iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VII Month of publication: July 2023

DOI: https://doi.org/10.22214/ijraset.2023.54772

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

Design Implementation and Performance Analysis of M-QAM and PAM-n Signalling Schemes

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Abstract: Two circuits have been simulated in the Optisystem 20 software. One circuit has M-QAM and the other has PAM-n. Both the circuits have been compared on the basis of Bits per symbol, signal power,Noise power, etc. The total power and noise power havebeen calculated in the electrical power meter visualizer.In both the circuits, PRBS generator is used to generate the sequence of the bits. In M-QAM,return to zero pulse generator is used and in PAM-n notreturn to zero pulse generator is used. The full width pulse is also known as NRZ (not return to zero) and halfwidth pulse is also known as RZ (return to zero). The main objective of the simulation is to get perfect Eye diagram in the Eye Diagram Anaylzer. The parametriccomparison of different types of QAM have also be doneon the basis of number of samples, sequence length, samples per bit and output power in dBm andcomparison is done by state of art. In the final result, itwill be concluded that M-QAM performs much better than the PAM-n as it is capable of transferring higher data rates. The different types of M-QAM and PAM-n eye diagrams have been plotted like 16-QAM, 64-QAMand PAM-3.
Keywords: QAM, PAM, Eye Diagram Analyzer, Optisystem software, EPMV (Electrical power meter visualizer).

I. INTRODUCTION

The M-QAM basically means M-Ary Quadrature Amplitude modulation. This signalling scheme have the specification of both ASK (Amplitude Shift Keying) and PSK (Phase Shift Keying). These schemes are basically used to transmit binary sequence through free space. The message signal switches between 2 voltage levels correspondingly one of the parameters of carrier signal switches between 2 possible values. Therefore, these schemes are called as 'switching or keying'. The binary values 1 and 0 are represented by presence of carrier and lack of the carrier respectively, in ASK also referred to as ON-OFF keying. In PSK, binary 1 is represented with actual carrier and binary 0 is represented with 180 degrees phase shift of carrier.

PAM-n basically means Pulse Amplitude Modulation. It is one of the 3 basic types of pulse modulation in which the pulse amplitude varies with the modulating message signal.

This modulation scheme is used in digital transmission. It is suitable for Time Division Multiplexing. It has manyapplications like it is used in television, Ethernet, etc.

The bandwidth for M-QAM= $2R_b/\log_2 M$ (For full width rectangular pulses only).

If sinc pulses are used for M-QAM, then bandwidth = $R_b/\log_2 M$.

II. OBJECTIVES

1) Design of M-QAM in the Optisystem 20 software.
2) Design of PAM-n in the Optisystem 20 software.
3) Implementation and performance analysis of M-QAMand PAM-n.
4) Comparison is done by state of art.

III. MATERIAL AND METHODS

The M-QAM has bit rate of 10e+006 bit/s with 64 samples/bit and sequence length of 2048 bits. In the M-QAM circuit, the PRBS generator is connected with the Fork 1*2. The Fork divides the signal into two parts. One part is connected with QAM sequence generator which generates the sequence of the QAM pulses and the other part is connected with the RZ pulse generator which produces return to zero pulses for its digital transmission. Further, QAM sequence generator is connected with 2 M-Ary pulse generatorwhich has a gain of 1. Both are connected with Electrical Constellation Visualizer which shows the constellation diagram of various M-QAM. Further the signal gets modulated at Quadrature modulator which is having 550MHz frequency and then the signal is demodulated at the Quadrature demodulator which is having cut of frequency of 10MHz.

With the demodulator the signal goes into two different eyediagram analyzers and the eye diagram of the circuit can be analyzed. Then, the signal goes straight into the M-ary threshold detector in which there are Threshold amplitudesand the output amplitudes with the delay compensation of 0 secs. Then, the signal moves to the QAM sequence decoder which is responsible for decoding the bits persymbol. Different bits per symbol are used to obtain the graph of M-QAM like for M=16, the bits/symbol is 4 and for M=64, the bits/symbol is 6, etc. The signal goes furtherto the RZ pulse generator and finally to the oscilloscope Visualizer. The different oscilloscope Visualizer are connected with different parts of the devices in the circuit tosee graph between amplitude and time.

