi k\Delta ft} & 0 < t < T_s + T_g, k = 0,..,N_c - 1 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

At the receiver, the guard interval is removed and only the time interval $[0, T_s]$ is evaluated, which is symbol time. Thus, the guard interval is pure system overload. The total OFDM block duration is $T = T_s + T_g$ = base period. If the guard interval length T_g is larger than the maximal delay in the radio channel, no ISI occurs at all and the Orthogonality of the subcarriers is not affected.

II. LITERATURE SURVEY

In recent years, OFDM has emerged as a promising air-interface technique. In the context of wired environments, OFDM techniques are also known as Discrete Multi Tone (DMT) transmissions and are employed in the American National Standards Institute's (ANSI), Asymmetric Digital Subscriber Line (ADSL), High-bit-rate Digital Subscriber Line (HDSL) and Very-high-speed Digital Subscriber Line (VDSL) standards as well as in the European Telecommunication Standard Institute's (ETSI) VDSL applications. In wireless scenarios, OFDM has been advocated by many European standards, such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting for Terrestrial Television (DVB-T), Digital Video Broadcasting for Handheld Terminals (DVB-H), Wireless Local Area Networks (WLANs), and Broadband Radio Access Networks (BRANs).

The first OFDM schemes date back to the 1960s, which were proposed by Chang and Saltzberg. In the classic parallel data transmission systems, the frequency-domain (FD) bandwidth is divided into a number of non overlapping sub channels, each of which hosts a specific carrier widely referred to as a subcarrier. While each subcarrier is separately modulated by a data symbol, the overall modulation operation across all the sub channels results in a frequency-multiplexed signal. Since the modulated signal's spectrum is multiplied by a rectangular window corresponding to the length of the time-domain (TD) OFDM symbol, the subcarriers have to be convolved with resultant FD sinc-function. Similarly to classic ISI-free orthogonal TD Nyquist-signalling, all of the sinc-shaped FD sub channel spectra exhibit zero-crossings at all of the surrounding subcarrier frequencies and, hence, the individual sub channel spectra are orthogonal to each other. This ensures that the subcarrier signals do not interfere with each other, when communicating over perfectly distortion less channels, as a consequence of their Orthogonality.

The early OFDM schemes required banks of sinusoidal subcarrier generators and demodulators, which imposed a high implementation complexity. This drawback limited the application of OFDM to military systems until 1971, when Weinstein and Ebert suggested that the discrete Fourier transform (DFT) can be used for the OFDM modulation and demodulation processes, which significantly reduces the implementation complexity of OFDM. Since then, more practical OFDM research has been carried out. For example, in the early 1980s Peled and Ruiz proposed a simplified FD data transmission method using a cyclic prefix aided technique and exploited reduced complexity algorithms for achieving a significantly lower computational complexity than that of classic single-carrier time-domain QAM modems. Around the same era, Keasler et al. invented a high-speed OFDM modem for employment in switched networks, such as the telephone network. Hirosaki designed a sub channel based equalizer for an orthogonally multiplexed QAM system in 1980 and later introduced the DFT-based implementation of OFDM systems, based on which a so-called group band data modem was developed. Cimini, Jr. and Kalet investigated the performance of OFDM modems in mobile communication channels. Furthermore, Alard and Lassalle applied OFDM in digital broadcasting systems, which was the pioneering work of the European DAB standard established in the mid-1990s.

III. PROPOSED SYSTEM MODEL

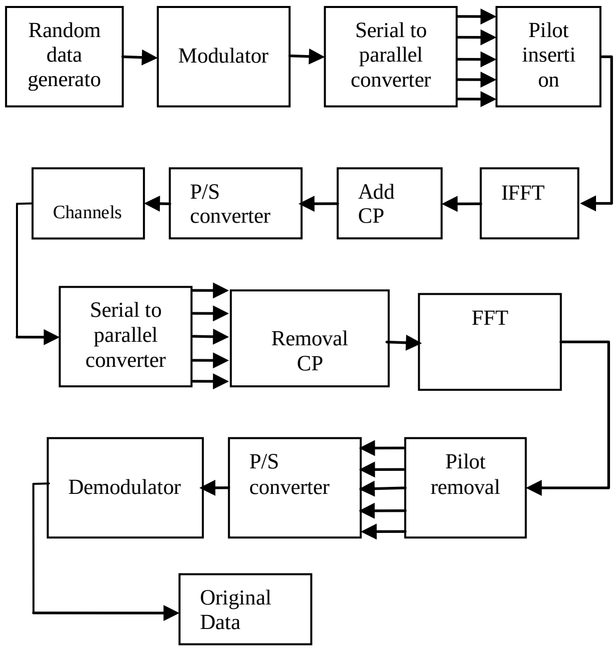

Fig. 3 Block diagram of DT-OFDM Model [6]

