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Analysis of effects of height of substrate on Minkowski based fractal patch antenna

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Abstract: In this paper a Minkowski algorithm based antenna has been designed. The Minkowski fractal geometry is utilized to generate multiple frequency bands as well as to provide a miniaturized design .The proposed antenna has been designed in three steps. In the first part no iteration has applied as shown in fig 2.The configuration of the antenna are having FR4 substrate with relative permittivity €sub=4.4 and thickness t=1.59mm having dimensions L× W=80 mm×80mm. In this paper change of dielectric material has been experimented where dielectric material of substrate changed and simulated results are obtained return loss minimized up to -50db and bandwidth obtained up to 1 GHz. Designed simulated on HFSS tool.
Keywords: Microstrip line, Dielectric loading, fractal antenna, multifrequency antenna, slot antenna.

I. INTRODUCTION

TODAY world of wireless communication, small, compatible and cheap microstrip patch antennas are required. A microstrip patch antenna is used to process ultra high frequency signals. Microstrip patch antenna is a wideband, narrow beam, occupy less space antenna placed over an insulating material such as FR4, glass, ceramic etc whose dielectric constant lies between $2.2 \leq \varepsilon r \leq 12$ The microstrip antenna mainly consist of Ground , Substrate , patch and feed line. The base of the antenna is known as ground plane. Just above the ground with the same dimension a substrate is placed. A substrate is the intermediate part of the antenna having different dielectric constant. The patch in the antenna is made of a conducting material CU (copper) or Au (gold) and this can be in any shape rectangular, circular, triangular, and elliptical or some other common shape. Microstrip antennas are used mostly in many applications such as WIMAX (worldwide interoperability microwave access), WI-FI(Wireless fidelity), USB dongle, satellite radio or cell phone receiver or is mounted on an aircraft or spacecraft due to their compact size, less weight, low cost on mass production, ease of installation with multi-frequency bands. The disadvantages of patch antenna are narrow B.W., lower gain and surface waves. High dielectric constant is the simplest solution but it cause narrow B.W. and poor efficiency For obtaining multiband, wideband characteristics different techniques such as stub loading, cutting a resonant slot inside the patch, fractal geometry is used. This technique is used to reduce the size of patch antenna. Stacking of patches is the common technique to introduce multiple bands. The primary aim of this paper is to design a multiband antenna confirming to multiple wireless standard. One major disadvantage of etching multiple slots on a patch antenna is that it reduces the overall gain of the antenna as major portion of the antenna as major portion of the antenna is etched out. FRACTAL means broken or irregular fragments. They do not have a predefined size or shape and composed of multiple copies of themselves. In this paper we are using two iterations on patch antenna also known as Minkowski Fractal Island.

II. ANTENNA DESIGN AND IMPLEMENTATION

Multiband fractal patch antenna has been designed using Minkowski fractal geometry. Square shaped fractal patch antenna is obtained by three iterations of fractal geometry to form self-similar geometry. The proposed antenna has been designed in three steps. In the first part no iteration has applied as shown in Figure 2.The configuration of the antenna are having FR4 substrate with relative permittivity €sub=4.4 and thickness t=1.59mm having dimensions L× W=80 mm×80mm. The 50Ω CPW feed line is designed to have a center conductor with of s=6mm and a gap with of 1mm. The antenna has been designed by using transmission line model which is most accurate method

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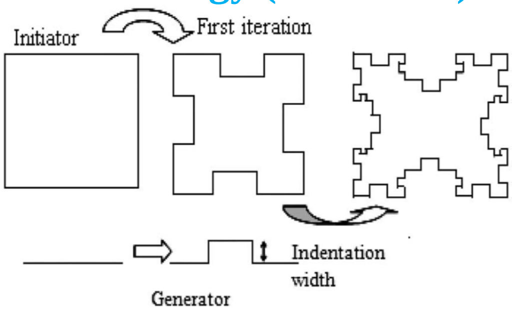
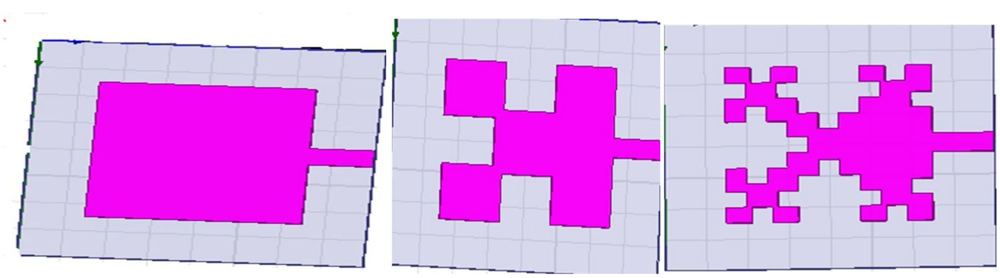


Figure 1: Generation of Minkowski Fractal Island

Table-1**:** Design parameter and corresponding values

Subject	Dimensions
Ground Size	80×80mm
Patch Size	50×50mm
Loss Tangent	.02
Feed line size	6×15 mm
Substrate Used	FR4
Thickness	1.59 mm
Feed line Technique	Microstrip line feed.
Feed point	(37,65,1.64)
Length of 1st iteration Fractal cut	15mm
Length of 2nd iteration fractal cut	5mm

Minkowski fractal geometry algorithm has been applied to square patch and different fractal geometry iterations are shown by Figure 2 (a), 2 (b), and 2 (c). In these geometries ground plane configurations remains same. Here square patch having a length of 50 mm is taken as shown in Figure 2 (a) and microstrip feed line has been given at (37,65,1.64). Feed point has been chosen in such a way that impedance matching of 50Ω take place. Square patch as shown in Figure 2(b) is made by using concept of fractal geometry. Vertical length of 50 mm is divided into 3 parts, each of length 15 mm. Two cuts are made in vertical direction i.e. along x-axis.and one cut along y-axis. This square shaped patch is example of microstrip patch antenna with slot cut inside it. Now to make square shaped fractal square cuts of length 5 mm are made in each square of dimension 15mm. This design is made using HFSS13.0 simulation software.



