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Iterative Receiver Based on Flip-OFDM in Optical Wireless Communication

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Abstract: To assure nonnegative signals in optical wireless communication (OWC) system, flipped orthogonal frequency division multiplexing (Flip-OFDM) transmits the positive and the negative parts of the signal over two consecutive OFDM sub-frames (positive sub frame and negative sub-frame, individually). As in the conventional receiver for Flip-OFDM recovers the data by subtracting the negative part of the signal from the positive one. As the signal analysis shows that the information will be transmitted by both the OFDM sub-frames. But in the conventional receiver there is a loss of data. To overcome this problem an iterative receiver is then proposed to improve the performance of Flip-OFDM by exploiting the signals in both the OFDM sub-frames. Simulation results demonstrate that the proposed iterative receiver provides significant signal to noise ratio (SNR) gain over the conventional receiver.

Index Terms: Optical wireless communication (OWC), Orthogonal frequency division multiplexing (OFDM), Flip-OFDM, Iterative receiver.

I. INTRODUCTION

With the widespread organization of light-emitting diodes (LEDs), optical wireless communication (OWC) has attracted an increasing interest in educated community and industry recently [3].Due to its distinct advantages such as rich range assets and high correspondence security, OWC has been anticipated to be an attractive alternative to radio frequency (RF) systems, especially in indoor scenarios. In addition the joining of illumination and communication makes OWC a standout amongst the most vital green technologies [4].

In order to achieve high data rate and to minimize or decrease the inter-symbol interference (ISI), orthogonal frequency division multiplexing (OFDM) is used in OWC [5]–[7]. Since intensity modulation and direct detection (IM/DD) technique is commonly used in OWC for transmission of data, the transmitted signals must be real and positive. Real time-domain signals can be obtained by applying Hermitian symmetry on the OFDM subcarriers. Moreover, to deal with the issue of bipolarity in OFDM signals, a few OFDM schemes have been proposed for OWC. For example, direct current biased optical OFDM (DCO-OFDM) [1]-[8],asymmetrically clipped optical OFDM (ACO- OFDM) [9] and pulse amplitude modulated discrete multitone (PAM-DMT) [10]. DCO-OFDM adds DC bias to the OFDM symbols, which rises power dissipation of the signal significantly. There is no any DC biasing in ACO-OFDM and PAM-DMT only clipping operation is there, but the spectral efficiency is half of DCO-OFDM .The authors in [11] proposed a novel OFDM technique known as Flip-OFDM in which both the positive and negative parts of the signal are separately transmitted over two consecutive OFDM subframes. In [12], We can see how we are going to replace the DCO-OFDM with nearly equal or more spectral efficiency using Flip-OFDM in OWC.

In the conventional receiver the data is recovered by subtracting the negative part of the signal from the positive one [9]. This method is basic and straightforward. it rises the noise variance of the received symbols, making the performance much worse than that of bipolar OFDM with the same modulation method. To improve the execution of Flip-OFDM, a time-domain noise filtering technique was proposed in [2]-[13] and examined in [14]. Furthermore, the algorithm does not make full use of the signal structures. So iterative receiver is proposed for Flip-OFDM by fully exploiting the signals in both the subframes. By MATLAB simulation we can see that the proposed receiver is better than the conventional receivers.

II. SYSTEM MODEL

A. Optical Wireless Channel

applications, an infrared emitter i.e. LED is used as optical transmitter to generate optical signal x(t). This signal represents the intensity of the optical carrier transmitted over the optical wireless channel.

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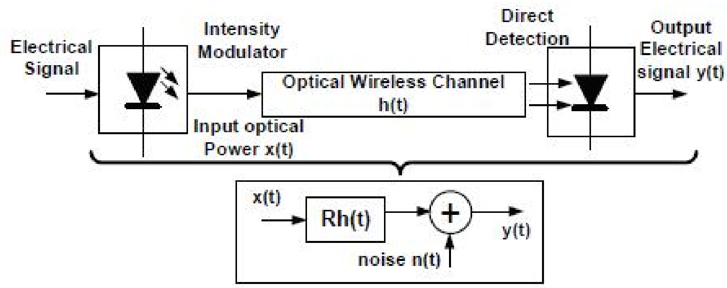

Fig. 1. Equivalent based band channel model for IM/DD optical wireless channels

At receiver end, a photodetector collects the optical signals and convert it into an electrical signal y(t). As shown in Fig. 1. Given the channel impulse response and noise component h(t) and n(t) respectively, the received electrical signal can be given as,

$$y(t) = x(t) * h(t) + n(t) \qquad (1)$$

Where $*$ denotes convolution.

