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A Novel Power-Efficient Scheme Spectrally and Energy Efficient (SEE) - OFDM for IM/DD Optical Systems

Nimitha N[1], Poovizhi S[2]
R.M.K College of Engineering and Technology,Puduvoyal
Gummidipoondi Taluk, Thiruvallur District, India
[1,2]Assistant Professor, Department of Electronics and Communication Engineering, Anna University

Abstract: Spectrally and energy efficient orthogonal frequency division multiplexing (SEE-OFDM) is an optical OFDM technique based on combining multiple asymmetrically clipped optical OFDM (ACO-OFDM) signals into one OFDM signal. By summing different components together, SEE-OFDM can achieve the same spectral efficiency as DC-biased optical OFDM (DCO-OFDM) without an energy-inefficient DC-bias. This paper introduces multiple methods for decoding a SEE-OFDM symbol and shows that an iterative decoder with hard decisions gives the best performance. Being a multi-component format, different energy allocation amongst the different components of SEE-OFDM is possible. However, equal energy allocation performs 1.5 dB better than unequal energy allocation. A hard-decision, iterative subtraction receiver can further increase performance by another 1.5 dB over soft-decision subtraction and reconstruction receivers. SEE-OFDM consistently performs 3 dB or better and with higher spectral efficiency than ACO-OFDM at the same bit-error-rate (BER). Comparing other combination methods at the same BER, SEE-OFDM performs up to 3 dB better than hybrid asymmetrically clipped optical.

I. INTRODUCTION

Optical wireless systems with intensity modulation direct detection (IM/DD) have been extensively studied in recent decades [1-3]. They can be effective alternatives to radio frequency (RF) wireless systems for indoor high-speed data transmission. Compared to RF communication, Optical wireless communication (OWC) offers unlimited transmission bandwidth and efficient spatial diversity achieved with short carrier wavelengths and alarge area detector [4]. Multipath distortion, especially in an indoor environment, caused by reflection from walls or furniture, severely affects the transmission quality of an optical signal. Orthogonal frequency division multiplexing (OFDM) [5] is a promising modulation technique and has been widely used to combat inter-symbol interference(ISI) resulting from multipath propagation inRF communication. The technique of OFDM has been successfully applied in IM/DD optical wireless systems, such as a DC-biased optical OFDM (DCO-OFDM) [6] and an asymmetrically clipped optical OFDM (ACOOFDM) [7,8]. Combining the techniques of the previous two schemes, an asymmetrically clipped DC-biased optical OFDM (ADO-OFDM) [9] has been developed, and it is more efficient in terms of bandwidth and optical power. Also, there are some other full spectrally efficient optical OFDM systems, such as hybrid ACO-OFDM [10] and polar-OFDM [11].

In IM/DD optical wireless systems, the information data stream is modulated into the intensity of optical carriers. Thus, only real and non-negative values can be used to realize the intensity modulation. In order to obtain a real signal, we apply an inverse fast Fourier transform (IFFT) to convert blocks of Hermitian symmetry complex symbols. For the non-negative requirement of the transmitted optical signals, two mainstream approaches are extensively adopted, adding a DC bias and clipping. In DCO-OFDM, a DC bias is added to eliminate the negative values in the transmitted signal. However, the performance of DCO-OFDM strongly depends on the DC bias level [12]. If the added DC bias cannot exceed the negative peak, the remaining negative values must be clipped to zero, then all subcarriers will be affected by the clipping noise. If the DC bias is larger than the negative peak, it makes the DCO-OFDM inefficient in terms of optical power. The advantage of DCO-OFDM is bandwidth efficiency because both odd and even subcarriers are used to carry data. In ACO-OFDM, all the negative values are clipped to zero, leaving the positives. In [13], we found that the clipping approach reduces the amplitude of the original symbols by half, and the clipping noise falls onto the even subcarriers without distorting the data on the odd subcarriers. Thus, only odd subcarriers are used to carry data in ACO-OFDM. Compared to DCOOFDM, ACO-OFDM is more optical power efficient, but its bandwidth is as twice that of DCO-OFDM.

