iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** X **Month of publication:** October 2016

DOI:

www.ijraset.com
IC Value: 13.98

Volume 4 Issue X, October 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

BER analysis to mitigate PAPR in a turbo coded OFDM System

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Abstract**-** ***This The peak to average power ratio (PAPR) of a transmitted signal is one of the main bottleneck problem in wideband multi-carrier systems that uses orthogonal frequency division multiplexing (OFDM) technique and mitigating the effects of PAPR on such system is critical. In this paper, different techniques to reduce PAPR are reviewed and analyzed. Also the Bit error rate is analyzed for an OFDM system by adding turbo codes which is one of the popularly used forward error correction code (FEC) along with PAPR reduction techniques. Simulation is done considering the additive white Gaussian noise (AWGN) and Rayleigh channels. Simulation results show the improvement in system throughput and error rate by using the PAPR reduction techniques in concatenation with a turbo coding.***

Keywords— OFDM, Channel coding, Turbo codes, PAPR

I. INTRODUCTION

This OFDM is a modulation technique where multiple low data rate carriers are combined by a transmitter to form a composite high data rate transmission. Digital signal processing makes OFDM possible. To implement the multiple carrier scheme using a bank of parallel modulators would not be very efficient in analog hardware. However, in the digital domain, multi-carrier modulation can be done efficiently with currently available DSP hardware and software. Not only can it be done, but it can also be made very flexible and programmable. This allows OFDM to make maximum use of available bandwidth and to be able to adapt to changing system requirements.

Each carrier in an OFDM system is a sinusoid with a frequency that is an integer multiple of a base or fundamental sinusoid frequency. Therefore, each carrier is like a Fourier series component of the composite signal. In fact, it will be shown later that an OFDM signal is created in the frequency domain, and then transformed into the time domain via the Fast Fourier Transform (FFT).

A. Peak Average Power Ratio (PAPR)

The phase of different subcarriers add up to form large peaks, an important complication comes in OFDM systems. This problem is called Peak Average Power Ratio (PAPR) and it is defined for each OFDM signal on a time interval [n, n+Ts] by the following formula:

For continuous signals:

$$\chi_n = \frac{\max\limits_{t\in[n,n+T_s]} |x(t)|^2}{\int_n^{n+t_s} |x^2(t)|\,dt} \quad \ldots\ldots\ldots\ldots(1)$$

For Discrete signals:

$$\chi_n = \frac{\max\limits_{k} |x_n[k]|^2}{E\{|x_n[k]|^2\}} \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

In OFDM systems PAPR can have very high values for certain input sets of sample $(X_n[k])$ and overload non-linear characteristics of systems, causing inter-modulations among different carriers and undesired out-of-band radiation. Another main drawback of PAPR can be seen as quantization noise domination towards the performance of system. This domination can be excited by avoiding the clipping effect of the maximum level of the Digital to Analog Converter (DAC) that is set too high. Various techniques are proposed to reduce PAPR in OFDM signals, but that reduction is not obvious because PAPR and SNR are closely linked. We will not expound those techniques in this paper, they can be found in reference.

B. Effect of PAPR in OFDM signals

When transmitted signals have high PAPRs, amplifiers may produce "clipping". In some way, clipping can be regarded as peaks of the input signal being simply cut-off by amplifiers. Consequences of clipping are out-of-band radiation and inter symbol interference between subcarriers. In order to avoid these undesired effects that reduce OFDM performances, one has either to use amplifiers with dynamic range, or try to reduce PAPR. The first alternative is expensive, the second one is more often used.