B. Flip-OFDM

Fig. 2 shows a block diagram of a Flip-OFDM transmitter. Let Xn be the transmitted QAM symbol in the n-th OFDM subcarrier. The output of Inverse Fast Fourier Transform (IFFT) operation at the k-th time instant is given by

$$x(\mathrm{k}) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \exp\left(\frac{j2\pi nk}{N}\right) \qquad (2)$$

Where, N is the IFFT size. If the symbols Xn contained in each OFDM subcarrier are independent, the time domain signal x(k) produced by the IFFT operation is complex. This can be avoided by imposing the Hermitian symmetry property, i.e,

$$X_n = X_{N-n}^* \quad n = 0, 1, 2...., N/2 - 1 \qquad (3)$$

Where, * denotes complex conjugation. Hence, half of OFDM subcarriers have to be sacrificed to generate the real time domain signal. The output of IFFT operation is given as,

$$\mathrm{x(k)} = \frac{2}{\sqrt{N}} \sum_{\mathrm{n}=1}^{N/2-1} \mathrm{Re}\left[X(\mathrm{n}) \exp(j2\pi kn/N)\right] \qquad (4)$$
$$\mathrm{k} = 0, 1, \cdots, N-1.$$

Where, Xn represents the QAM symbols. Flip-OFDM uses half of the total OFDM subcarriers to carry information so that the output of IFFT block is a real & bipolar signal x(k) = x+(k) + x−(k), where the positive and negative parts are defined as,

$$x^+(k) = \begin{cases} x(k) & \text{if } x(k) \geq 0 \\ 0 & \text{otherwise} \end{cases}$$
$$x^-(k) = \begin{cases} x(k) & \text{if } x(k) < 0 \\ 0 & \text{otherwise} \end{cases} \qquad (5)$$

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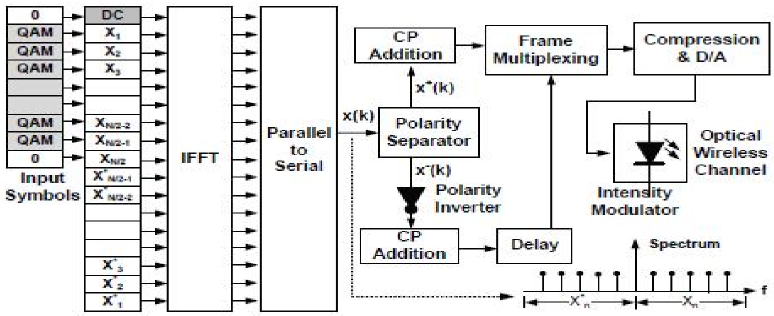

Fig. 2 Block Diagram of OFDM Transmitter

Where, k = 1, 2, ...,N. The positive signal x+(k) is transmitted over the first OFDM sub-frame, while the second OFDM sub-frame is used to carry the flipped (inverted polarity) signal −x−(k). At the Flip-OFDM receiver, the two received sub-frames are used to reconstruct the bipolar OFDM frame as shown in Fig. 2. The cyclic prefixes associated with each OFDM sub-frame are first removed and the original bipolar signal is regenerated as,

$$y(k) = y^{+}(k) - y^{-}(k) \qquad (6)$$

Where, y+(k) and y−(k) represent the respective time samples belonging to first and second sub-frames. Fast Fourier Transform (FFT) operations are performed to recreate the bipolar signal in order detect the transmitted information symbols at the receiver.

