Performance Evaluation of OFDM System-A Simulation Study

Ritika Kondal, Ravikant Sharma, Dr. Abhay Sharma
Department of electronics & communication Engineering,
Green hills engineering college,
Solan, H.P.
India-173029

ABSTRACT

OFDM is a combination of modulation, multiplexing and wireless technology. OFDM involves a broadband multicarrier modulation method that offers superior performance and benefits over older, more traditional single-carrier modulation methods because it is better fit with today's high-speed data requirements and operation in the UHF and microwave spectrum. In recent years, OFDM has come up with successful use in terrestrial DVB and has proved its strong candidature as a modulation technique for future wireless systems.It completely fulfills today's increased need of high speed data transmission. In this paper the channel capacity for different channels has been studied. Also the bit error rate has been reduced and SNR has been improved so as to find out that which channel is better for OFDM transmission and under which modulation scheme.

Keywords: OFDM (orthogonal frequency division multiplexing), fading channels, FDM (frequency division multiplexing), DVB, FFT (fast Fourier transform), guard band, symbol period, ISI (inter symbol interference), ICI (inter carrier interference), BER, SNR,spectral efficiency.

IJERT

1.INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a multicarrier system in which the transmitter combines the multiple low data rate carriers so as to form a composite high data rate transmission. OFDM is a special case of FDM. It divides the channel into a number of equally spaced frequency bands and each subcarrier carrying message signal is transmitted through each channel. The spacing between the subcarriers provides Orthogonality in OFDM so as to prevent demodulators from looking at the frequencies other than their own [3]. Orthogonality is the main concept whichdiffersin between OFDM and FDM. In OFDM all the subcarriers are orthogonal to each other[1]. The two major features of OFDM system are High spectral efficiency and multipath immunity. OFDM is an effective technique to combat frequency selective multipath fading and this is the key to OFDM success[10]. The transmission in OFDM is high data rate transmission.Short symbol period must be used for transmitting high data rates. Symbol period(T) is inversely proportional to the baseband data rate(R) i.e. (T=1/R).In multicarrier transmission short symbol period leads to greater chance of inter symbol interference (ISI). This is eliminated by OFDM by providing high data rate with long symbol period. Also it removes inter carrier interference (ICI) by providing technique which allows the bandwidth of the modulated carriers to overlap without interference [2][4].

In this paper, the performance of OFDM system has been studied under various channels and modulation techniques. Also, the channel capacity of different channels is compared to find out that which channel is better for OFDM transmission.The rest of thepaper is organized as follows: Section 2 describes the OFDM system. Section 3 describes the Modulation followed by modulation techniques used. Section 4 describes BER (bit error rate) and SNR (signal to noise ratio). Section 5 describes fading, its causes and effects. Section6describes Channel Capacity followed by spectral efficiency and different channel used. Section 7discussesthe simulation results. And the last section concludes the paper.

2. SYSTEM DESCRIPTION

2.1. OFDM System Model

At the transmitter, the input from the source is high speed complex data. High speedinput data streams are coded at the code rate by encoder and then mapped to one of the symbols by the symbol generator. The symbol generator providescomplex output symbols of duration T. Then the data is given to serial to parallel converter so as to provide different OFDM subcarriers with different data groups[6]. The set $\{a_i, 0 < n < N-1\}$ is the set of symbols which is modulated by IFFT and are converted from frequency domain to time domain. Then a cyclic prefix is added to De multiplexed IFFT output. And finally, the obtained signal is then converted to a continuous time analog signal. Then it is passed through low pass filter to filter out the constraints before transmitting it through the channel. Now at the receiver side an inverse operation is performed so as to extract the high speed output data.