Now, in the PAM-n circuit, there are two PRBS generators which are joined with NRZ pulsegenerator. The NRZ pulse generator is further connected with directly modulated laser measured which is having 850nm frequency and power 0dBm. The bit rate is 25e+009bits/s. The samples/bit is 64 and sequence length is of 128 bits. Then, the signal goes to the power combiner 2*1 where it gets combine and moves seamlessly to the optical Fiber CWDM with attenuation of 0.5 dB/km and 1 km length. The optical time domain Visualizers and optical spectrum analyzers are connected with the optical Fiber CWDM. Further, signal goes to the optical attenuator whereattenuation gets 0db. Then, the signal moves to the PIN photodiode where optical signal gets converted into an electrical signal. Then, the signal moves to the low pass Bessel filter having c.o.f = 0.75*symbol rate Hz. The Electrical power meter visualizer is connected withthe Bessel filter. The band limited signal moves to the 3R regenerator where signal strength gets amplified and finallymoves to the Eye Diagram Analyzer.

TABLE 1- PARAMETRIC COMPARISON OFDIFFERENT QAM DESIGNS:

TOPOLOGY/ TECHNIQUE	SAMPLE PER BIT	SEQUENCE LENGTH (bits)	N0. OF SAMPLES	OUTPUT POWER (dBm)
3) VLC/4-QAM	2	16384	65536	13.01
9) OFDM-RoF with 16-QAM	32	1024	32768	71.617
5)CO- OFDM with QAM	8	16384	131072	8.479
This work	64	2048	131072	23.533

IV. RESULTS AND DISCUSSIONS

The basic M-QAM circuit is given below (in Fig 1), and furtherby changing number of bits per symbol, different eye diagramswould be analyzed (in Fig 3 and Fig 5).

The constellation diagram of M-QAM represents quadrature or Q element on the vertical axis and in-phase element or I on the horizontal axis.

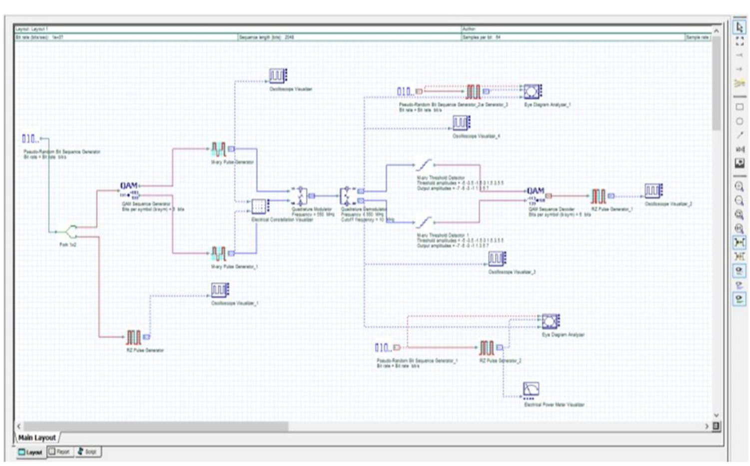

Fig. 1

The total power of M-QAM is coming out to be 23.533 dBm and 225.576 E-3 in Watts (in Fig 2). The noise power is coming out to be 1 mW.

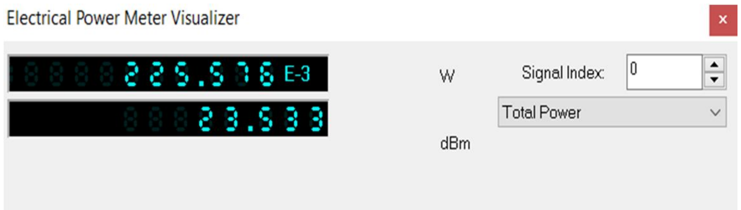

Fig. 2

For 16-QAM maps 4 bits/carrier. The frequency is 550 MHz and COF is 10 MHz. The eye diagram is analyzed (in Fig 3). The eye diagram appears like a human eye. The main purpose ofeye diagram is to check from where the distorted signal is coming and what are its effects on the signal.

