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# Amplifier Operated Multiple OWC System to Improve Q-factors in Optical Communication

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***Abstract: ISL played a very important role for information transmission among satellites and also for advanced information broadcasting from one satellite to another and then to ground stations. IsOWC managed the utilization of wireless optical communication with the help of lasers rather than conventional radio and microwave systems. However, there are various internal and external factors which affect the inter-satellite optical communication links. And in the conventional works, the performance of the inter-satellite optical communication links has been optimized by considering different parameters over single OWC channel link, however, it has been analyzed that in the conventional systems, the quality of the system was not much high and consequently, the inefficient systems with degraded performance and low-quality was attained. In order to address this issue, the conventional system in upgraded in this proposed work. In order to do so, the multiple-OWC channel links are implemented in the proposed work and along with that, the optical amplifier is used. The simulation of this proposed multiple-OWC-Amplifier approach is performed in terms of Q-factor by considering different data rates and different wavelengths, in order to demonstrate its efficiency. And from the obtained results, it has been analyzed that the proposed multiple-OWC-Amplifier approach outperformed conventional OWC system in terms of considered parameters.***
***Keywords: Optical Wireless Communication, FSO, Inter-satellite link, multiple OWC.***

## I. INTRODUCTION

Optical Wireless Communication (OWC) is the most preferred technology in the field of broadband access systems. For past few years its growth was very high, because of which in a short period time, OWC has become accompaniment for Radio Frequency (RF) technologies. Wireless technology always preferred different connection for internet and multimedia services with high frequency information propagation that can use in both long regimes and short haul connectivity [1].

Currently OWC technologies depend on distance range. These are generally divides into indoor OWC and outdoor OWC. Indoor OWC also named as wireless IR communication as it uses IR band and Visible Light Communication (VLC) if it works under visible spectrum. And the outdoor OWC is called as Free Space Optical (FSO) communication [2]. As demands of potential deliverable bit rate to the end user are increasing, typical RF technologies does not meet these requirements. The optical spectrum is well chosen for one of the most preferred by user for offering the needed bandwidth both for indoor and outdoor applications [3]. Outdoor wireless optical links also called as FSO are continuously proving best networks communication, and providing bandwidths different than that of the available RF technologies. However, due to weather related issues a potential on their installation in area with high degree bearing is required. FSO poses an attractive nature for communication applications. This communication is possible only via a line-of-sight connection between transmitter and receiver for broadcasting of information from one point to another [4]. Here, the data signal from the receiver is carried on the optical carrier, and this carrier signal is then allowed to broadcast through the atmospheric channel or free space, rather than wired optical fibers, towards the receiver. Ground-to-satellite (optical uplink) and satellite-to-ground (optical downlink) involve broadcasting of optical beam through the atmosphere as well as in free space. Therefore, these connections are a combination of terrestrial and space links. From past few years, OWC have been enhanced with many new features by organization like corporations, government organization, individuals and other academies in many different places. Transmission of information signals through transmitter via vacuum in the atmosphere between different satellites is known as inter-satellite OWC (ISOWC) [5]. Because of which, ISOWC connects the satellites in any way which it demands like dissimilar orbits or similar orbits. Light wave system is widely used in different field liked with the satellites communication. The numerous uses of IS-OWC can be physically sub-categorized as follow.

*A.* Broadband/Internet links
*B.* Deep space optical communication
*C.* Satellite launch support

Some other uses of ISOWC are under water, satellite aircraft, terrestrial communication and deep space.

In these FSO systems, the strength of optical source is modulated to transfer signals over channel. Optical transmission system includes modulation of optical signal, its transmission, detection and demodulation. There are various types of modulation schemes applicable for FSO systems with respect to the regular received optical power needed to get required BER at given information rate [6]. An efficient power modulation method is required to decrease the ratio of peak to regular power. The easiest and mostly adopted modulation methods in atmospheric optics are magnitude modulation with strait detection. Frequently, the modulation methods have to select on the basis of low cost deployment, power efficiency, bandwidth efficiency, simple design requirement, and resistance to interference radiations.

The performance of terrestrial FSO links is analyzed for different modulation format, detection approaches and different parameters. Some of the existing works that analyzed the performance of FSO links are discussed in the next section:

## II. LITERATURE REVIEW

FSO used optical carrier in and around infrared band to setup either terrestrial links within the Earth's atmosphere or inter-satellite or ground-to-satellite. This section reviewed the literature study related to performance analysis of FSO systems.