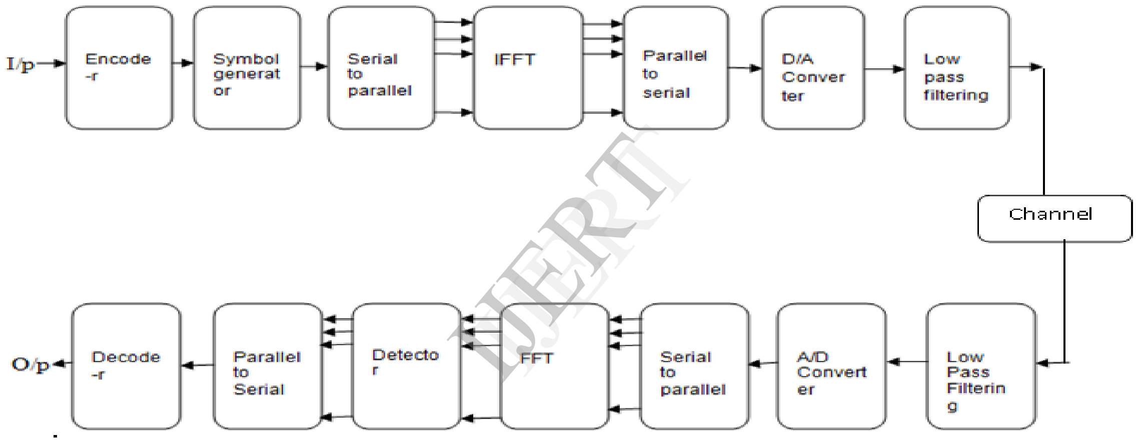

Fig.1. OFDM system model

The IFFT block is used to transform the data sequence of length N (frequency domain) into time domain signal according to the following equation:

$$x(n) = \sum_{\omega=0}^{N-1} X(\omega)\, e^{\frac{j2\pi\omega n}{N}} \qquad (1)$$

Where,
X(n)=discrete time signal
X(ω)=Fourier transform
N = FFT length
m = number of symbols
w = frequency ($-\infty to \infty$)

To prevent inter symbol interference and to eliminate inter carrier interference, the guard time is chosen to be larger than expected delay spread. The OFDM signal is:

$$x_t(m) = \begin{cases} X(N+m), & m = -N_g, \ldots\ldots -N_g + 1 \\ X(m), & m = 0,1, \ldots\ldots\ldots N+1 \end{cases} \qquad (2)$$

Where,

N_g = length of guard interval

Followed by D/A converter, the transmitted signal will pass through the fading channel with noise. The received signal is given by:

$$y_r = x_t(n) * H(n) + n \qquad (3)$$

At the receiver side:

$$y(n) = y_r\left(m + N_g\right) \qquad (4)$$

After passing it through FFT and considering no ISI, the output equation is:

$$Y(\omega) = X(\omega)H(\omega) + n \qquad (5)$$

3. MODULATION

Modulation is basically a process in which some characteristics (amplitude, phase or frequency) of carrier signal are varied in accordance with the instantaneous value of the modulating signal. It is generally used to remove interference and reduce noise. Carrier signal is signal which is transmitted at a pre-determined frequency to act as carrier of 'voice' or 'data' [8]. The various modulation techniques used are BPSK (Binary phase shift keying), QPSK (Quadrature phase shift keying) and QAM (Quadrature amplitude modulation). BPSK (or 2-PSK) is the simplest form of phase shift keying. It uses phases which are separated by 180° and for this reason it is called as 2-PSK. In BPSK, the phase shift occurs in two levels only. In QPSK, the two successive bits are combined. This combination of two bits forms four distinct symbols. When the symbol is changed to next symbol, then the phase of the carrier is changed by $\frac{\pi}{4}$ radians. In QAM, the two carrier waves are out of phase with each other by 90° and are thus called Quadrature carriers or Quadrature component. It conveys two analog message signals by modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. In this paper performance of OFDM system is studied under various channels and modulation techniques by varying BER with respect to SNR.

4. BER AND SNR

Bit errors are the errors or alteration due to noise, interference, distortion etc. in received data bits as compared to the transmitted data bits. The bit error rate or bit error ratio (BER) is the ratio ofthe number of bit errors to the total number of transferred bits during. BER is a unitless performance measure, and is often expressed as a percentage.The bit error probability is the expectation value of the BER, means that the BER can be considered as an approximate estimate of the bit error probability. And this estimate is considered accurate for a long time interval and a large number of bit errors. If strong signal strength is chosen then, BER can be improved.