In order to maintain the advantages and avoid the drawbacks of the previous two optical systems, a combination scheme called

ADO-OFDM has been designed. ACOOFDM symbols modulate odd subcarriers while DCOOFDM symbols modulate even subcarriers. The negative values generated by ACO-OFDM and DCO-OFDM are separately clipped to zero. Then, the sum of the remaining two non-negative signals is transmitted by a light emitting diode (LED) [14,15]. ACO-OFDM symbols can be easily recovered by detecting the data carried on the odd subcarriers. The ACO-OFDM clipping noise can be estimated from the received ACO-OFDM signals. By adding a moderate DC bias at the transmitter, the clipping noise caused by DCO-OFDM is negligible compared to the wanted signal. Finally, DCO-OFDM symbols are successfully recovered by subtracting the estimated ACOOFDM clipping noise from the received DCO-OFDM signals.

Adding a DC bias is a simple and direct approach, but it leads to a large waste of optical power. A full spectrally efficient optical system, hybrid ACO-OFDM, is proposed by Bilal Ranjha and Mohsen Kavehrad. Without using the DC bias, it is more power efficient than ADO-OFDM. The ideas for the system design of the hybrid ACO-OFDM and our proposed system are similar. For both, the odd subcarriers are used to carry ACO-OFDM symbols, which are drawn from quadrature amplitude modulation (QAM) constellations. The differences are that the hybrid ACOOFDM uses the imaginary parts of the even subcarriers to carry PAM-DMT symbols, while we still map the QAM symbols onto the even subcarriers. We believe that our proposed system will be better than the hybrid ACOOFDM because the average power of QAM symbols is much smaller than that of PAM symbols in the same level of constellation case.

So far, the Hermitian symmetry constraint is usually enforced on the signal vector for obtaining real signals. However, Hany Elgala and Thomas D. C. Little provided another scheme, polar-OFDM(P-OFDM), to generate real unipolar signals without this constraint. The QAM symbols are only mapped onto the even subcarriers. After taken by IFFT, the complex signal vector satisfies the half-wave even symmetry. Then, the authors applied the cartesian-to-polar operation to convert the complex form into the exponential form. The amplitude and the phase values of different samples are transmitted. At the receiver, Hany Elgala and Thomas D. C. Little used the reverse operation to recover the original complex symbols. The designing ideas of P-OFDM and our proposed system are quite different. The main difference depends on the use of the Hermitian symmetry constraint.

In this paper, we propose a novel scheme, calledan asymmetrically and symmetrically clipping optical (ASCO)-OFDM, to simultaneously transmit ACO-OFDM symbols on the odd subcarriers and symmetrically clipping optical (SCO)-OFDM symbols on the even subcarriers. If the length of an ACO-OFDM signal is $2N$, an ACO-OFDM symbol that consists of only odd subcarriers has the property of $x(n) = -x(n+N)$ [13,16].However, an OFDM symbol converted from only even subcarriers satisfies the property that $x(n) = x(n + N)$, which is proved in Appendix 1. After clipping, the same negative values are removed in the first and in the second half. It is the reason that the non-negative signals are called SCO-OFDM signals. Fortunately, the SCO-OFDM clipping noise does not affect ACO-OFDM symbols because it falls onto the even subcarriers. We prove this claim in Appendix 2. By using the same operation in ADO-OFDM, we can recover ACO-OFDM symbols by extracting the data on the odd subcarriers. Also, the ACO-OFDM clipping noise can be accurately estimated from the recovered ACO-OFDM signals. The data on the even subcarriers are distorted by the ACO-OFDM clipping noise, the SCO-OFDM clipping noise, and all other noises. The details of reconstructing SCO-OFDM are discussed in Section 2.2. Since no DC bias is added to all subcarriers, this novel scheme exhibits better performances in terms of optical power and symbol error rate (SER) than ADO-OFDM does. Moreover, the existing technique [17] can be applied to improve the SER performance [18].