II. TURBO CODED OFDM

A. Proposed System

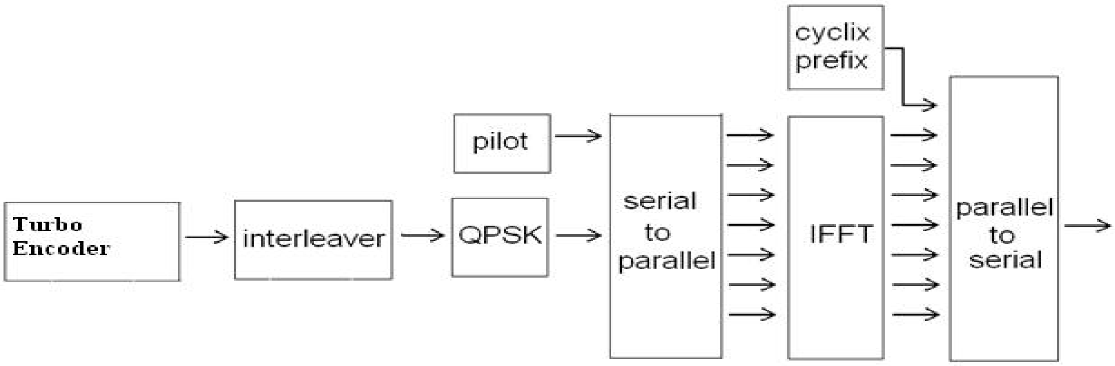

Fig 1: Turbo coded OFDM System- Transmitter Part

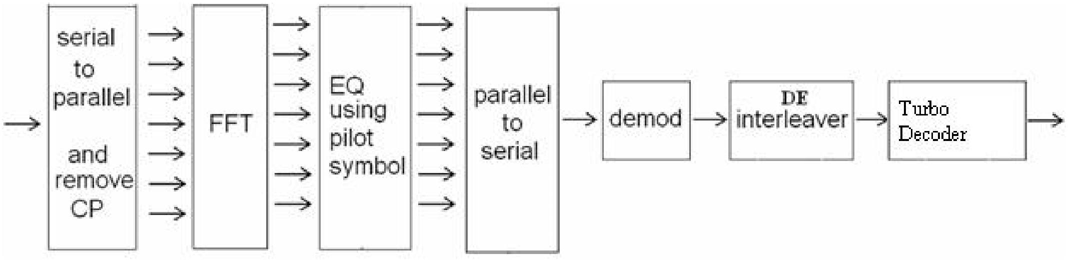

Fig 2: Turbo coded OFDM System- Receiver Part

B. Turbo codes

A block diagram of a turbo decoder is shown in Figure 3. The encoder for a turbo code is a parallel concatenated convolutional code. The binary input data sequence is represented by d_k=(d1,….d_N) the input sequence is passed into the input of a convolutional encoder], and a coded bit stream, ENC1 is generated. The data sequence is then interleaved. That is, the bits are loaded into a matrix and read out in a way so as to spread the positions of the input bits. The bits are often read out in a pseudo-random manner. The interleaved data sequence is passed to a second convolutional encoder, and a second coded bit stream, ENC2 is generated. The code sequence that is passed to the modulator for transmission is a multiplexed (and possibly punctured) stream consisting of systematic code bits and parity bits from both the first encoder 1and the second encoder 2

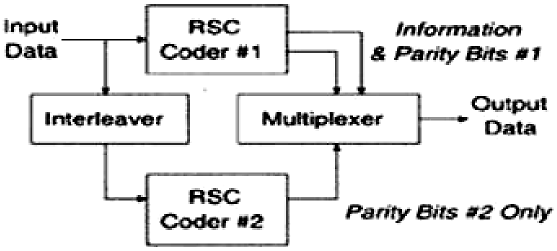

Fig 3: Schematic of a turbo encoder

A block diagram of a turbo decoder is shown in Figure 4. The input to the turbo decoder is a sequence of received code values from the demodulator. The turbo decoder consists of two component decoders to decode. Each of these decoders is a Maximum A Posteriori (MAP) decoder.The output of is a sequence of soft estimates of the transmitted data is called extrinsic data. This information is interleaved, and then passed to the second decoder . This extrinsic data, formed without the aid of parity bits from the first code. This procedure is repeated in a iterative manner. The iterative decoding process adds greatly to the BER performance of turbo codes. The decoding estimates and do not necessarily converge to a correct bit decision. If a set of corrupted code bits form a pair of error sequences that neither of the decoders is able to correct, then and may either diverge, or converge to an incorrect soft value.