SNR (Signal-to-noise ratio) is the ratio of received signal at the output to the received noise at output. SNR is basically a two level measurement, followed by a simple calculation. First, the output is measured without applying any input [6]. Secondly, the output is measured by applying some input. It can be said that SNR isthe ratio of signal power to noise power is measured by applying some input.

IJERT

$$\mathrm{SNR} = \frac{\mathrm{P_{signal}}}{\mathrm{P_{noise}}} \qquad (6)$$

5. FADING

In wireless communication, fading is deviation of the attenuation which affectsthesignal during transmission. In general we can say that fading is simply distortion of signal. In order to understand fading concept of multipath must be clear. Multipath means more than one path between transmitter and receiver. Fading may occur due to multipath propagation, called multipath induced fading, or due to shadowing from obstacles, called shadow fading. Fading varies with time, geographical position or radio frequency, and is a random process. A communication channel where fading occurs is called fading channel.

5.1. Causes and effects of Fading

Multiple paths are created due to the presence of reflectors surrounding the transmitter and receiver. As a result, there is superposition of multiple copies of the transmitted signal at the receiver, each of which traverses a different path. Each signal will experience attenuation, delay and phase shift. This results in interference at the receiver. Strong destructive interference is called as a deep fade and may result in temporary failure of communication due to a severe decrease in SNR(signal to noise ratio). Main causes of fading are Doppler shift, reflection, diffraction and scattering. The shift in received signal frequency due to relative motion w.r.t. the signal source is called Doppler shift. Doppler shift will be positive or negative depending on whether the mobile receiver is moving towards or away from the base station. Diffraction is described as the apparent bending of waves around small obstacles and the spreading out of waves past small openings. Diffraction looks like a reflection at high frequencies [6]. Scattering is a process where some forms of radiation are forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass.

6. CHANNEL CAPACITY

Channel is the path through which data from transmitter is transmitted to the receiver. The maximum rate at which data transmission can be achieved through a channel with small error probability is called as Channel capacity. Unlike AWGN channel, there is no single definition of capacity for fading channels that could be applied in all scenarios. Here, AWGN channel is used as a base to study the channel capacity of wireless fading channels.The Optimal power allocation is a “water-filling” or “water-pouring” technique used to achieve channel capacity on frequency selective fading channels [5][7]. Here, the optimal rate adaptation technique is used for comparing the channel capacity of fading channels with the AWGN channel. Also, the power of the fading channel is kept same as that of the AWGN channel and rate of transmission is varied so as to compare the channel capacity of different channels. Now, with increase in SNR and spectral efficiency the channel capacity increases. And improved channel capacity allows efficient OFDM transmission.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

6.1. Spectral Efficiency

Spectral efficiency refers to the rate at which data can be transmitted over a given bandwidth in a communication channel. It is a measure of how efficiently a limited frequency spectrum can be utilized. Let 'm' be the indicator of fading severity, then

$$step\ size = \frac{1}{m} \qquad (7)$$

As the value of 'm' increases, the step size as well as the fading decreases. And as result of this, the channel capacity increases. Fading is completely removed at $m = \infty$. And for AWGN channel this is the case.

6.2. Rayleigh fading channel

Rayleigh fading channel is a statistical model which is used in wireless communication such as OFDM for reducing the distortion or fade caused according to the Rayleigh distribution. Rayleigh distribution is the radial component of sum of two uncorrelated Gaussian random variables. The delays associated with different signal paths in a multipath fading channel change in an unpredictable manner. And these delays can be only characterized statistically[9]. If there are a number of signal paths, the central limit theorem holds good for modeling channel impulse response as complex valued Gaussian process irrespective of the distribution of the individual When the impulse response is modeled as a zeromean complex-valued Gaussian process, the channel is referred to as Rayleigh fading channel. Some properties of Rayleigh channel are correlation, level crossing rate, average fade duration and Doppler power spectral density.