The paper [7] proposed an efficient survey on different issues faced by FSO system for ground-to-satellite/satellite-to-ground and inter-satellite links (ISL). In order provide higher connection feasibility, it provided with detailed of different working reduction methods.

F. Shah, et al. [8] introduced the function of a combination of error management coding scheme and advancing to the inter-satellite free space optic connection. By using convolution coding the BER working was enhanced to benefits the intensity modulation/ direct detection scheme.

The authors [9] proposed, enhanced examination via deployment of a square root module using OPTISYSTEM simulator to accomplished an ISL among two satellites a parted by a distance of 1000 Km at information rate of 2.5 Gbps which was not reported in previous examined performance.

A high efficiency IsOWC system applying various modulation techniques were presented in [10]. The developed system was able to accomplish by adopting DWDM by several modulation methods.

The author [11] introduced the working of an earth-to-satellite FSO link with respect to BER for 3 intensity modulation (IM), M-ary pulse position modulation (M-PPM) and M-ary differential PPM (M-DPPM) and direct detection receiver.

The paper [12] focused on the information transmission among Low Earth Orbit satellites and provided the Is-OWC connection working. The system working involve bit rates, input power, wavelength and distance on an inter-satellite connections were examined.

K. Vimal and S. Prince [13] developed various ways to deal the impact of satellite vibration by maximizing the framework of system structure.

The paper [14] adopted channel diversity method which provides improved outcomes than that of single channel. To maximize the Q-factor and signal strength at large distance, Diversity method of Is-OWC system provided with various ways.

In paper [15], the optical ISL was constructed with the opt system and then analysis was carried out to review the impact of changing the wavelength between two satellites estranged by a distance of 1300 km at data rate 3 Gbps.

The author in paper [16] designed a system with pre-amplification in the ISL to cope with the losses with the amplification factor of 30 dBm and noise figure of 6dB. In paper [17], author studied the impact of election of various operating wavelength and types of detector as well as the pointing failures at the transmitter and receiver side on the working of an inter-satellite free-space optical connection. By measuring and evaluating the bit error rate and elements of signal collected under various circumstances the performance of the connection was being improved. It provides efficient performance; however, there are also various factors in the system that needed to be upgraded so that quality of the system can be enhanced further. Therefore, it is required to upgrade the conventional system that will help to enhance the quality of the system.

## III.PRESENT WORK

In the above section, different existing works related to FSO system performance analysis are reviewed. One such most efficient approach is reviewed [17] in which the performance of an inter satellite optical link was optimized in terms of BER and Q-factor which are affected by variation of different internal parameters. In this work, the ISOL provide the efficient performance.

However, in this work, the conventional system has not been upgraded and only the analysis has been performed on the basis of few parameters. Also, in this, the quality of the system is not enhanced.

Thus, to make the system more enhanced and to improve the quality of system, a novel work is proposed in this paper.

In the proposed work, the system is upgraded in such a way that the multiple Optical Wireless Channels are used in the system. The multiple Optical Wireless Channels will help to enhance the quality of the system.

The use of multiple OWC can further enhance the efficiency of the system in terms of different parameters and help to enhance the system quality. The multiple OWC enhances the throughput (data rate) of wireless access, even under conditions of interference, signal fading and multipath for long distances. Thus, multiple OWC are used in the proposed work.

Also, in the proposed work, the amplifier is introduced in the link. The amplifier is introduced because with the increase in distance of communication, the signal power get degraded and noise get added which will increase the error rate in the system and thus degrade the quality of the system. However, the amplifier helps to boost the signal power and thus the quality factor will consequently get enhanced.

Therefore, the proposed work in which multiple OWC and amplifier is introduced will help to achieve an efficient system with enhanced quality.

## IV. SIMULINK MODEL

The schematic diagram of the proposed system is represented in below figure 1. The working of this system is described as below:

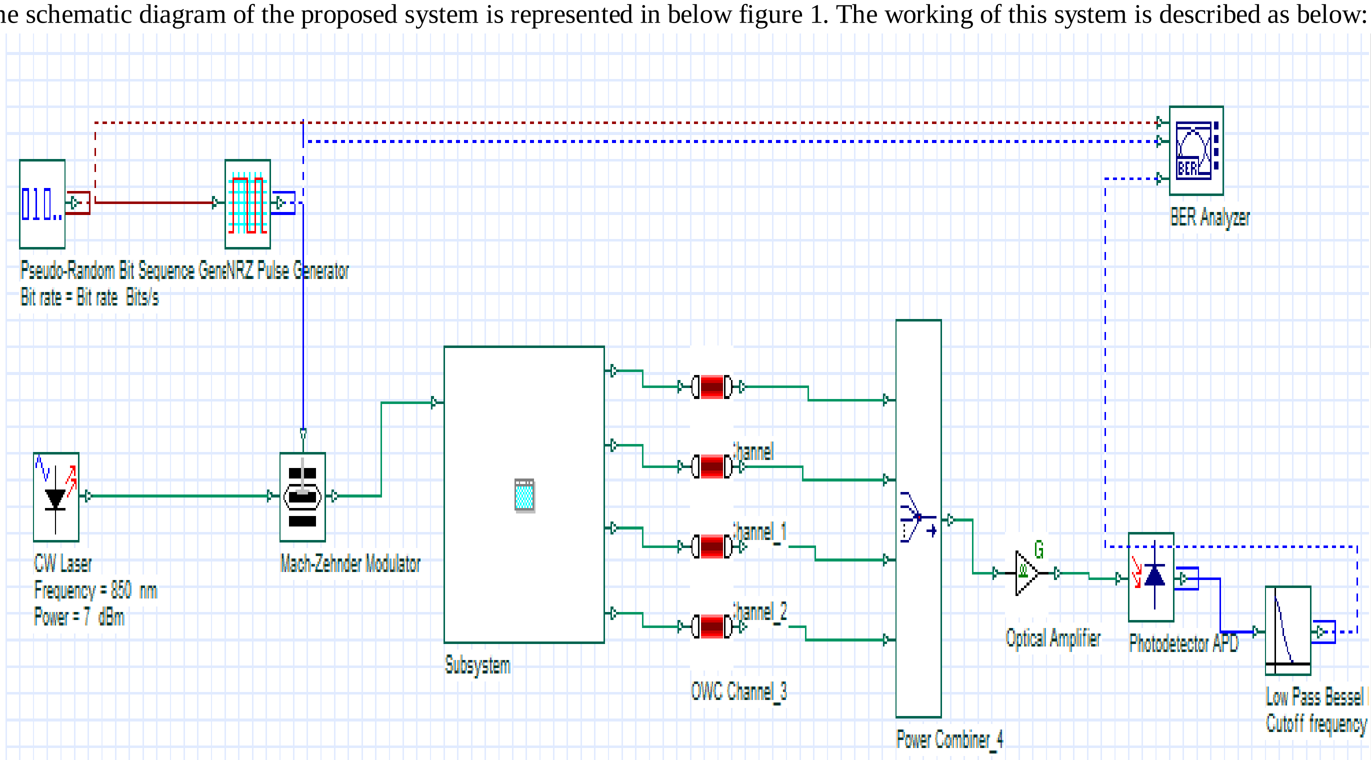


Figure 1: Schematic Diagram of proposed system

The initial information is required for the communication purpose and this initial information is generated with the help of Pseudo random sequence generator. The information generated by the Pseudo random sequence generator is in the digital form which cannot be transferred through the optical medium, thus is it required to convert this digital information into the electrical information so that it can be transmitted for the communication. In order to convert this pseudo generated information into the electrical information, the NRZ pulse generator is used. The resulting signal is combined with the light wave by the CW laser and the modulation is performed using Mach-Zehnder Modulator. The modulated signal is then transmitted via OWC channel. In this proposed work, the multiple OWC channels are used which are represented as channel 1, 2, 3 in the figure. After that, the power emitted by these multiple OWC channels are combined at the power combiner. And then, the optical amplifier is used to boost the signal strength and enhance the quality of the channel. Then the photo-detector is applied to receive the light signal. The noise is introduced to the signals when the signals are passed through the channel, thus the low-pass Bessel filter is applied at the receiver side to filter the noise from the received signals. The performance parameter of the proposed work is then evaluated in terms of BER, for which the BER analyzer is applied.