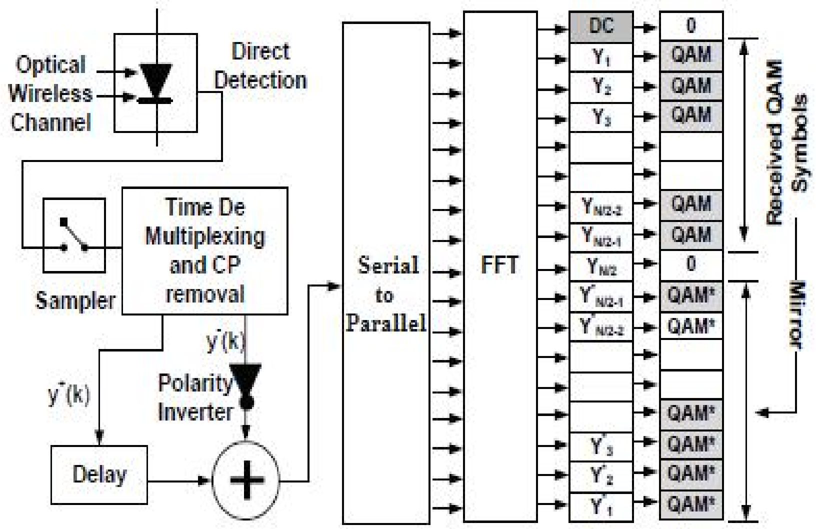

Fig. 3 Block Diagram of OFDM Receiver

III. PROPOSED DESIGN

In this work the OFDM transceiver system is designed with AWGN channel using QAM modulation in MATLAB Simulink

A. Data source

Data source consists of Random Integer Generator and Integer to bit converter. The Random Integer Generator used to generate random uniformly distributed integers in the range of (0 to M-1), where M is the M-ary no. Then Integer to bit converter maps a vector of integer value into the vector of bits.

B. IQ Mapper

It gets the input from the data source and consists of Bit to integer converter which converts digital bits into integer numbers and then IQ mapper modulates the input signal using QAM method.

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C. OFDM modulator

The output of the IQ Mapper is given to multiport selector which selects the rows then the matrix concatenation occurs and the output is given to IFFT, then a cyclic prefix is added before transmitting the signal.

D. AWGN

AWGN Adds white Gaussian noise to the input signal that passes through it. The input signal can be real or complex signal.

E. OFDM Demodulator

this process the receiver, receives the signal and then cyclic prefix is removed after that FFT occurs. Then the process of frame status conversion, removing zero padding occurs and at last pilots are removed.

F. IQ Demapper

Output from the above process is given to IQ Demapper where the conjugation of the signal is taken, then general QAM demodulator is used and then Integer to bit converter is used.

G. Data sink

The output of above process is given to input of data sink i.e. bit to integer converter, from where we can get the desired output. The design of Flip-OFDM and Iterative receiver i.e. OFDM transceiver model in MATLAB Simulink as shown in the figure below.