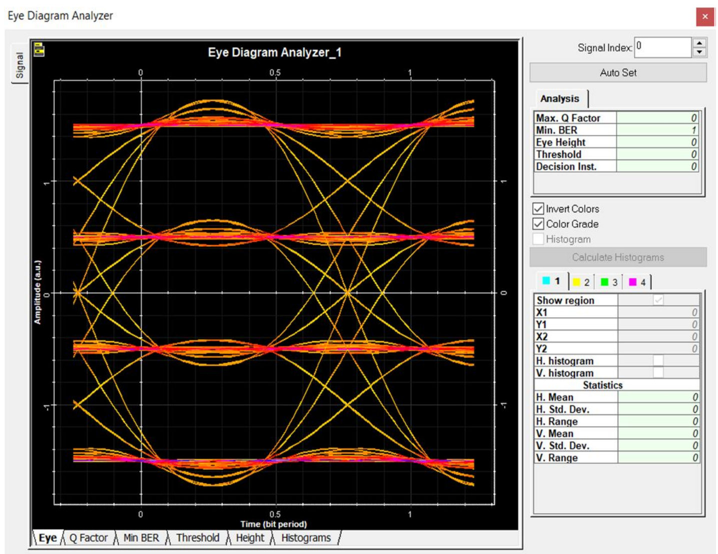

Fig. 3

The electrical constellation diagram of 16-QAM is given below (in Fig 4). In this, Amplitude graph is taken with maxvalue of 3.3 a.u to min -3.3 a.u. In each quadrant we can observe 4 signal points and 4 quadrants are there. Therefore,4*4 = 16 signal points. Thus, it accounts to be 16-QAM.

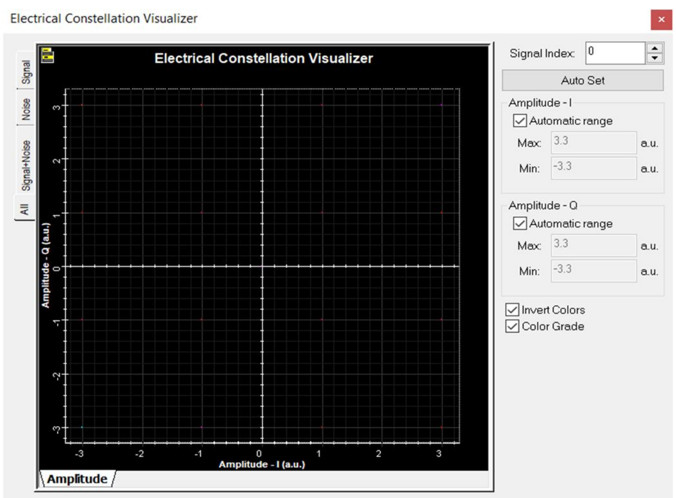

Fig. 4

For 64-QAM maps 6 bits/carrier. The frequency and cut off frequency remains the same i.e. 550 MHz and 10 MHz respectively. The eye diagram is analyzed (in Fig 5).

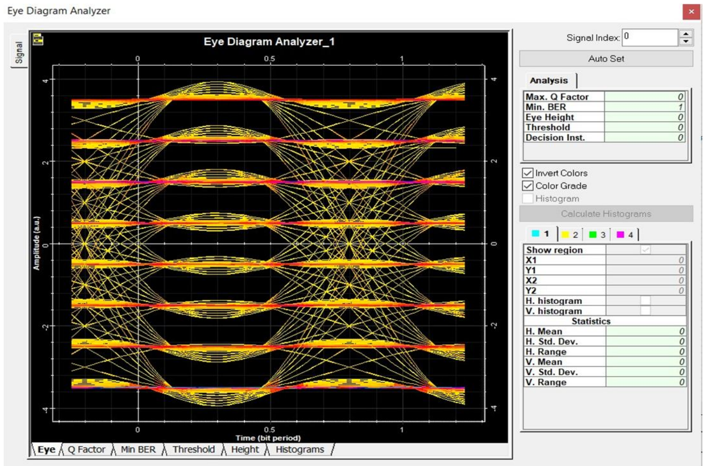

Fig. 5

The electrical constellation diagram of 64-QAM is given below (in Fig 6). In this, Amplitude graph is taken with max value of 7.7 a.u to min value of -7.7 a.u. In each quadrant, 16 signal points are present and 4 quadrants are there. Therefore, 16*16 = 64 signal points. Thus, it accounts to be 64-QAM.

