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Performance Analysis of an OFDM System for Different channel Models

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Abstract- In today's world depending on the requirements in the wireless communication, a system which provides high capacity and high performance and yields lower bit error rate (BER) value is preferred. Orthogonal frequency division multiplexing (OFDM) technique provides high spectral efficiency and transmits data using a number of subcarriers which are dependent on the principle of orthogonality. In this paper, the effect of various fading channels on BER is analyzed which gives the performance of OFDM system and the Doppler Effect on the Rayleigh fading channel is taken into account. Bit error rate among the considered fading channels is observed. With the help of MATLAB, the performance of the system is analyzed and the results are imparted.
Keywords: FFT based OFDM, BER, QAM, AWGN channel, Rayleigh channel, and Rician fading channel.

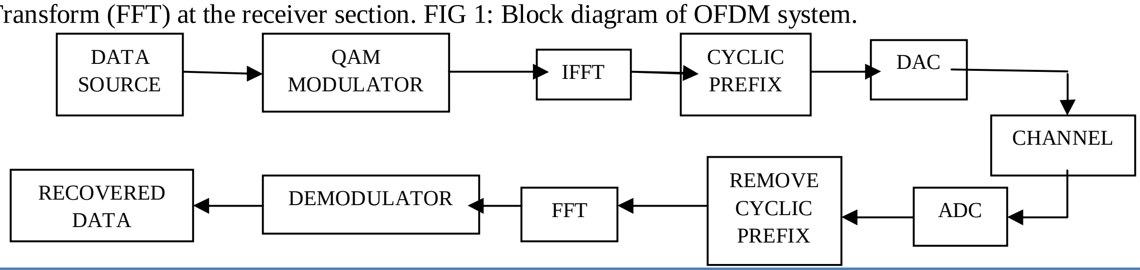
I. INTRODUCTION

The multiplexing technique which offers high resistance to the fading channel environment and has high data transmission capability and high bandwidth efficiency is the OFDM technique. By using the principle of orthogonality the use of bandwidth can be reduced and the inter carrier interference (ICI) between the subcarriers is reduced. In an OFDM system, FFT and IFFT are used to generate the signal. In the concept of OFDM system, the total bandwidth available is divided in to N symbols and are modulated and sent over N subcarrier channels which are orthogonal. These carriers may undergo inter symbol interference (ISI) and degrades the OFDM system performance. The means of dealing the ISI effect is to add the guard interval between the consecutive OFDM symbols. The methods of adding the guard interval is discussed in the later sections.

In wireless channels the phenomenon called 'fading' which is the variation of signal amplitude over frequency and time. The common source of signal degradation is fading which is characterized as a disturbance which is non-additive in the wireless channel. Fading can also be due to multipath propagation. The radio wave signal propagated from the transmitter reaches the receiver passing through various obstacles resulting in a faded signal. This paper is organized as: section II describes the OFDM system. In section III bit error rate (BER) is explained. Section IV deals with the modulation techniques used. Section V explains about fading and multipath. In section VI Doppler shift effects are explained. Section VII consists of the simulation results followed by section VIII consisting of conclusion to summarize this paper.

II. OFDM SYSTEM USING FFT

In the concept of OFDM the data to be transmitted is spreaded over a large number of carriers which are further modulated. By choosing the frequency spacing between them the orthogonality between the carriers is achieved. When compared to the Frequency Division Multiplexing the overlapping of the carriers in OFDM is allowed as the property of orthogonality ensures the separation of the subcarriers at the receiver with a better spectral efficiency and also avoids the use of a band pass filter. The symbols transmitted in the OFDM system are a set of complex numbers. As these complex numbers which are in frequency domain should be converted in to time domain. This conversion is achieved by Inverse Fast Fourier Transform (IFFT) at transmitter section and Fast Fourier Transform (FFT) at the receiver section. FIG 1: Block diagram of OFDM system.



To reduce the inter carrier interference and to avoid the signal amplitude reduction guard interval is added. The guard interval of OFDM is inserted in two ways. First is the cyclic extension in the OFDM symbol with cyclic prefix or cyclic suffix. Zero padding (ZP) is the second technique which pads the guard interval with zeros. The total time period of the symbol is the sum of the time period of the subcarrier and the time period of the guard interval.