II. EXISTING SYSTEM(ASCO-OFDM)

The block diagram of ASCO-OFDM is shown in Figure 1. Since the ASCO-OFDM system uses a novel transmission scheme, the input block of complex symbols is first separated into three parts, which have two $(N/2) \times 1$ signal vectors and one $(N/2 - 1) \times 1$ signal vector. Thus, the length of the input block is $3N/2 - 1$. Similarly, in order to obtain a real signal, we have to make the input of IFFT have the Hermitian symmetry. Two $(N/2)\times 1$ signal vectors are, respectively, combined with their conjugate sequences and are inserted by zeroes into the even subcarriers to form two $2N \times 1$ signal vectors, Xi odd and Xj odd. The $(N/2 - 1) \times 1$ signal vector is defined in a similar way with zeroes inserted into the odd subcarriers to form a signal vector.

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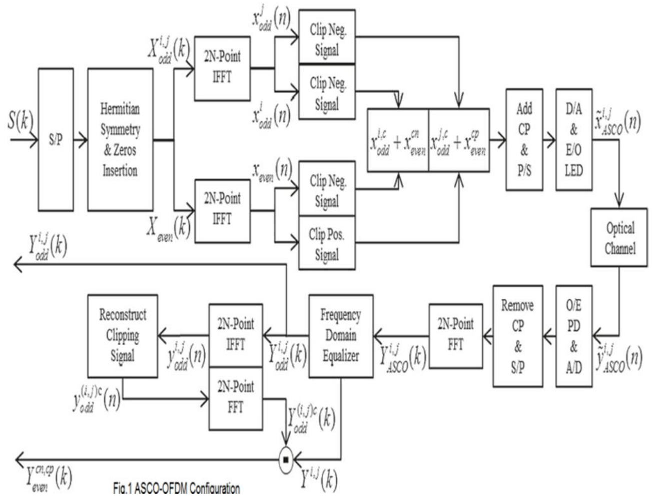

Fig 1. ASCO –OFDM System

All three signal vectors *Xi* odd, *Xj* odd, and *X*evenare constrained to the Hermitian symmetry. They are taken by a 2*N*-point IFFT to produce real bipolar signal vectors *xi* odd, *xj* odd, and *x* even, respectively. To ensure the non-negative requirement of the transmitted signals, all negative values in *xi* odd and *xj* odd are clipped to zero to generate *xi*,*c* odd and *xj*,*c*odd. As each sample in *x* even is converted from even subcarriers, It has the relation that *x* even*(n)* = *x*even*(n + N)*. By clipping the negative values, half of the information carried in *x*even is lost. Thus, two signal vectors, *xcn* even and *xcp* even, are generated for transmitting the information in *x* even. *Xcn* even represents that all negative values of *x* even are clipped to zero. *Xc p*even represents that all positive values of *x* even are clipped to zero and the remaining negative values are turned to positive. Then, we construct a transmitted signal that consists of two consecutive sub-blocks, *xi* ASCO and *xj*ASCO.

The transmitted signals, *xi* ASCO and *xj*ASCO, with the cyclic prefix are denoted by ˜*xi* ASCO and ˜*xj*ASCO. They are transmitted through an optical channel by an LED. The impulse response of optical channel *h(n)* is modelled as *h(n)* =[*h*(0), *h*(1), · · · · · · , *h(l)*], and the sum of all noise, *wi(n)* or *wj(n)*, is approximately modelled as additive white Gaussian noise. After removing the cyclic prefix, the arrival signals, *yi*ASCO and *yj*ASCO, are, respectively, transformed by a 2*N*-point FFT into the frequency domain to yield *Yi* ASCO and *Yj*ASCO. Then, a frequency domain equalizer with the knowledge of channel state information is applied to *Yi* ASCO and *Yj*ASCO.*A* is a 2*N* × 2*N* diagonal matrix whose diagonal is the 2*N*-point FFT of *h(n)*, and _*H* indicates the Hermitian matrix of _. The frequency domain equalizer can be a MMSE equalizer *(α* = 1*)* or a ZF equalizer *(α* = 0*)*. *Yi* and *Yj*can also be shown in the frequency domain.