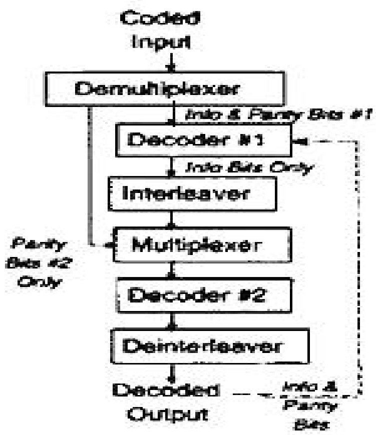

Fig 4: Schematic of a turbo decoder

C. *Fading Environments*

1) *Additive white Gaussian noise (AWGN):* AWGN is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. AWGN channel is considered as an important reference or benchmark model for comparing the performance evaluation of communication systems and modulation formats. However, when the signal travels from transmitter to receive via multiple propagation paths then a practical fading channel model must be used to model the propagation environment. There are some factors affecting fading including multipath propagation, speed of surrounding objects, speed of the mobile, the transmission symbol duration and the transmission bandwidth of the signal.

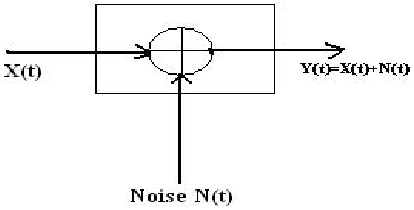

Fig 5: AWGN channel

The theoretical BER for BPSK or QPSK using AWGN channel:

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \quad \text{.........(4)}$$

where,N0 is spectral noise density and Ebis energy per bit.

2) *Rayleigh Fading:* Let the mobile antenna receives a large number (say N) of replicas of same signal. The transmitted signal at frequency ωc reaches the receiver via number of paths. The amplitude and phase of the i th path are ai, andϕi . If there is no direct path or line of sight (LOS) component, the received signal s(t) can be expressed as,

$$s(t) = \sum_{i=1}^{N} a_i \cos(\omega_c t + \phi_i) \quad \text{......(5)}$$

If there is a relative motion between transmitter and receiver the Doppler shift has to be considered. If ω di represents the shift in ith component, the received signal can be expressed as,

$$s(t) = \sum_{i=1}^{N} a_i \cos(\omega_c t + \omega_{di} t + \phi_i) \quad \ldots(6)$$

The phase ϕi is assumed to be uniformly distributed over [0,2π]. If N is large, the in-phase and quadrature components of received signal becomes zero mean Gaussian with standard deviationσ . The probability density function (PDF) of the received signal envelope can be given as ,

$$f(r) = \frac{r}{\sigma^2}\left\{\frac{-r^2}{2\sigma^2}\right\} \quad r \geq 0 \qquad \ldots\ldots\ldots(7)$$

The theoretical BER for BPSK or QPSK using Rayleigh fading channel:

$$P_e = \frac{1}{2} erfc(1 - \sqrt{\frac{E_b/N_0}{E_b/N_0 + 1}}) \qquad \ldots\ldots\ldots\ldots(8)$$

where,N0 is spectral noise density and Eb is energy per bit.

D. PTS Technique

A set of sub-carriers of an OFDM symbol is divided into V non-overlapping sub-blocks [**Error! Reference source not found.**]. Each sub-block undergoes zero-padding by inserting zeroes at those sub-carriers which are already represented in other sub-blocks. All V sub-blocks are transformed into the time-domain by IFFT resulting in V partial transmit sequences denoted by p(k), k=1…V..

The transmit sequence is obtained as a linear combination of PTSs: $\sum_{k=1}^{V} p(k)b(k)$, where b(k) is a rotation factor. The optimization is performed over the rotation factors b(k) for each OFDM symbol. It is shown that four rotation angles ($b(k) \in \{\pm 1 \pm j\}$) is already enough for significant peak power reduction.