III. BIT ERROR RATE

It is the key parameter system used for accessing the system for transfer of digital data from a source to a destination. It is used to find out the rate of error occurring in a transmission system i.e., it determines how many of the received bits are in error.

$$\text{BER} = \frac{\text{number of bits in error}}{\text{total number of bits transmitted}}$$

The energy per bit can be increased by using higher power transmission but it has an drawback that it causes interference with other systems. A higher bit rate decreases the energy per bit at the same time increases the capacity which is an important parameter for a system. Among these optimizing the E_b/N_o is a balancing factor. Therefore the bit error ratio is a figure of merit parameter in a digital communication system.

SNR is the ratio of the signal strength of the received signal and the noise strength over the operating frequency range. SNR is inversely related to BER i.e., high SNR causes low BER. It is not easy to determine the relation between SNR and BER in the multi channel environment. SNR is used to evaluate the performance of an communication system which is measured in decibels and is given by

$$\text{SNR} = 10 \log_{10}\left(\frac{\textit{signal power}}{\textit{noise power}}\right)$$

E_b/No is a normalized signal to noise ratio known as SNR per bit. This parameter is considered whenever the BER performance for different modulation schemes is considered without taking the bandwidth in to account.

In this paper the results are imparted in terms of BER on the performance of the wireless channels namely Rayleigh, Rician and the additive white Gaussian channel environments.

IV. MODULATION TECHNIQUES

Using the different modulation schemes we can transform digital signals into waveforms that are compatible with the communications channel. The different types of modulation are Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM).

A. QAM Modulation

QAM modulation is a combination of both ASK and FSK. The signal is modulated by the amplitude and phase variations of the carrier. It has an I and Q components in the modulated signal. Using the quadrature amplitude modulation the bit error rate can be decreased without any increase in the bandwidth of the channel. 64 QAM modulation has 64 levels i.e., 2^6=64 with each symbol representing six bits. Using higher levels of QAM increases the performance of the system.

V. FADING AND MULTIPATH

In wireless mobile channels the RF signal transmitted undergoes under fading distortion and signal dispersion. The transmitted signal reaches the receiver through different paths due to reflectors and obstacles termed as multipath reaches the receiving antenna in two or more different path propagation.(i.e.,) Multipath propagation occurs due to both the non line of sight (NLOS) and line of sight (LOS) paths. Due to the different multipath propagation lengths the signal received at the receiver has time delay and amplitude and phase fluctuations which reduce the signal strength at the receiver. This fluctuation in the signal amplitude leads to multipath fading. The channel which has different fading phenomenon during the signal transmission is known as a fading channel. Basically fading can be classified in to two different types

- Large scale fading
- Small scale fading

The different types of small scale fading models are Rayleigh fading, Rician fading, and additive Gaussian model.

A. Rayleigh Fading Channel

The most common fading model is the Rayleigh Fading model which occurs due to the objects in the environment that scatter the

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radio signal before it reaches the receiver. Rayleigh fading results when there is a non line of sight component as the dominant component between the transmitter and the receiver. Rayleigh fading is also called as small scale fading because if the reflective paths are more in number and there is no line of sight component, then the Rayleigh distribution is modeled by the envelope of the channel response.
A Rayleigh PDF is given by)

$$P(r) = \frac{r}{\sigma 2}\exp\left(-\frac{r2}{\sigma 2}\right) \qquad \text{for } 0 \le r \le \infty$$

$$P(r) = 0 \qquad \text{for } r < 0$$

Where r is the envelope amplitude of the signal received and σ gives the RMS value of the signal voltage before envelope detection at the receiver. Rayleigh fading component is also called as diffuse or scatter component.

B. Rician fading channel

In Rician fading channel a dominant line of sight component is present along with the multipath components. Specular component is considered as line of sight component and scatter component is considered as the multipath component. The amplitude distribution of the scatter component will have zero-mean value whereas the specular component will have non-zero mean value.
Rician fading is defined using the below two parameters. They are

1) *Rice factor (K):* The ratio of power of specular component to the power of scatter component is called Rice factor.
2) *Scaling factor (Ω):* It is the total power from both paths and acts as a scaling factor to the distribution.

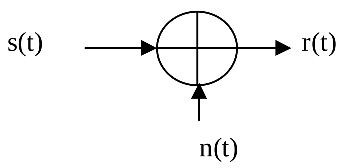
For a Rician fading, the K-factor is typically between 1 and 10. If there is a K-factor of 0 then it corresponds to Rayleigh fading.