Xi odd and*Xi* Odd are the 2*N*-point FFT of *xi* odd and *Xi* odd. The other corresponding terms in Equations 12, 13, 18, 19 are similarly defined. Note that the symbols of 0.5*Xi* odd and 0.5*Xj* odd fall onto the odd subcarriers of *Yi* and *Yj*, and the other symbols that consist of the remaining terms, 0.5 *Xi* Odd + *X*even + |*X*even| And 0.5 *Xj*Odd − *X*even + |*X*even| _ , fall onto the even subcarriers of *Yi* and *Yj*, respectively. Thus, the complex symbols of *Xi* odd and *Xj*odd can be easily recovered by extracting the symbols of *Yi* odd and *Yj*odd, which are the odd components of *Yi* and *Yj*, because the clipping noises resulting from *xi*,*c*odd and *xj*,*c*odd only affect the even components of *Yi* and *Yj*. In order to accurately estimate the clipping noise, *Yi* odd and *Yj*odd are transformed into the time domain to yield two blocks of real bipolar signals *yi*odd and *yj*odd, respectively. *yi*,*c*odd and *yj*,*c*odd are two blocks of clipping reference signals which are generated in the same way as *xi*,*c odd* and *xj*,*codd*, respectively; then, they are transformed back into the frequency domain to yield *Yi*,*c*odd and *Yj*,*c*odd, respectively. Compared to *Yi* odd and *Yj*odd, *Yi*,*c*odd and *Yj*,*c*odd have the same symbol on the odd subcarriers, but the clipping noise appears on the even subcarriers. Therefore, *Ycn*even and *Ycp*even are obtained by subtracting *Yi*,*c*odd and *Yj*,*c*odd from *Yi* and *Yj*, respectively.

III. PROPOSED SYSTEM (SEE-OFDM)

Spectrally and energy efficient orthogonal frequency division multiplexing (SEE-OFDM) is an optical OFDM technique based on combining multiple asymmetrically clipped optical OFDM (ACO-OFDM) signals into one OFDM signal. The block diagram of wireless network system using SEE-OFDM technique is shown in Fig.2 below. By summing different components together, SEE-

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OFDM can achieve the same spectral efficiency as DC-biased optical OFDM (DCO-OFDM) without an energy-inefficient DC-bias. This paper introduces multiple methods for decoding a SEE-OFDM symbol and shows that an iterative decoder with hard decisions gives the best performance. Being a multi-component format, different energy allocation amongst the different components of SEE-OFDM is possible. However, equal energy allocation performs 1.5 dB better than unequal energy allocation.

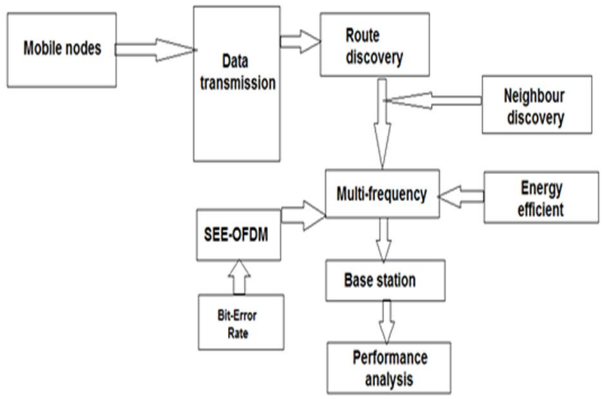

Fig 2.SEE OFDM technique

A hard-decision, iterative subtraction receiver can further increase performance by another 1.5 dB over soft-decision subtraction and reconstruction receivers. SEE-OFDM consistently performs 3 dB or better and with higher spectral efficiency than ACO-OFDM at the same bit-error-rate (BER).