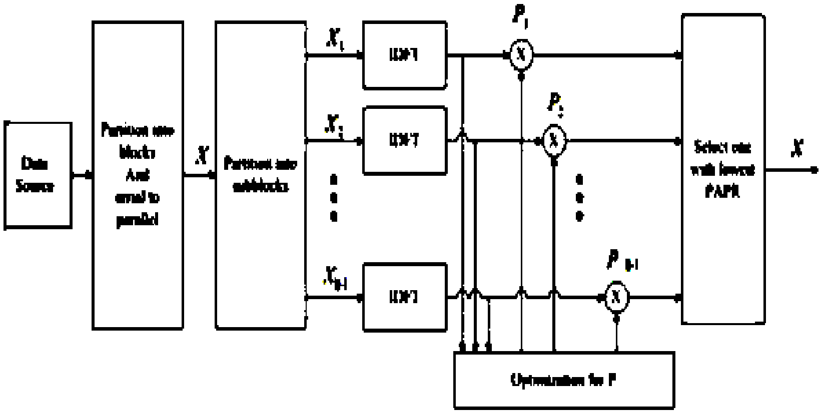

Fig 6:PTS - PAPR reduction technique

III.SIMULATION RESULTS

Simulation shows the peak-to-average power ratio (PAPR) reduction and bit error rate (BER) for the AWGN and Rayleigh fading channel.

In the system, the following specifications are used for the PAPR reduction of OFDM:

Parameters of the simulation: bandwidth is 10 MHz, FFT/IFFT block is 256, and PTS technique.

Two types of modulation techniques i.e., BPSK and QPSK are used in simulations.

Simulation results of BER vs. SNR using BPSK and QPSK modulation techniques through AWGN channel are given below:

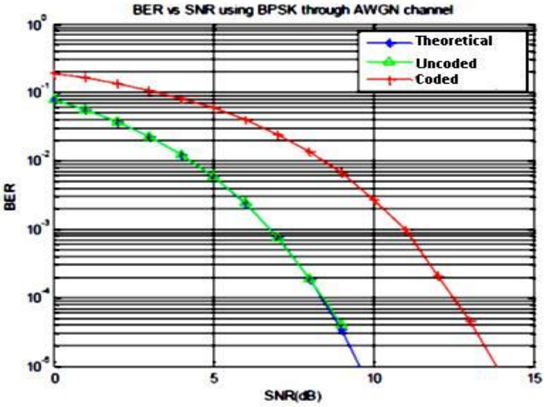

Fig 7: BER Vs SNR using BPSK through AWGN Channel

Theoretical and without coding curves are nearly same while with coding gives better results. The results are given below:
BER= 10^{-3} at SNR ≈ 7 dB for theoretical and without coding.
BER= 10^{-3} at SNR ≈ 11 dB with coding.

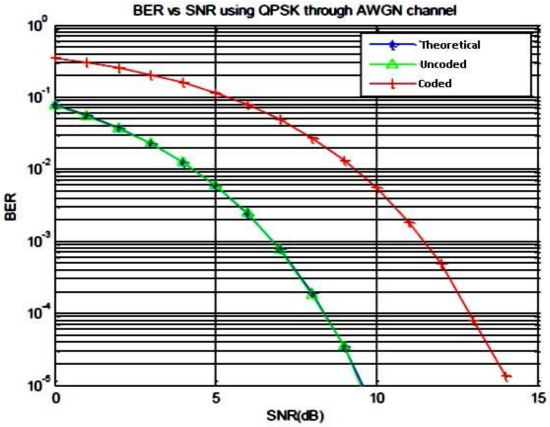

Fig 8: BER Vs SNR using QPSK through AWGN Channel

Theoretical and without coding curves are nearly same while with coding gives better results. The results are given below:
BER= 10^{-3} at SNR ≈ 7 dB for theoretical and without clipping.
BER= 10^{-3} at SNR ≈ 11.5 dB with clipping.