C. AWGN Channel

The most used channel in the communications is the AWGN channel. AWGN channel is a combination of white or Johnson noise with Gaussian distribution. The assumptions are considered as the noise is additive noise and the samples taken have Gaussian distribution.
The mathematical expression of the received signal is given by

$$r(t) = s(t) + n(t)$$

Where r (t) is the received signal
s (t) is the transmitted signal
n (t) is the noise signal



The channel capacity of AWGN channel is given by

$$C = \frac{1}{2}\log\left(1+\frac{P}{N}\right)$$

VI. DOPPLER SHIFT

Doppler shift occurs due to the change in position of the transmitter or the receiver which causes frequency shift in the signal. Depending on the change of velocity the signals undergo different Doppler shifts there by undergoing different phase shifts. Doppler spread is referred to as the width of Doppler power spectrum. As the Doppler frequency increases the system performance decreases.
Doppler spectrum bandwidth is given by

$$B_d = 2f_m$$

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f_m is the maximum Doppler shift.

VII. SIMULATION RESULTS

The simulation is carried out using MATLAB and bit error rate (BER) is calculated. The model is carried on Rayleigh, AWGN and Rician fading channel. As the transmitter is in motion the signals reached at the receiver undergo Doppler Effect. The performance of the FFT base OFDM system is compared among all the three channels used in the implementation and the graphical results are shown.

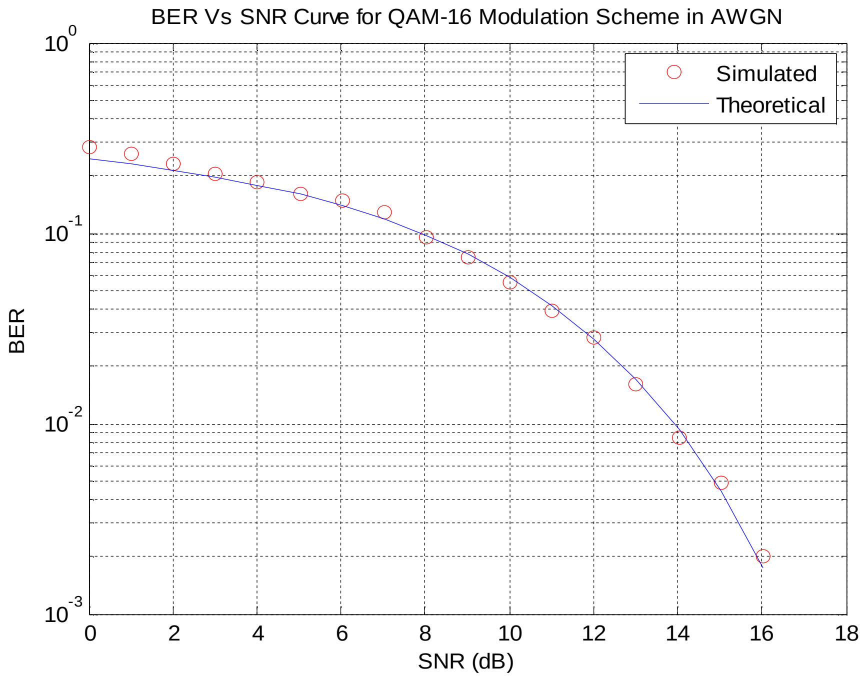

Fig 2: Plot of BER for 16-QAM MODULATION

From the figure 2 we observe that as the signal to noise ratio (SNR) is increasing the value of bit error rate (BER) decreases linearly.