IV. ALGORITHM

A. SEE-OFDM Algorithm

1) We propose new data-gathering mechanisms for largescale sensor networks when single or multiple Mcollectors are used.

2) We focus on the problem of minimizing the length of each data-gathering tour and formulate it into a mixed-integer programming (MIP).

3) We propose a spanning tree covering algorithm for the ingle M-collector case.

4) We also consider utilizing multiple M-collectors and propose Multihop data-gathering algorithm where multiple M-Collectors traverse through several shorter sub tours concurrently to satisfy the distance/time constraints.

5) We carry out extensive simulations. The effectiveness of our proposed algorithms is verified by comparing with another data-gathering algorithm.

V. SIMULATION RESULTS

Our simulation to analyze the performance of the AODV with multihop data gathering algorithm using Networks. The replication surroundings are produced in NS-2, in that provides maintain for a wireless networks. NS-2 was using C++ language and it has used for an Object Oriented Tool Command Language. It came as an extension of Tool Command Language (TCL). The execution were approved out using a wireless Sensor network environment of sensor nodes over a simulation area of 1200 meters x 1200 meters level gap in service for 10 seconds of simulation time. The radio and IEEE 802.11 MAC layer models were used. The network based data processing or most expensive and data communication level on their performance on the network. Hence, the simulation experiments do not account for the

overhead produced when a multicast members leaves a group. Multiple sources create and end sending packets; each data has a steady size of 512 bytes. Each mobile node to move randomly on their network, it's more and most expectable on their networks.

VI. PERFORMANCE ANALYSIS

A. Transmission Range-80M

The performance analysis of SEE-OFDM technique is measured in two different geographical regions that vary in size from each other. It is plotted as a graph having number of nodes in the x axis and the distance from the node in the y axis. It clearly shows that the performance gradually increases with the increase in number of nodes which is shown in the figure below:

Fig 3. Transmission range for 80M

B. Transmission Range-60M

The next figure shows the performance analysis of the data gathering in a geographical area of size 60m. Similar to the previous plot here also the x-axis corresponds to the number of nodes and the y-axis corresponds to the tour of distance. From the plot it can be understood that the data gathering high when the tour of distance as well as the

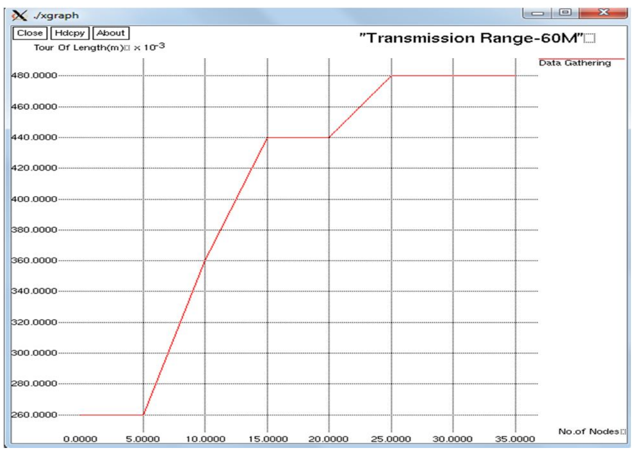

Fig 4. Transmission range for 60M

number of nodes are high and it is low when these two parameters are low.

VII. CONCLUSION

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, used in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, powerline networks and 4G mobile communications. OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data[1] on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth.