Algorithm for OFDM simulation has been given below:-
Random data :- t_data=randint(nbitpersym*nsym,1);
Modulator:- mod_data = modulate(M,t_data);
S to P :- par_data = reshape(mod_data,nbitpersym,nsym).';
Pilot insertion :-pilot_ins_data=[zeros(nsym,6) par_data(:,[1:nbitpersym/2]) zeros(nsym,1) par_data(:,[nbitpersym/2+1:nbitpersym]) zeros(nsym,5)] ;
IFFT:- IFFT Inverse discrete Fourier transform.
IFFT(X) is the inverse discrete Fourier transform of X.
IFFT(X,N) is the N-point inverse transform.
IFFT(X,[],DIM) or IFFT(X,N,DIM) is the inverse discrete Fourier transform of X across the dimension DIM.
IFFT_data = (64/sqrt(52))*ifft(fftshift(pilot_ins_data.')).';

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Adding CP:- cylic_add_data = [IFFT_data(:,[49:64]) IFFT_data].';
P to S :- ser_data = reshape(cylic_add_data,80*nsym,1);
we can pass data through different channel one by one
For AWGN channel
AWGN Add white Gaussian noise to a signal.
Y = AWGN(X,SNR) adds white Gaussian noise to X. The SNR is in dB. The power of X is assumed to be 0 dBW. If X is complex, then AWGN adds complex noise.
Y = AWGN(X,SNR,SIGPOWER) when SIGPOWER is numeric, it represents the signal power in dBW. When SIGPOWER is 'measured', AWGN measure the signal power before adding noise.
we use the following statement in coding as a awgn function
chan_awgn=sqrt(80/52)*awgn(ser_data,snr(ii),'measured'); % awgn addition
For Rayleigh channel
[data_rx]=sqrt(80/52)*channel_rly(ser_data,snr(ii));
For Ricean channel
[data_rx]=sqrt(80/52)*channel_ricean(ser_data,snr(ii));
At receiver side
S to P:- **:** ser_to_para = reshape(data_rx,80,nsym).';
Removing cyclic prefix:- cyclic_pre_rem = ser_to_para(:,[17:80]);
FFT_recdata=(sqrt(52)/64)*fftshift(fft(cyclic_pre_rem.')).';
rem_pilot=FFT_recdata(:,[6+[1:nbitpersym/2]7+[nbitpersym/2+1:nbitpersym]]);
ser_data_1 = reshape(rem_pilot.',nbitpersym*nsym,1);
z=modem.pskdemod(2);

IV. SIMULATION PARAMETERS AND RESULTS

A. SIMULATION PARAMETERS

TABLE I SIMULATION PARAMETERS

Number of bit per symbol	52
Number of symbol	10000
Length of FFT	64
Number of subcarrier	52
Digital modulation technique	BPSK, QPSK, 16-QAM
Noise Channel	AWGN, Rayleigh, Rician
Signal frequency	8MHz
Sub-carrier Frequency	0.125MHz
Cyclic prefix	1/4
SNR	0-12

B. BER PERFORMANCE OF AWGN, RAYLEIGH AND RICIAN FADING CHANNEL WITHOUT USING OFDM

Fig. 4 shows BER vs. SNR performance analysis of BPSK, QPSK and 16-QAM modulation technique over Additive White Gaussian Noise channel.

BPSK has lower BER than QPSK and 16QAM. For example at SNR=2, BER in BPSK is 0.07 where QPSK & 16QAM is around 0.1. At SNR=12 , BPSK, BER=0 but QPSK-BER>10^{-4} and 16 QAM-BER>10^{-2}.

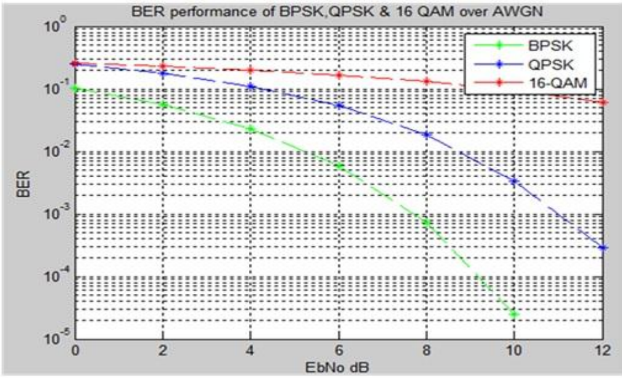

Fig. 4 BPSK, QPSK & 16-QAM over AWGN channel

Fig. 5 shows BER vs. SNR performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rayleigh fading channel.