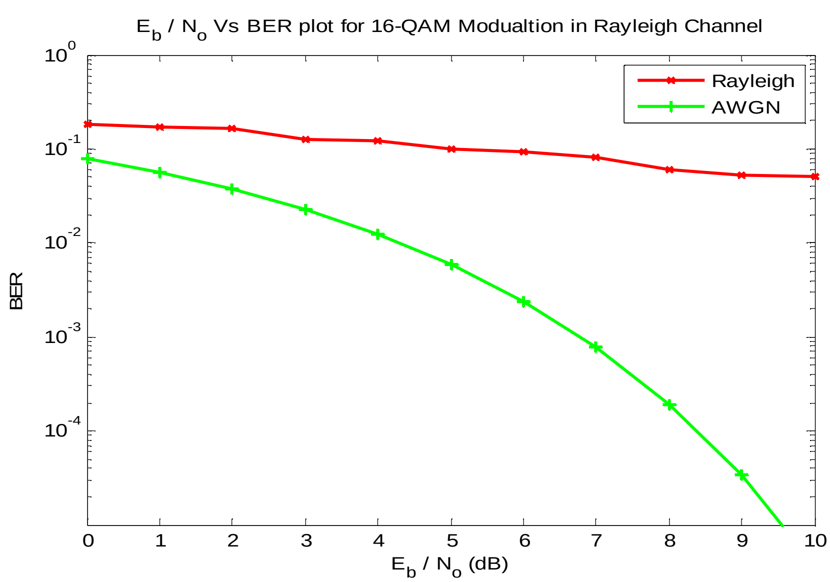

Fig 3: performance of BER on rayleigh and AWGN channel.

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The plot shown in the figure 3 shows the comparison between the Rayleigh channel and the additive white Gaussian noise (AWGN) channel.

Depending on the motion of the transmiter and the receiver the doppler frequency is calculated. As the doppler frequency increases the channel amplitude varies significantly. As the doppler frequency increases the systems performance degrades.

From figure 4 we can observe that variations in the amplitude of the received signal doesnot hav a strong effect because the dopplerfrequency is '0' Hz

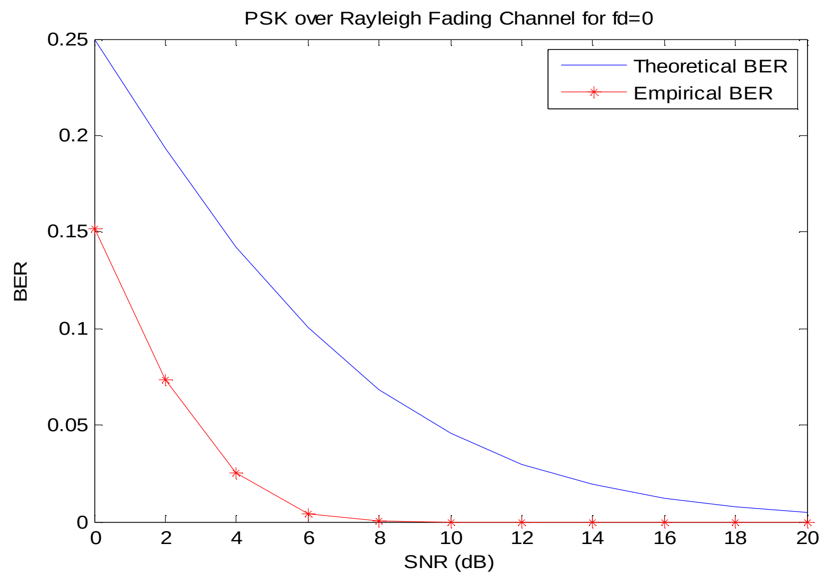

Fig 4: BER for a Doppler frequency of 0 Hz.

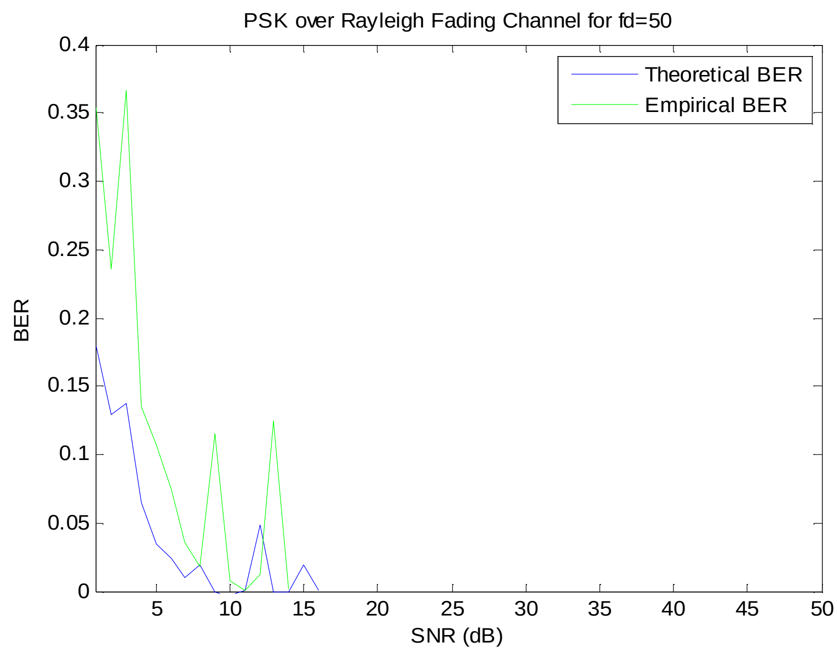

Fig 5 : BER for a Doppler frequency of 50 Hz.