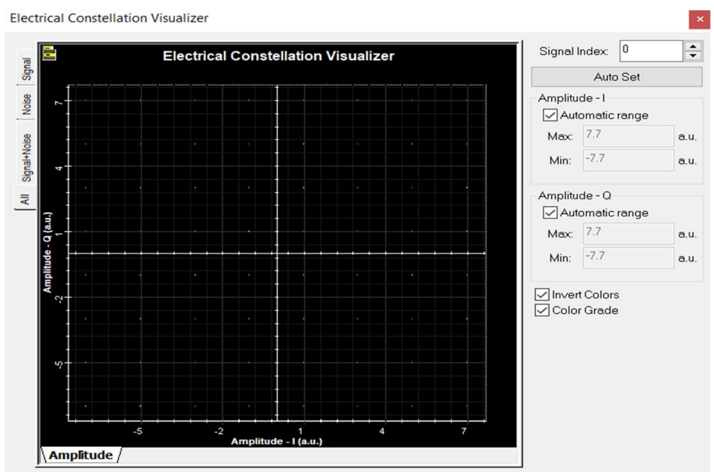

Fig. 6

The PAM-3 circuit is given below (in Fig 7). In this circuit, we have used 2 directly modulated laser measured and the output gives PAM-3 result. If we want to increase PAM-3 to PAM-4, we just have to add 1 more directly modulated laser measured and then the output will give PAM-4 result. For the PAM-4, we have to use 3*1 power combiner in the circuit.

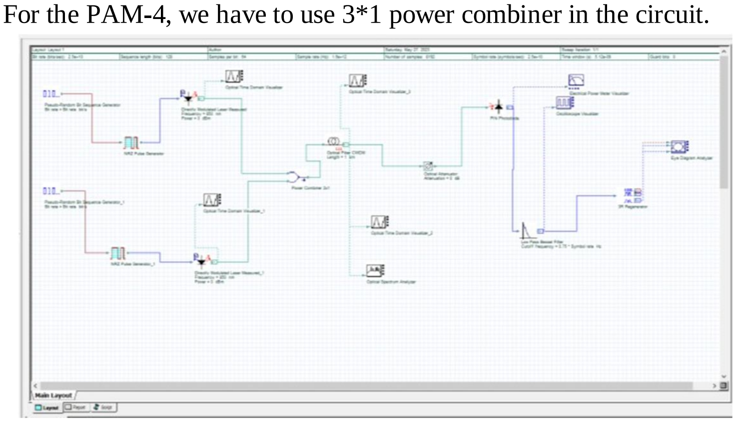

Fig. 7

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The total power of PAM-3 is coming out to be -29.723 dBm(in Fig 8). The noise power is coming out to be 592.090e-12Watt.

Fig. 8

The eye diagram for PAM-3 is given (in Fig 9) having a max Q factor 4.21609. The eye diagram is plotted betweenamplitude(a.u) and time(bit period) and various other graphs can also be observe like Q Factor, Min BER, Threshold, Height, etc just by clicking the bottom buttons given in the graph.