The primary advantage of OFDM over single carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire,narrowband interference and frequency-selective fading due to multipath without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate intersymbol interference (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

Table.1 Parameters and values

PARAMETERS	VALUE
Version	NS-allinone 2.28
Protocols	AODV,Multihop
Area	1200m x 1200m
Broadcast area	250m
Transfer model	UDP,CBR
Data size	512 bytes

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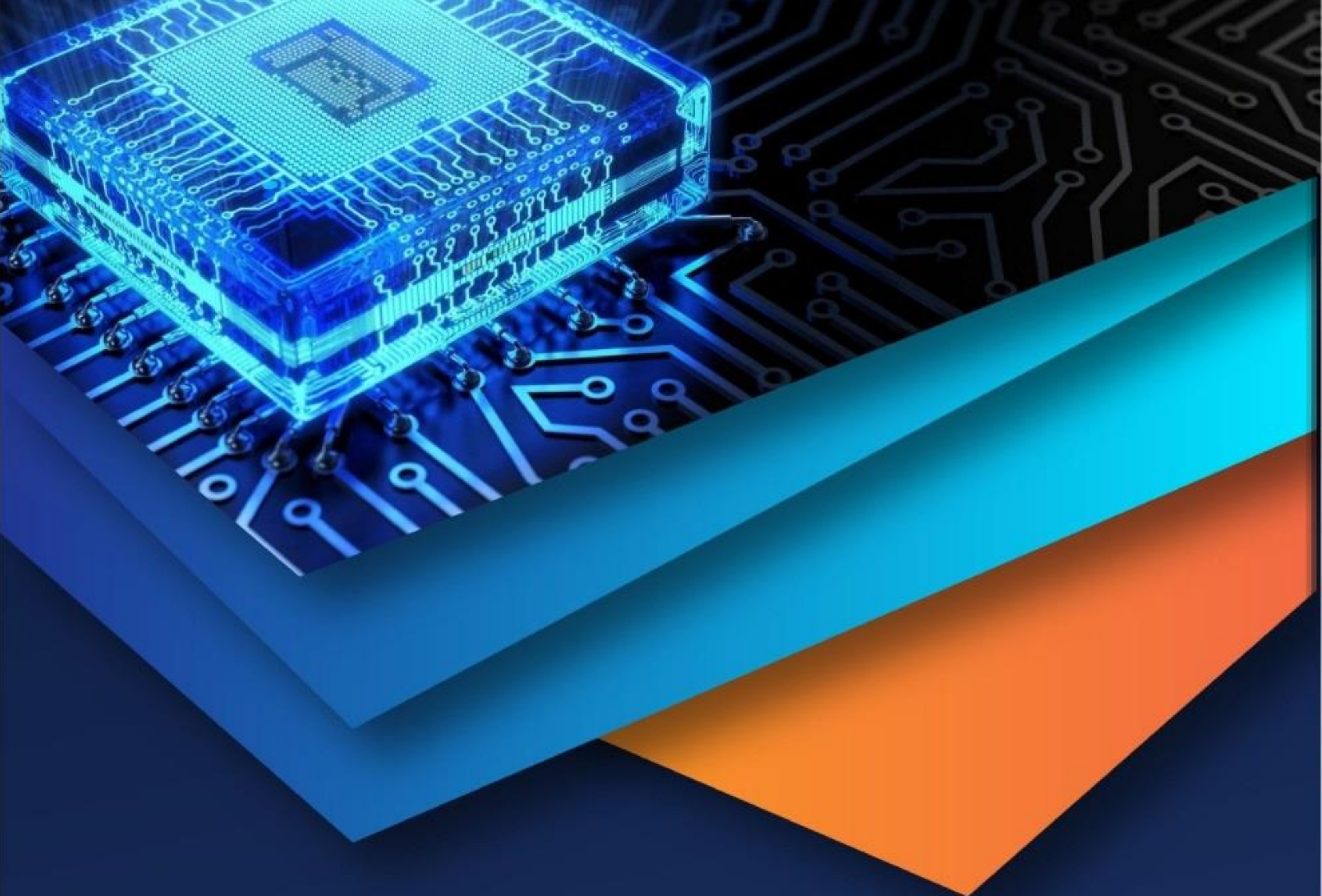

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