Figure 5 and 6 show that as the doppler frequency is increasing from 50 Hz to 100 Hz the distortions in the signal received increases simultaneously. As the doppler frequency increases the SNR value decreases which is not a good feature for an communication system.

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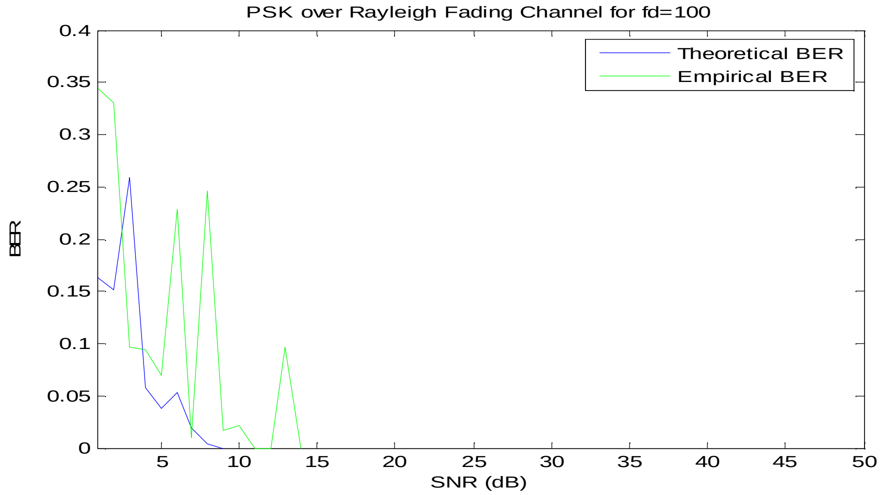

Fig 6 : BER for a Doppler frequency of 100 Hz

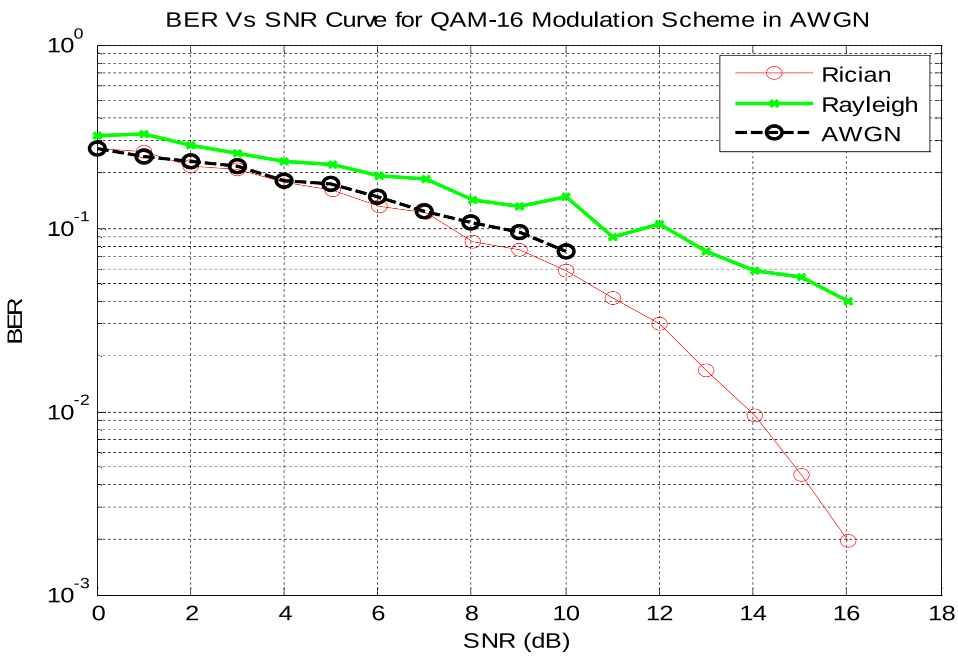

Fig 7: BER comparision of the channels.

From figure 7 we observe that performance is compared in terms of BER using 16 QAM modulation.