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Now, the block diagram of the proposed work is illustrated in below figure

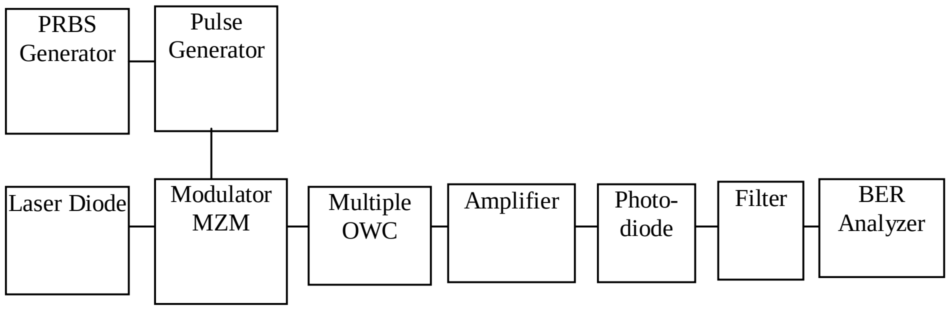


Figure 2: Block diagram of proposed work

The performance of this proposed work is then analyzed for which the simulation is performed. The results obtained from the simulation are represented in next section:

## V. RESULTS AND DISCUSSIONS

In the proposed work, the multiple OWC channels and amplifier is introduced in order to enhance the quality of the system. This proposed system is analyzed in terms of Q-factor at different data rates and different lengths, and also is analyzed for operating wavelength 850nm and 1550nm at varying input power. This analysis is performed in order to demonstrate the efficiency of system on introducing proposed work.

As represented in figure 3, the performance analysis of the proposed work is performed in terms of Q-factor by considering different data rates i.e. 2.5 Gbps, 5 Gbps, 10 Gbps, 20 Gbps and 40 Gbps, at different low earth orbit (LEO) distances which ranges between 200 km to 1200 km.

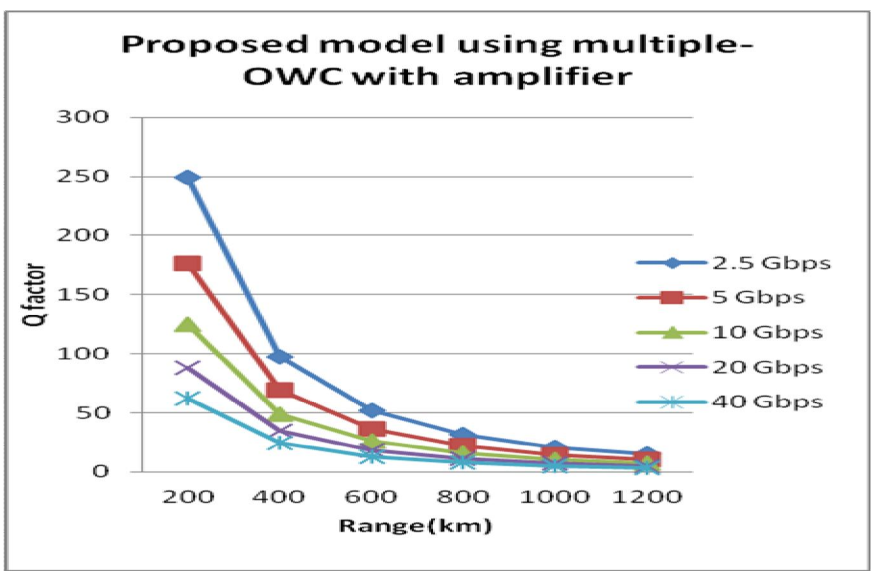


Figure 3: Q-factor analysis considering different data rates at different lengths

From the obtained graph, it is comprehensible that quality factor decreases with the increase in distance, and also the system has high quality factor at low data rate i.e. 2.5 Gbps and then goes on degrading with the increase in data rate.

Now, the comparison analysis between proposed Multiple-OWC-Amplifier approach and traditional OWC approach is performed in terms of Q-factor by considering different data rates. The values of the Q-factor at each data rate and at different lengths are recorded and are represented in table 1.

The table 1 illustrates that at smallest length i.e. 200 km and at lowest data rate i.e. 2.5 Gbps, the Q-factor of the proposed system is highest i.e. 249.4, which then goes on decreasing with increase in data rate and with increase in length. And consequently, the lowest value of Q-factor i.e. 3.67 is obtained at highest distance i.e. 1200 km and at highest data rate i.e. 40 Gbps. The values of Q-factor are high for proposed Multiple-OWC-Amplifier approach at all the different lengths as compared to traditional OWC approach. These values demonstrate that proposed approach leads to achieve system with high Q-factor.