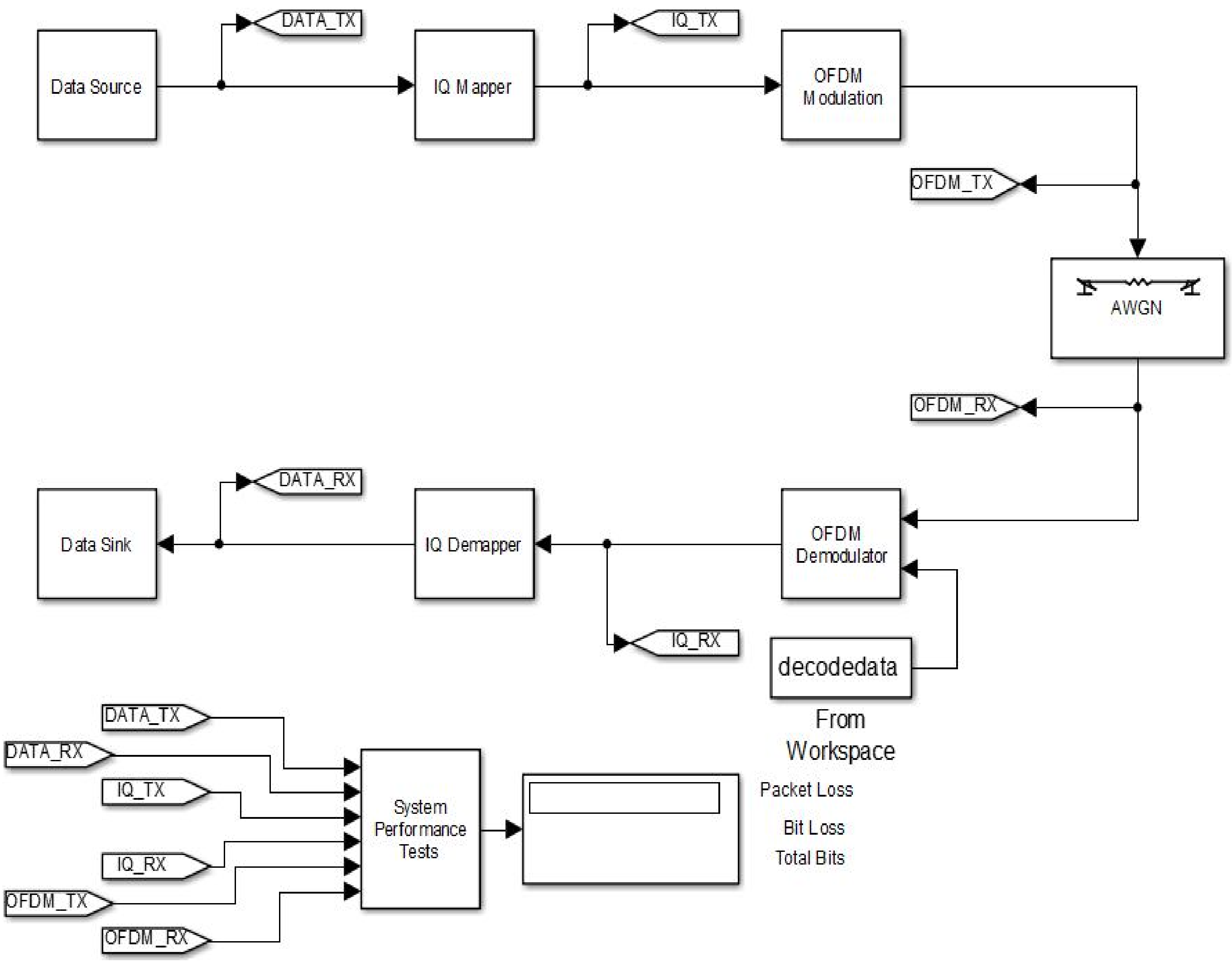

Fig. 4 Design of OFDM Transceiver system model in MATLAB Simulink

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IV. SIMULATION RESULTS

A. BER Vs SNR Curve

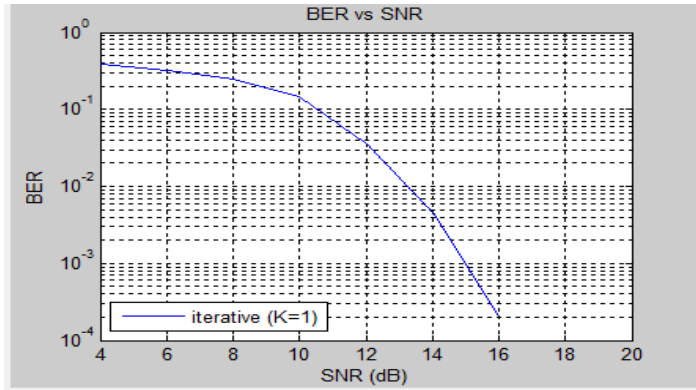

Fig. 5 BER performance of the iterative receiver.