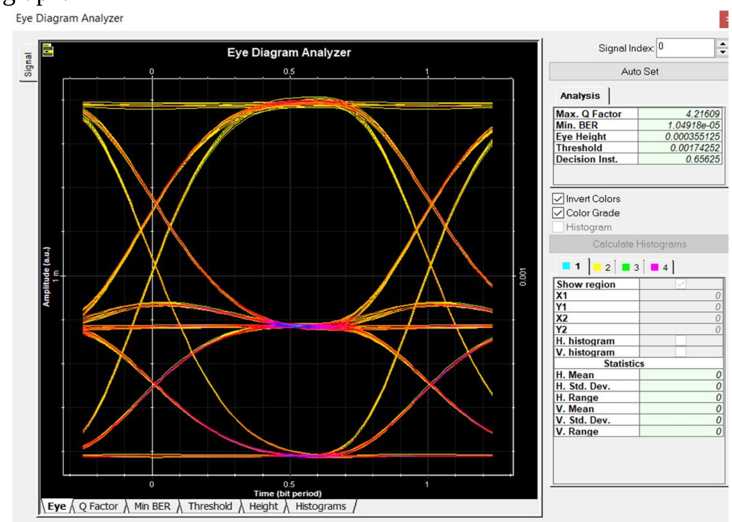

Fig. 9

The Optical Spectrum Analyzer which is connected with Optical Fiber CWDM of length 1 km shows the relation between power and wavelength (in Fig 10). The attenuationin the optical fiber is 0.5 db/km, that's why after fiber the signal moves to optical attenuator to compensate attenuation. The graph simply shows how the power (dB) varies with wavelength (m). The amplitude of the signal variesfrom 3.677 a.u to -104.937 a.u.

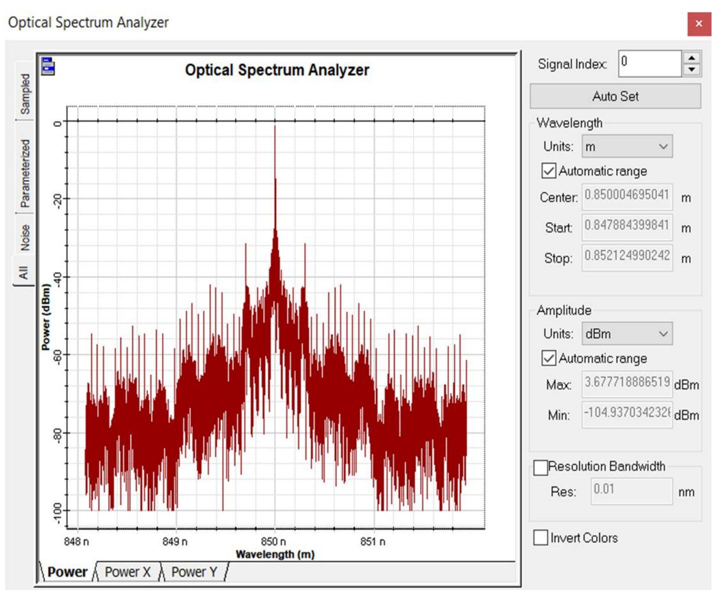

Fig. 10

Although M-QAM is capable of higher data rates, it uses both amptitude and phase shift keying for improving the radio communication efficiency. But there are some disadvantages. For example, the noise power is more in M-QAM. Due to close transmission states, there is less noise required to move the signal between the states.

TABLE 2- System Parameters

Values	M-QAM	PAM-n
Total power	23.533 dBm	-29.723 dBm
Noise Power	1 mW	592.090e-12 W
Bits per symbol	64-QAM: 6 16-QAM: 4	PAM-3: 1.5
Time window	0.0002048 s	5.119997e- 009 s
Sample rate	640e+006 Hz	1.6e+012 Hz
Sequence length	2048 bits	128 bits
Samples per bit	64	64
Symbol rate	10e+009 symbols/s	25e+009 symbols/s
No. of samples	131072	8192

V. CONCLUSIONS

M-QAM performs much better than the PAM-n as QAM constitute more bits/ carrier. For example- 64-QAM maps 6 bits/carrier,16-QAM maps 4bits/carrier and 8-QAM maps
2 bits/carrier. The 4-QAM is also called QPSK i.e Quadrature Phase Shift Keying. As we increase the M- QAM numerology, it depicts the ability to have more data with the number of symbols being the same. However, the variation of noise in the PAM-n system is less which meansprobability of error is also less. In the further research work,there will be proper comparison of M-Ary PSK and M-AryQAM. For M value greater than 8, M-Ary QAM is better than M-ARY PSK as probability of error will be very high in M-ARY PSK and for M value less than 8 M-Ary PSK isbetter.