Table 1: Q-factor values considering different data rates at different lengths

| Length (Km) | 2.5 Gpbs (Amp) | | 5 Gpbs (Amp) | | 10 Gpbs (Amp) | | 20 Gpbs (Amp) | | 40 Gpbs (Amp) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OWC | Multiple-OWC-Amplifier | OWC | Multiple-OWC-Amplifier | OWC | Multiple-OWC-Amplifier | OWC | Multiple-OWC-Amplifier | OWC | Multiple-OWC-Amplifier |
| 200 | 98 | 249.4 | 67 | 176.36 | 58 | 124.69 | 38 | 88.15 | 27 | 62.31 |
| 400 | 37 | 97.6 | 30 | 68.99 | 28 | 49.02 | 18 | 34.72 | 16 | 24.61 |
| 600 | 19 | 51.73 | 18 | 36.62 | 17 | 25.9 | 14 | 18.34 | 12 | 12.97 |
| 800 | 14 | 31.43 | 12 | 22.21 | 10 | 15.69 | 8 | 11.08 | 6 | 7.81 |
| 1000 | 9 | 20.83 | 8 | 14.71 | 7 | 10.37 | 5 | 7.33 | 3 | 5.17 |
| 1200 | 5 | 14.74 | 4 | 10.475 | 3 | 7.41 | 2 | 5.22 | 2.5 | 3.67 |

Now, the comparative analysis between proposed Multiple-OWC-Amplifier approach and traditional OWC approach is performed by considering different wavelengths i.e. 850 nm and 1550nm, and the obtained results are represented below:

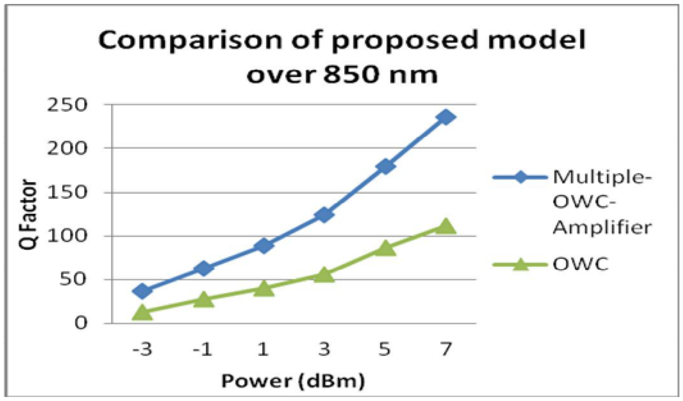


Figure 4: Q-factor comparative analysis considering 850nm wavelength

The comparative analysis between proposed and traditional approach is performed by considering wavelength of 850 nm at different input powers, and the obtained results are exemplified in graph of figure 4. From the graph, it is clearly observable that the value of Q-factor increases with increase in input power. And also, the high Q-factor is achieved by using proposed approach in contrast to the traditional approach.

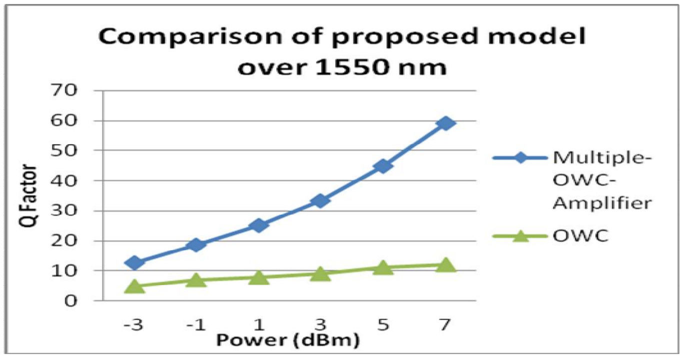


Figure 5: Q-factor comparative analysis considering 1550nm wavelength

The figure 5 represents the results of comparative analysis performed between proposed and traditional approach by considering the wavelength of 1550 nm. It is comprehensible on the analyzing the graph that the proposed multiple-OWC-amplifier approach is more efficient than the traditional OWC approach in terms of Q-factor at wavelength 1550 nm, as it has high value of Q-factor at all different power inputs.

Thus, all the obtained graphs represented in this section demonstrate that the proposed multiple-OWC-amplifier approach is more efficient than the traditional OWC approach in terms of Q-factor at different data rates and wavelengths.