IJERT

6.3. AWGN channel

AWGN(additive white Gaussian noise channel) basically adds white Gaussian noise to the input signal.AWGN is generally used to simulate background noise of the channel, multipath, terrain blocking, interference, ground clutter and self interference that systems encounter in terrestrial operation**.**The channel capacity of AWGN channel is calculated as:

$$C = \frac{1}{2}\log(1 + \frac{P}{n}) \qquad (6)$$

Where,

C = channel capacity of AWGN channel

P = maximum power of channel

If the message signal is transmitted through the channel with index (1 to M) and 'M' message signals are encoded to 'm' number of bits, then the rate is calculated as:

$$R = \frac{logM}{m} \qquad (7)$$

Where, R = rate at which signal is transmitted. The capacity 'C' is the highest achievable rate.

6.4. Nakagami fading channel

It has greater flexibility and accuracy as compared to other channels. It is also called as Nakagami-m fading channel because its performance can be varied by varying the value of ‘m’, the indicator of fading severity. The performance of Nakagami fading channel can be varied by varying the value of ‘m’ as follows:

If, $m < 1$, Nakagami fading channel is worse than Rayleigh fading channel.

If, $m = 1$,Nakagami fading channel is same as that with Rayleigh fading channel.

If, $m > 1$, Nakagami fading channel is better than Rayleigh fading channel.

In this paper we have considered $m > 1$ for comparing the channel capacity of different channels

7.SIMULATION RESULTS

Figure 5 showsthe comparison of channel capacity of Rayleigh Fading channel, Nakagami fading channel and AWGN channel. It can also be seen that with increase in spectral efficiency and signal to noise ratio the channel capacity also increases.Here, ‘m’, the indicator of fading severity is varied, so as to reduce the effect of fading, and then the channel capacity is compared.

The values of ‘m’ are varied as:$m = 1$, For Rayleigh fading channel;$m = 2$, for Nakagami fading channel; and $m = \infty$, for AWGN channel. This shows that with increase in value of ‘m’, fading reduces and at $m = \infty$ fading diminishes.The figure shows that fading reduces the channel capacity. Also the figure 5 shows that AWGN channel has high channel capacity because of no fading effect.

IJERT

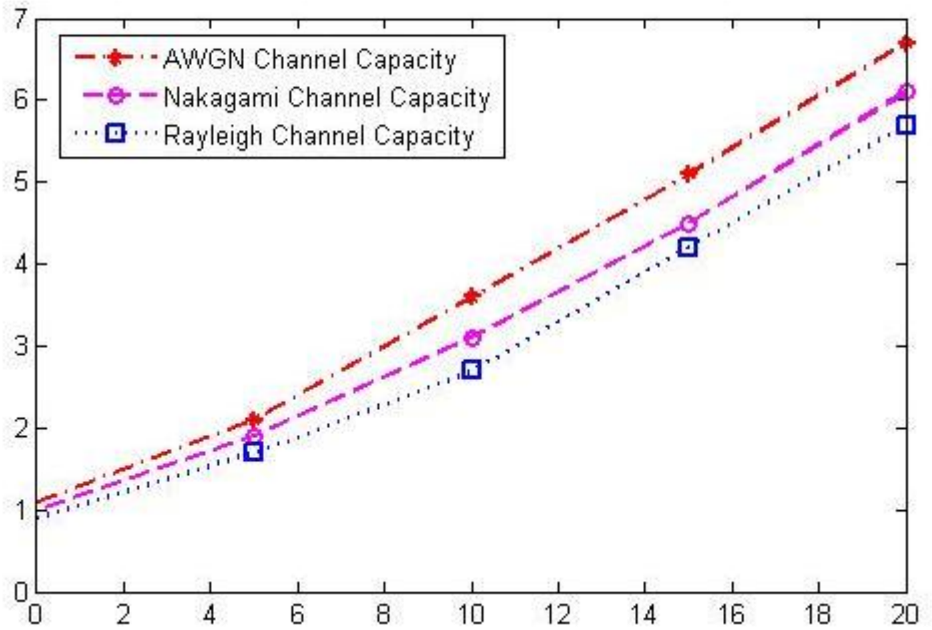

Fig. 5.Comparison of channel capacity of different channels.