VIII. CONCLUSION

In day to day applications the performance of the system plays a crucial role. BER and SNR are the major parameters which are to be considered in the development of the system. For an high performance system the bit error rate and the doppler effect are to be considered. The main criteria of this implementation is to compare the BER for different channels using 16 QAM modulation. The effect of doppler frequency on the rayleigh fading channel is observed. It is observed that from the comparison of all the three channels used in the system the rician channel provides less BER than the other two channels. The performance of the system for the bit error parameter is investigated for different channel models.

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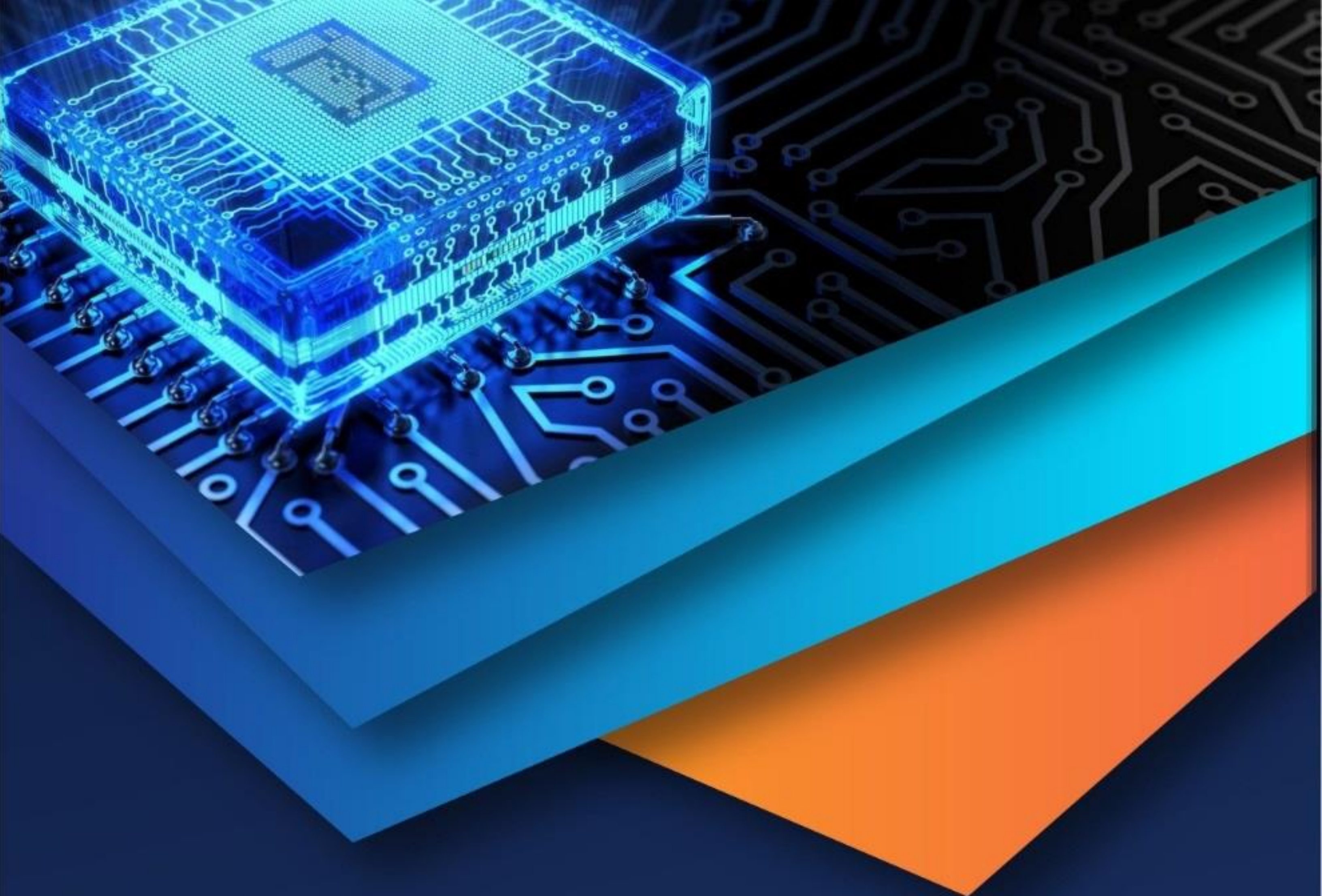

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