BER calculation for Rayleigh fading channel

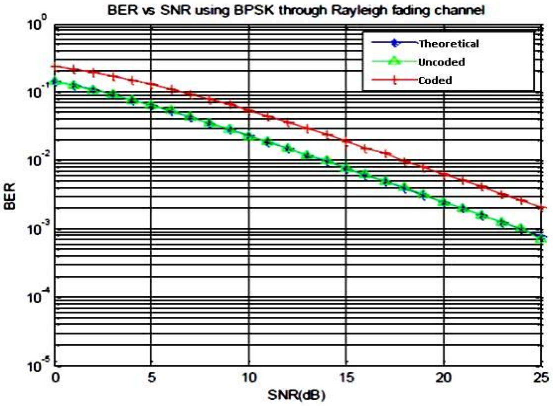

Fig 9: BER Vs SNR using BPSK through Rayleigh Fading Channel

Theoretical and without coding curves are nearly same while with coding gives better results.The results are given below:
BER= 10^{-2} at SNR ≈ 14 dB for theoretical and without coding.
BER= 10^{-2} at SNR ≈ 17.5 dB with coding.

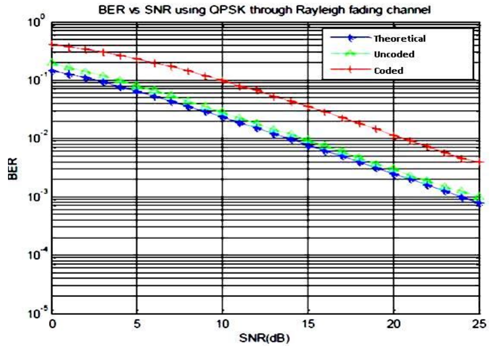

Fig 10: BER Vs SNR using QPSK through Rayleigh Fading Channel

Theoretical and without coding curves are nearly same while with coding gives better results.The results are given below:
BER= 10^{-2} at SNR ≈ 14 dB for theoretical and without coding.
BER= 10^{-2} at SNR ≈ 20 dB with coding
BER calculation for Different channels
Rayleigh fading channel compared to AWGN channel. The results are given below:
BER= 10^{-2} at SNR ≈ 8.5 dB for AWGN channel.
BER= 10^{-2} at SNR ≈ 17.5 dB for Rayleigh fading channel.

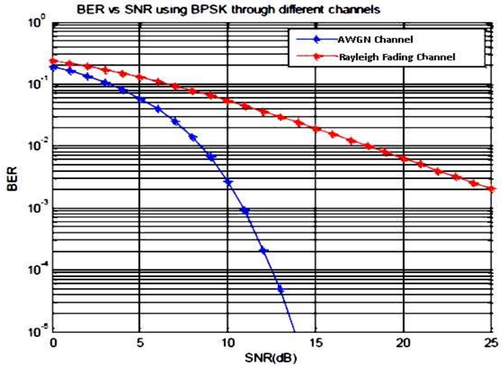

Fig 11: BER Vs SNR using BPSK through different Channels

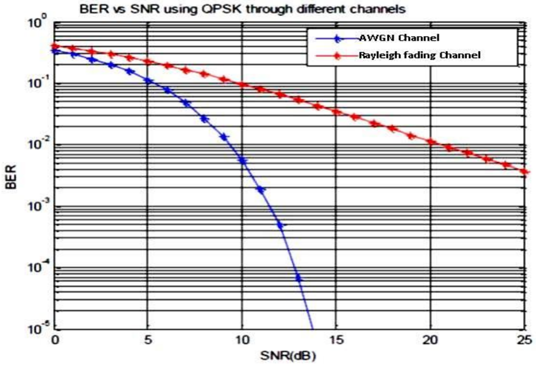

Fig 12: BER Vs SNR using QPSK through different Channels

Rayleigh fading channel is compared to AWGN channel .The results are given below:
BER= 10^{-2} at SNR ≈ 9 dB for AWGN channel.

BER= 10^{-2} at SNR ≈ 20 dB for Rayleigh fading channel.

IV.CONCLUSION

Turbo coded OFDM system has been discussed in this Paper. Peak to average power ratio issue was discussed, showing its effects on the transmitted signal. There were many reduction techniques presented to solve high peak to average power ratio such as, Signal distortion techniques, Coding Schemes, and Symbol-scrambling techniques. Partial Transmit Sequence (PTS) technique was one of the main focus of this paper. This paper also showed the simulation results of Coded OFDM symbol with and without PTS. The simulation results indicated that large PAPR reduction is possible with PTS technique, and showed by concatenating the turbo codes along with PAPR reduction techniques, SNR improvement of 3.5dB is achieved in case of AWGN channel and SNR improvement of 6dB and 3.5dB is achieved in case of Rayleigh fading channel with BPSK and QPSK modulation.