## VI. CONCLUSION

In order to optimize the performance of Is-OWC, various works were carried out; however, they fail to meet the high quality-factor requirement of the system. Therefore, in the proposed work, an upgraded system is developed with the intention to enhance the quality factor of the system. In this proposed work, the multiple OWC channel links are deployed unlike conventional single OWC channel link, which helps to enhance the efficiency of the system under various conditions and in terms of various factors. Also, the optical amplifier is used in the proposed work that helps to boost the strength of signal. In order to demonstrate the efficiency of proposed system, it is implemented in Optisystem and its simulation is performed in terms of Q-factor by considering different data rates and also by considering different wavelengths. With respect to these considered parameters, the comparison of the proposed multiple-OWC-amplifier approach is also performed with the conventional OWC approach. And the results obtained from the simulation represented that the proposed system is more efficient than the conventional system in terms of Q-factor as it has high value of Q-factor for all different data rates as well as for different wavelengths. Thus, it is verified that using proposed approach will help to achieve a system with high quality.

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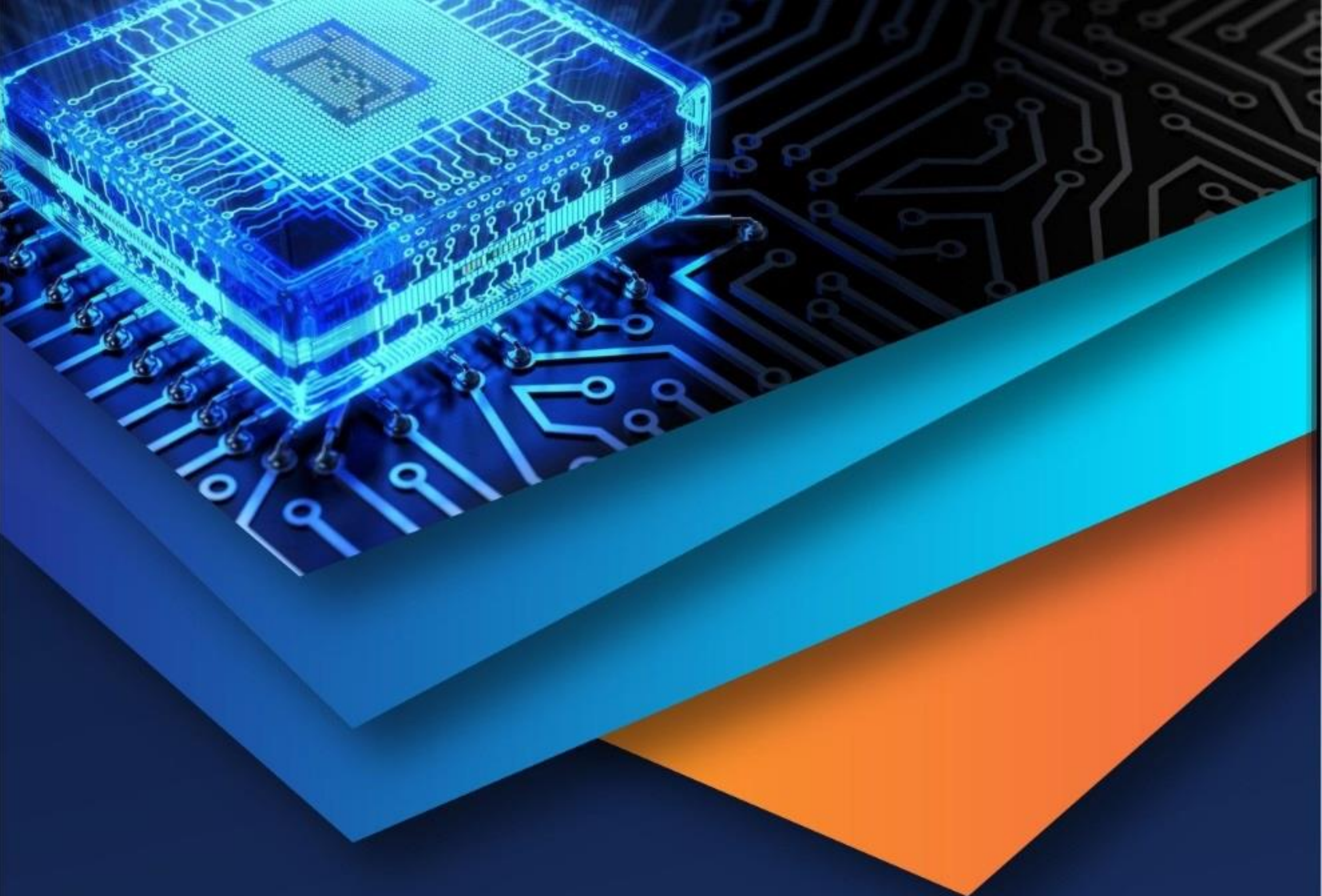

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