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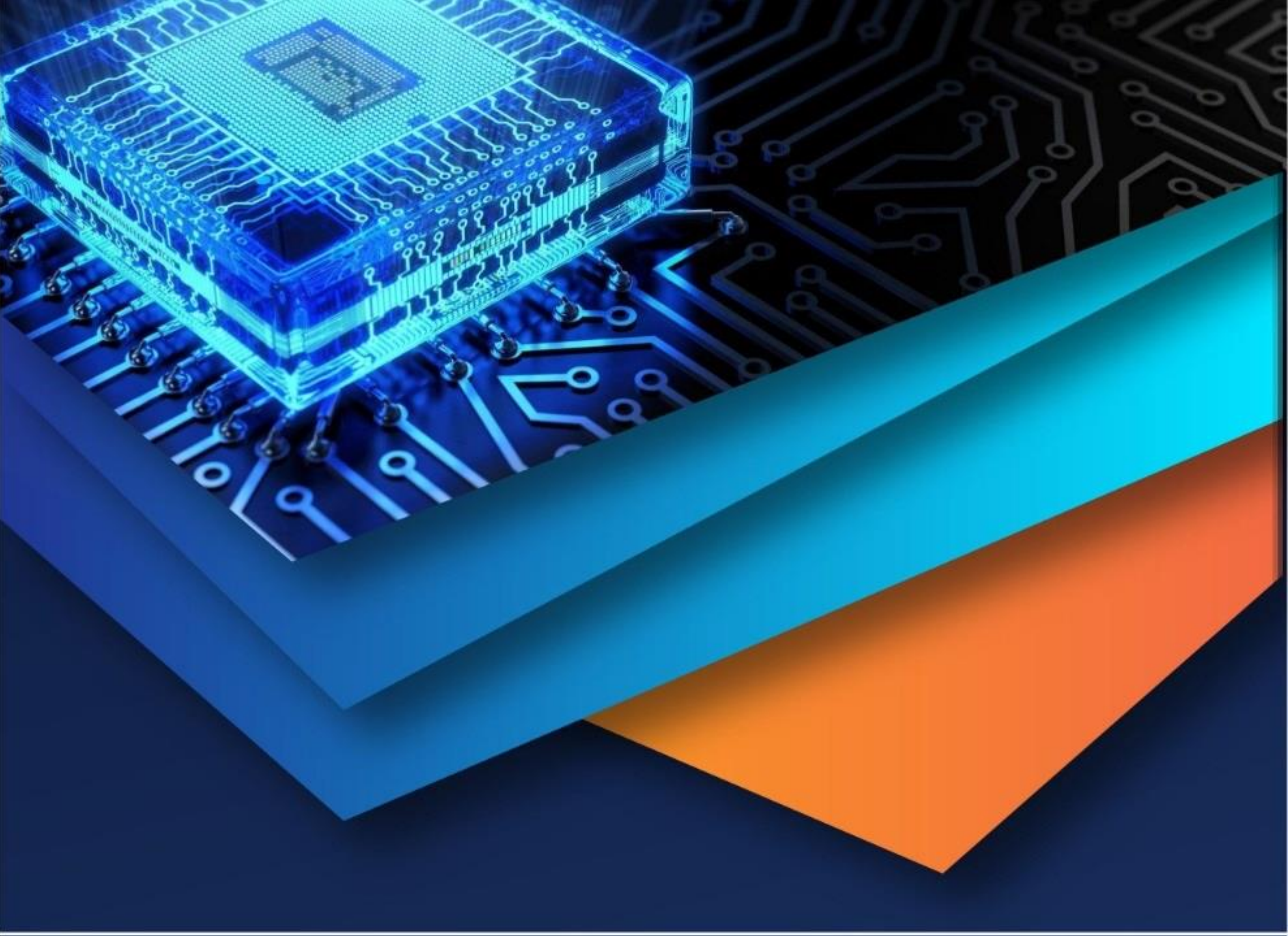

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