B. In AWGN channel

At T=50000 & SNR=60dB

Total bits= 10000512

Packet loss=0

Bit loss=0

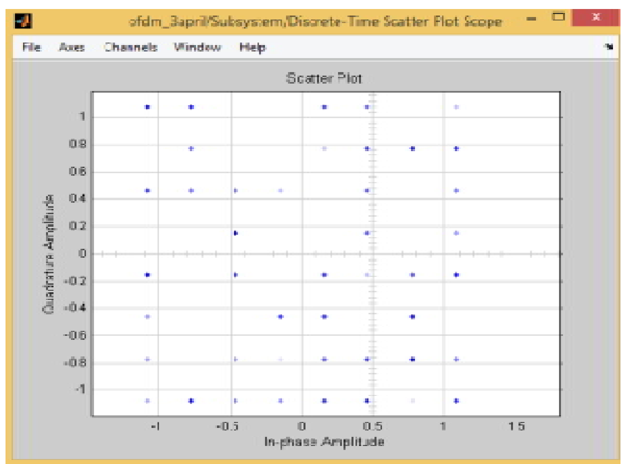

Fig. 5 Scatter Plot of Transmitted Data

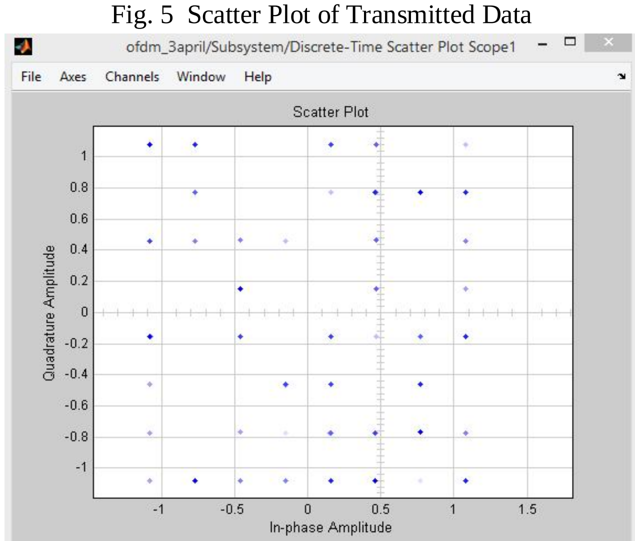

Fig. 6 Scatter Plot of Received Data

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C. In AWGN channel

At T=50000 & SNR=30dB
Total bits=10000512
Packet loss=4.3997747315337e-06
Bit loss=44

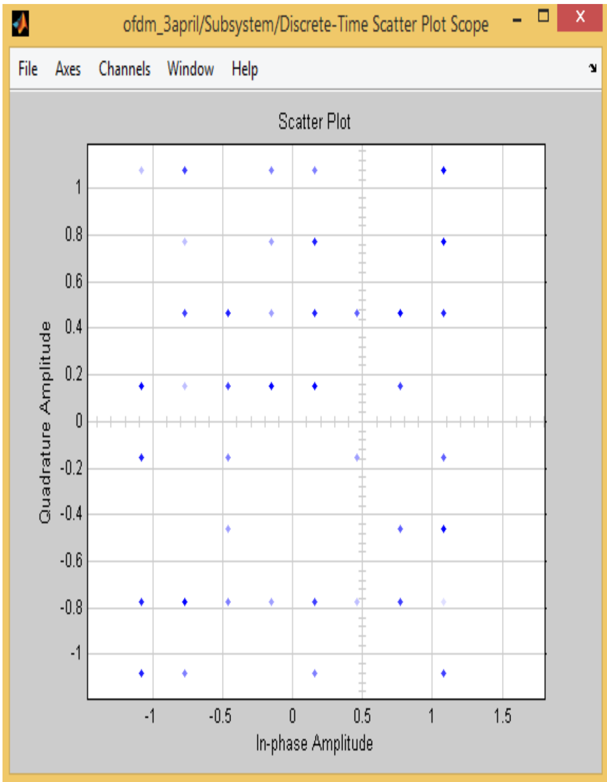

Fig. 7 Scatter Plot of Transmitted Data

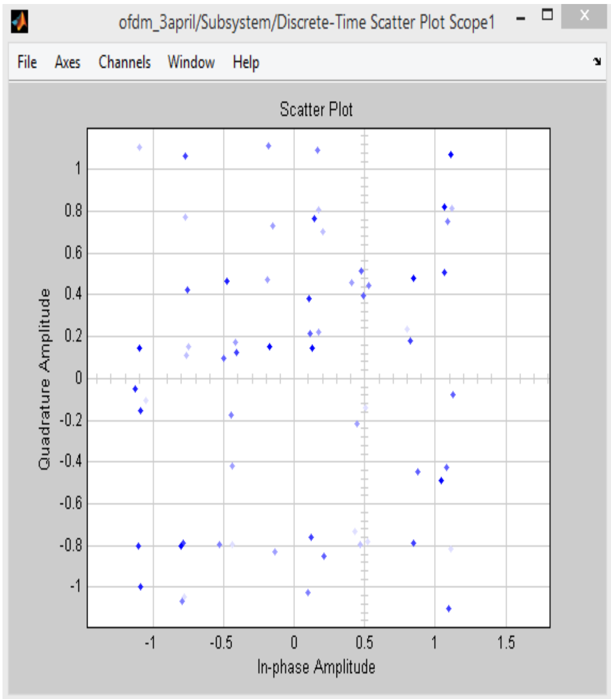

Fig. 8 Scatter Plot of Received Data

V. CONCLUSION

In this paper, an iterative receiver is proposed for Flip-OFDM in IM/DD based on optical wireless communication systems. In order to improve the receiver performance, the iterative receiver obtains the additional diversity gain by exploiting the signals in both the positive and negative sub-fames. The simulation results show that the iterative receiver is better than the conventional receiver.