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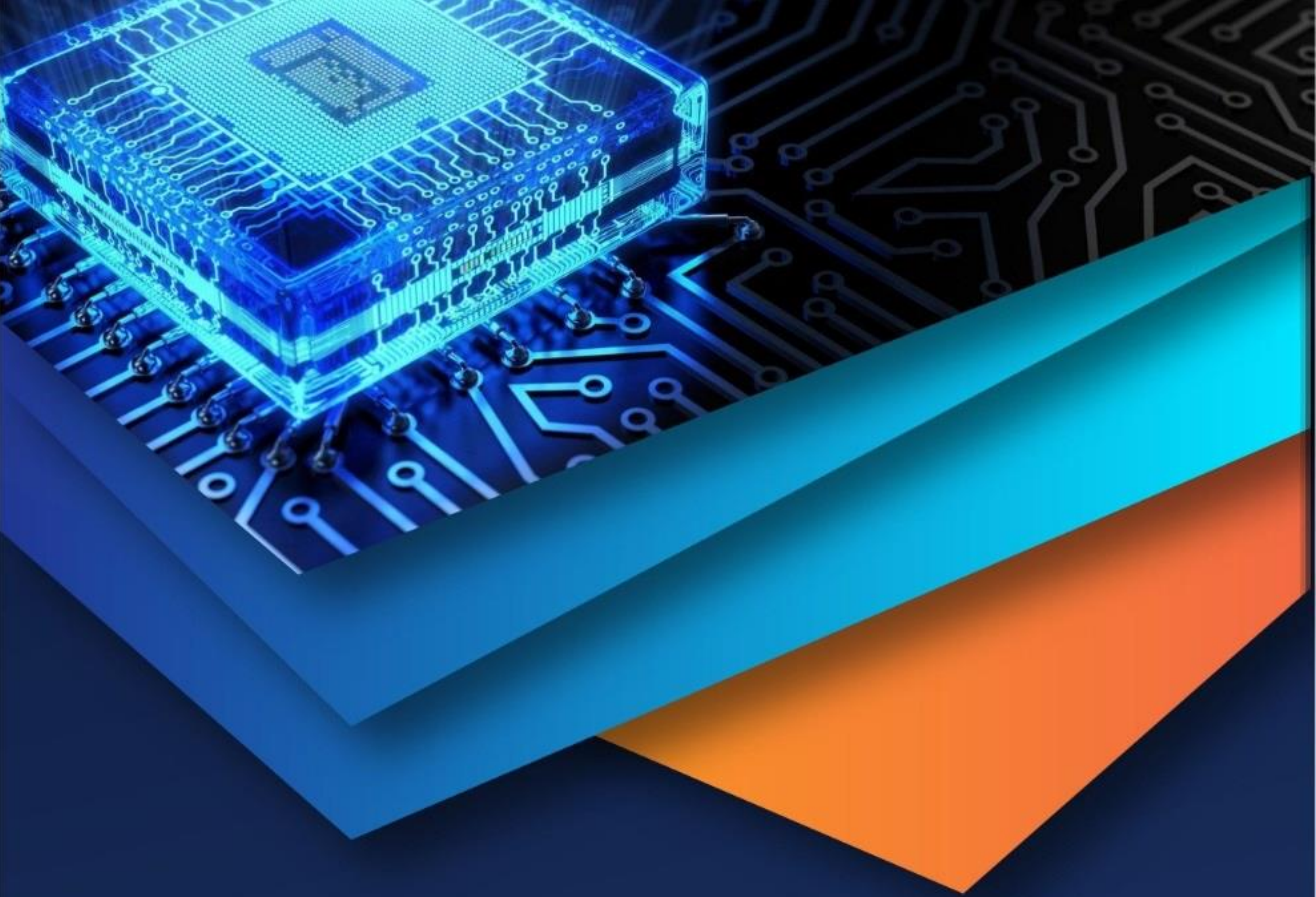

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