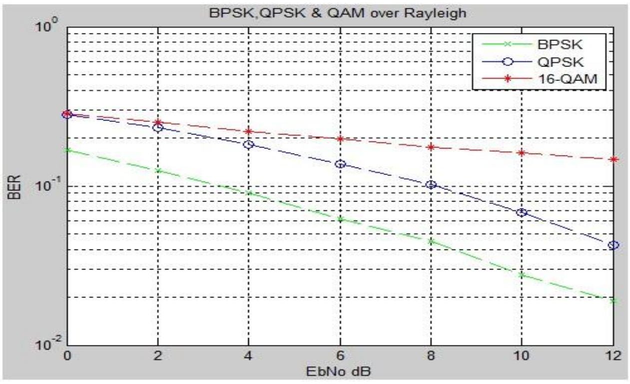

Fig. 5 BPSK, QPSK & 16-QAM over Rayleigh channel

Fig. 5 shows performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rayleigh fading channel. BPSK has lower BER than QPSK and 16QAM. For example at SNR=4, BER in BPSK is <10^{-1} (0.1) where QPSK & 16QAM is around 0.2. At SNR=12 ,BPSK, BER=0.02 but QPSK-BER>0.04 and 16 QAM-BER>0.1

TABLE II COMPARISON OF DIFFERENT MODULATION OVER RAYLEIGH CHANNEL

SNR(db)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
4	0.07	0.2	>0.2
8	0.02	0.1	0.1
12	0.01	0.03	<0.1

Fig. 6 shows BER vs. SNR performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rician fading channel. Fig. 6 shows performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rician fading channel. We know that if BER decreases than BER performance will be increases. In graph as the value of SNR is increases, BER is decreases in all three modulation technique, that mean for better performance signal to noise ratio must be high i.e. noise must be low for best communication. Here BER performance of BPSK is better than QPSK and 16-QAM. Also QPSK is better than 16-QAM. Result is almost same in all channels.

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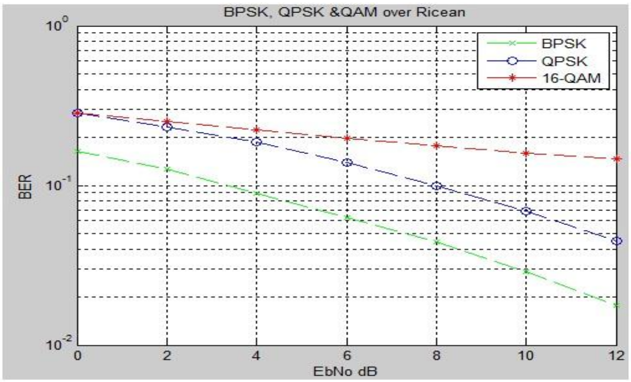

Fig. 6 BPSK, QPSK & 16-QAM over Rician channel

TABLE III COMPARISON OF DIFFERENT MODULATION OVER RICIAN CHANNEL

SNR(db)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
4	0.09	0.2	>0.2
8	0.03	0.1	< 0.2
12	0.01	0.03	0.1-0.2

C. BER PERFORMANCE OF AWGN, RAYLEIGH AND RICIAN FADING CHANNEL BY USING OFDM

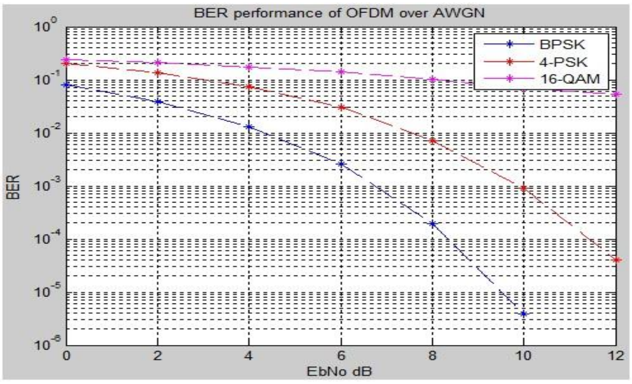

Fig. 7 BER performance of OFDM over AWGN channel

Fig. 7 shows performance analysis of BPSK, QPSK and 16-QAM modulation technique over Additive White Gaussian Noise channel using OFDM. In graph as the value of SNR is increases, BER is decreases abruptly in BPSK.