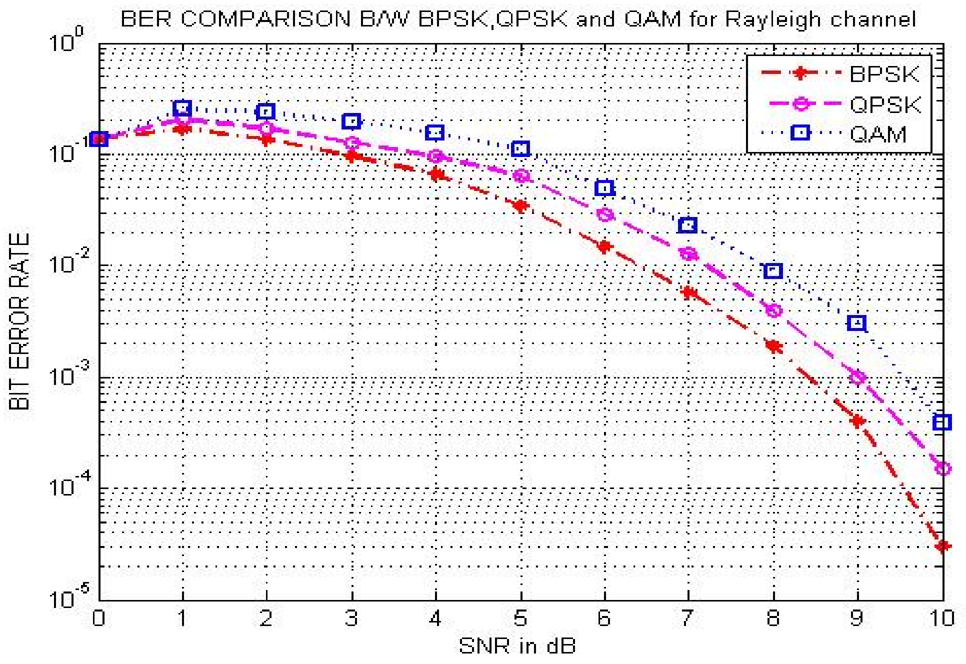

Fig. 6.BER Comparison between BPSK, QPSK, and QAM for Rayleigh channel.

Figure 6 shows the comparison of different modulation techniques say BPSK, QPSK, and QAM for Rayleigh fading channel. It can be seen that BPSK has least Bit error rate and QAM has maximum BER. This is due to the reason that BPSK requires 3 dB less SNR than required for QPSK to achieve the same BER. But this will be true only in case where BER is considered in terms of SNR per carrier.