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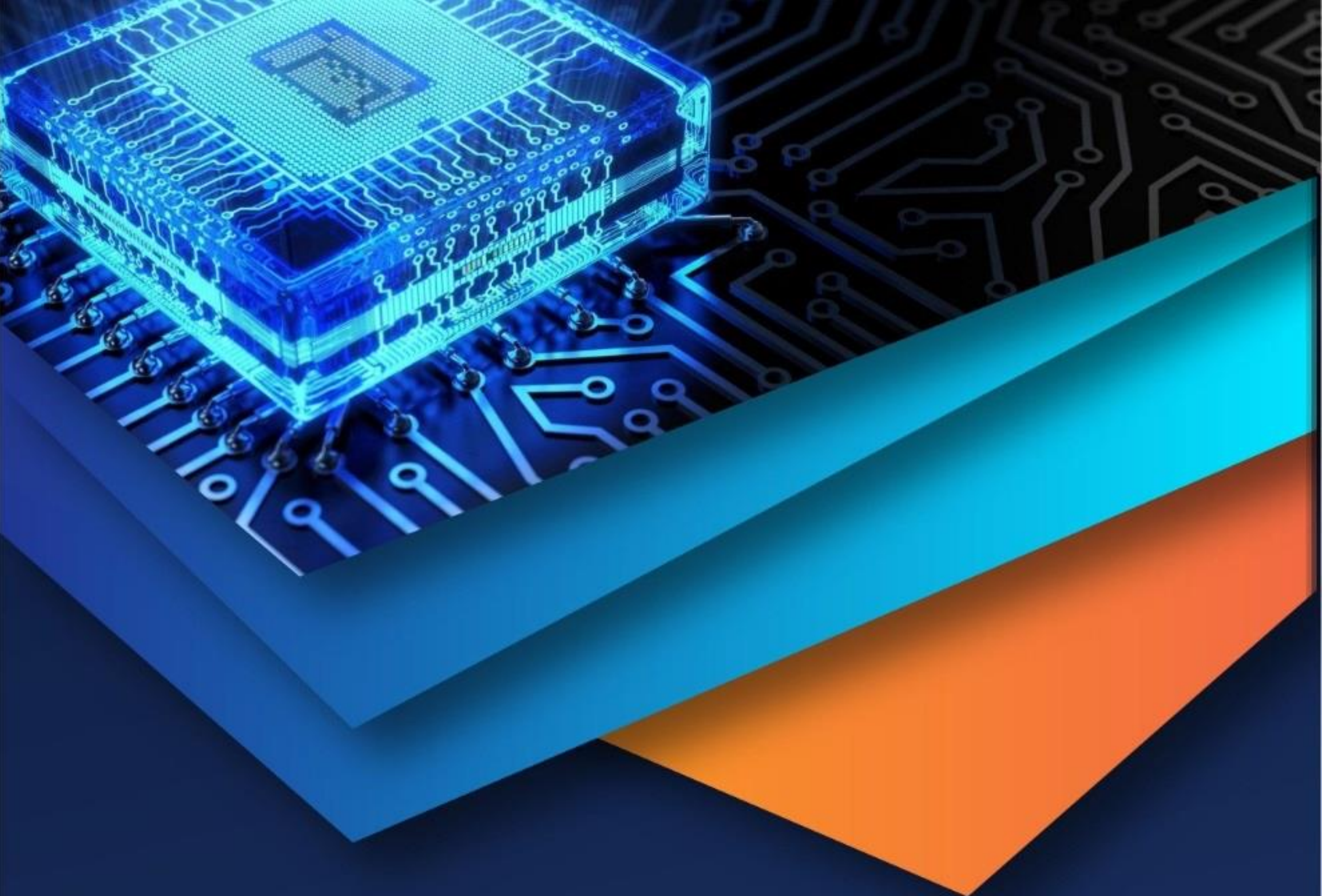

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