TABLE IV COMPARISON OF BER VS. SNR OVER AWGN CHANNEL

SNR (db)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
0	0.0798	0.2044	0.2387
2	0.0382	0.1373	0.2073
4	0.0025	0.0300	0.1744
6	0.0007	0.0075	0.1405
8	0.0001	0.0075	0.1030
10	10^{-5}	10^{-4}	0.0678
12	10^{-6}	10^{-5}	0.0396

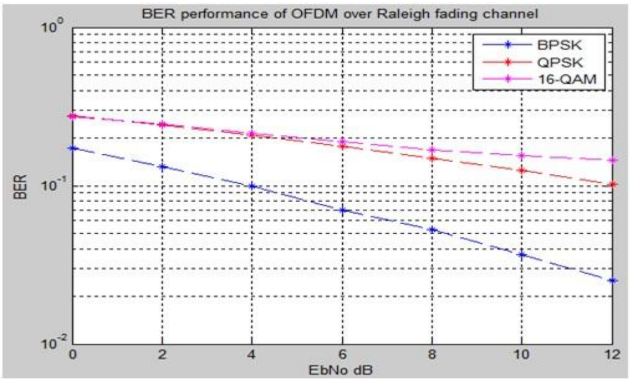

Fig. 8 BER performance of OFDM over Rayleigh fading channel

Fig. 8 shows performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rayleigh fading channel. In graph as the value of SNR is increases, BER is decreases in all three modulation technique. BER performance of BPSK is much better than QPSK and 16-QAM. Also QPSK is better than 16-QAM for higher SNR values.

TABLE V COMPARISON OF BER VS. SNR OVER RAYLEIGH FADING CHANNEL

SNR(db)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
0	0.1712	0.2746	0.2737
2	0.1344	0.2419	0.2404
4	0.1002	0.2062	0.2109
6	0.0738	0.1766	0.1876
8	0.0513	0.1505	0.1706
10	0.0379	0.1243	0. 1560
12	0.0260	0.1031	0.1453

There is no drastic difference or we can say that negligible or no difference between BPSK BER vs. SNR curve over any channel by using OFDM or not.

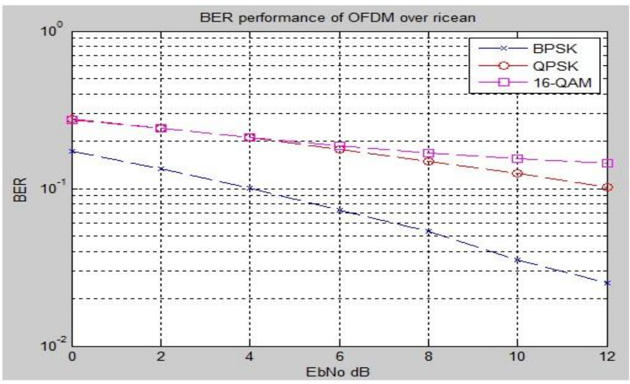

Fig. 9 BER performance of OFDM over Rician fading channel

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TABLE VI COMPARISON OF BER VS. SNR OVER RICIAN FADING CHANNEL

SNR (db)	BPSK(BER)	QPSK(BER)	16-QAM(BER)
0	0.1718	0.2758	0.2730
2	0.1337	0.2420	0.2418
4	0.1003	0.2091	0.2112
6	0.0717	0.1797	0.1882
8	0.0522	0.1515	0.1685
10	0.0359	0.1231	0.1546
12	0.0250	0.1021	0.1443

Fig. 8 shows performance analysis of BPSK, QPSK and 16-QAM modulation technique over Rician fading channel. In graph as the value of SNR is increases, BER is decreases in all three modulation technique is shown in Table V, that mean for better performance BPSK may preferred.

V. CONCLUSION

In this paper, the performance of OFDM system over different channels has been observed. The analysis is based on the study of Bit Error Rate (BER) and Signal to Noise Ratio (SNR). Also explain the design and implementation of OFDM system in terms of operation at transmitter end and receiver end. To remove the Inter Symbol Interference (ISI), a cyclic prefix addition method is used here. Also At last we conclude our work with the help of graph. From the results obtained it is concluded that the BER decreases as the SNR increases. The BPSK has an overall better performance as compared to QPSK & 16-QAM techniques. That means lower order of modulation techniques is better to use in communication system if spectral efficiency is not considered or taken in an account.

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BIOGRAPHY

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