IJERT

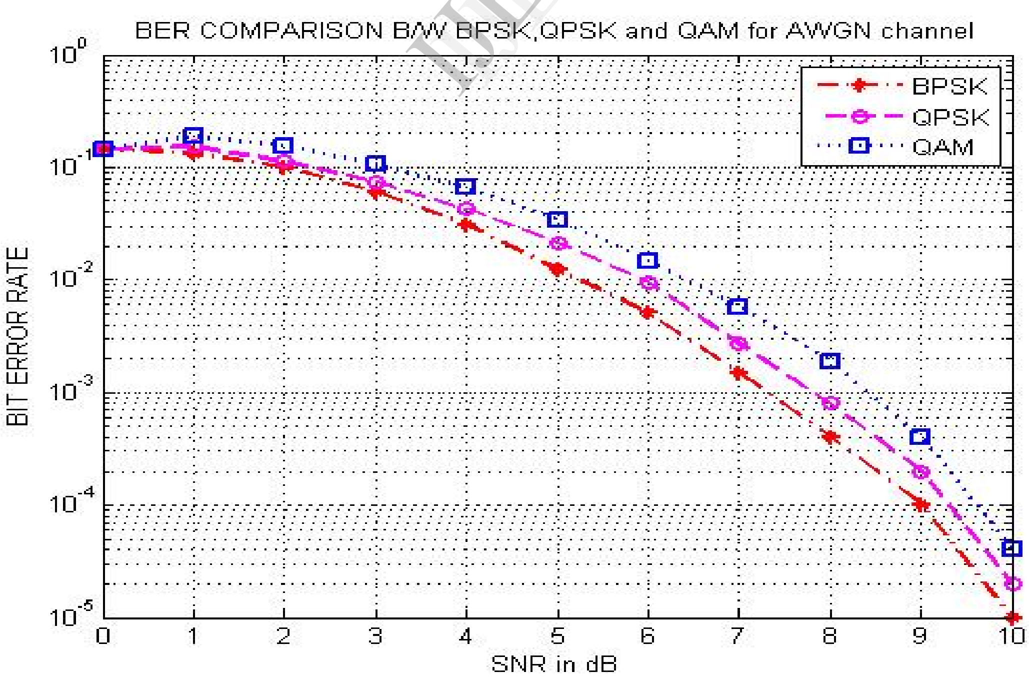

Fig. 7.BER Comparison between BPSK, QPSK, and QAM forAWGN channel.

Figure 7 shows the comparison of different modulation techniques say BPSK, QPSK, and QAM for AWGN channel. It can be seen that here also BPSK has least BER and QAM has maximum BER.From figure 6 and 7 it can be extracted that bit error rate performance of OFDM system is better in case of AWGN channel and under BPSK modulation technique.The effects of different modulation techniques under AWGN and Rayleigh fading channels were simulated in Mat Lab and it can be seen that in Rayleigh fading channel, the signal is more prone to errors because of fading.

7.CONCLUSIONS

OFDM is a multicarrier system and very effective in today's high speed data transmission. OFDM improves the channel conditions, reduces ISI and removes ICI. Also it allows multipath transmission.The simulation results show that fading reduces channel capacity. And the channel capacity of AWGN channel is better than Fading channels. Also with increase in spectral efficiency and SNR channel capacity also increases. Also the OFDM system performance is studied under different channels and modulation techniques. It is shown that BER performance of OFDM system for AWGN channel is better than Rayleigh channel and under BPSK modulation technique.

REFERANCES

[1]De CauasnonT., Monnier R., Raulf J.B. "OFDM for digital TV broadcasting, signal processing" (Elsevier), 39(1994) 1-32.

[2] H. Aoki, M. Konishi, F. Takchata, "Theoretical deviation of bit error rate in OFDM system with carrier frequency offset", Technical report of IEICE, SAT 98-95, Feb. 1999.

[3]Jonathan Stott. "The how and why COFDM", EBU: EBU Technical Review 278(winter 1998).

[4] P.H. Moose, "A technique for orthogonal frequency division multiplexing frequency offset corrections", IEEE Transmission communication. Vol.42, no.30,pp2908-2914, Oct.1994.

[5] R.G. Gallagar, "Information Theory and Reliable Communication". New York: Wiley, 1968.

[6] Shankar Jha, Uma et al.,"OFDM towards Fixed and Mobile Broadband Wireless Access'', Book (2007).

[7] S. Kasturia, J.T. Aslanis, and J.M. Cioffi, "Vector coding for partial response channels", IEEE Trans. Inform. Theory, Vol. 36, pp. 741-762, July, 1990.

[8] T.S. Rappaport, "Wireless Communication", Prentice Hall, 2009

[9] Yun Hee Kin, Iickho Song, Hong Gil Kim, "Performance Analysis of a coded OFDM system in time-varying multipath Rayleigh fading channels", IEEE, Vol-48, No.-5, Sep. 1999.

[10] Z. Wang and G.B. Giannakis, "Wireless multicarrier communication", IEEE Signal processing Mag., pp. 29-48, May. 2000.

IJERT