(a) (b) (c)

Figure 2: Square shaped **(a)** 0th Iteration, **(b)** 1st Iteration, and **(c)** 2nd Iteration

From Figure 2, it is clear that size of Square shape patch antenna is goes on decreasing but resonant length goes on increasing and

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area goes on decreasing.

III. RESULTS OF SQUARE SHAPED FRACTAL ANTENNA

square fractal patch antenna design are discussed and comparisons between results of different antenna designs using change in dielectric materials has made. All simulations were carried out in HFSS simulation software and tested results of fabricated antenna are compared. Return loss vs. frequency curve for different fractal geometry iterations are shown in Figure 3 .

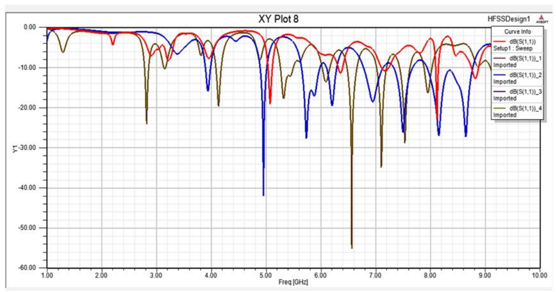

Figure 3: Return Loss Vs. Frequency for Different Fractal Iterations of Square-Shaped FWPA

For 0th iteration the antenna resonates at 6.55, 7.08, 7.52,9.2 GHz with return loss -55,-34.78,-28.82,-17.5 db. By applying 1st iteration antenna resonate at 6.18,6.93,7.50,8.64GHz with return loss -19.53,-18.49,-26.18,-27.32 dB. when next iteration that is 2nd iteration have been applied to fractal antenna it will resonate at 8.8 and 9 .42 GHz with return loss -12.81 and -21.189 dB. and remaining frequencies, return loss and gain are listed in table 2.

Table 2: Comparison Results of Different Iterations of square-Shaped fractal antenna

Iteration Number	Resonance Frequency(GHz)	Return Loss(dB)	Gain (dBi)	Bandwidth (MHz)
0th	4.11	-19.67	1.95	100.7
	5.30	-17.73	3.60	238.7
	6.07	-13.5	1.34	146.90
	6.55	-55.0	2.14	174.50
	7.08	-34.78	4.03	183.70
	7.52	-28.82	4.19	192.80
	7.94	-16.30	2.28	146.90
	9.2	-17.5	8.14	248.00
1st	3.92	-16.00	4.28	101
	4.94	-42.09	3.31	119.4
	5.72	-27.85	1.68	110.2
	6.18	-19.53	8.16	165.3
	6.93	-18.49	2.49	349
	7.50	-26.18	5.41	330.6
	8.14	-27.02	2.50	
	8.64	-27.32	4.24	826.6
2nd	5.06	-19.22	-2.41	64.3
	6.34	-11.48	1.63	91.8
	7.16	-10.91	5.23	137.7
	8.10	-22.9	7.46	55.1
	8.8	-12.81	3.72	606.2
	9.42	-21.189	5.46	514.3

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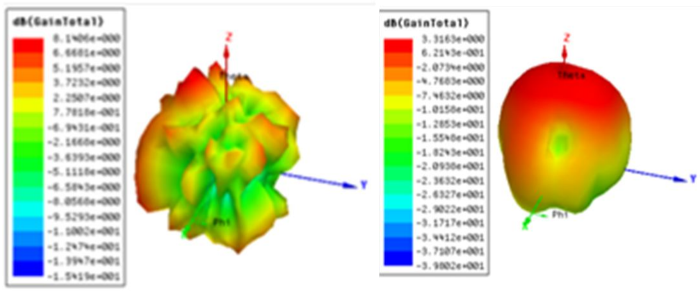
From these, it is found that, as number of iterations increases, results improves but complexity increases. From this table it is found that as number of iterations increases, resonant length increase, area decreases but number of bands increases. Here antenna is having bandwidth of 826.6 MHz in X band which could be improved.. Further characteristics of antenna can be improved by applying different dielectric material. The gain of these different resonant frequencies is listed below:



(a) (b)

Figure4: Radiation pattern of conventional patch antenna for (a) 8.14GHz (b) 8.16GHz

IV. EFFECT OF CHANGE OF DIELECTRIC SUBSTRATE

The dielectric constant plays an important role in deciding performance of antenna. If we want to minimize the size of microstrip antenna we have to used substrate of high dielectric constant, but it cause narrow B.W. ,high loss and poor efficiency due to surface wave excitation. As dielectric constant increases, the resonance frequency decreases. FR-4 epoxy and Rogers RT Duroide 5880 are two different substrates that are used mostly in microstrip antenna design. FR-4 substrate has dielectric constant of 4.4 and loss tangent of 0.02 whereas Rogers RT Duroide 5880 has dielectric constant of 2.2 and loss tangent of 0.0009. In proposed design FR-4 has been used as substrate because it reduces size of antenna and has good efficiency and bandwidth.

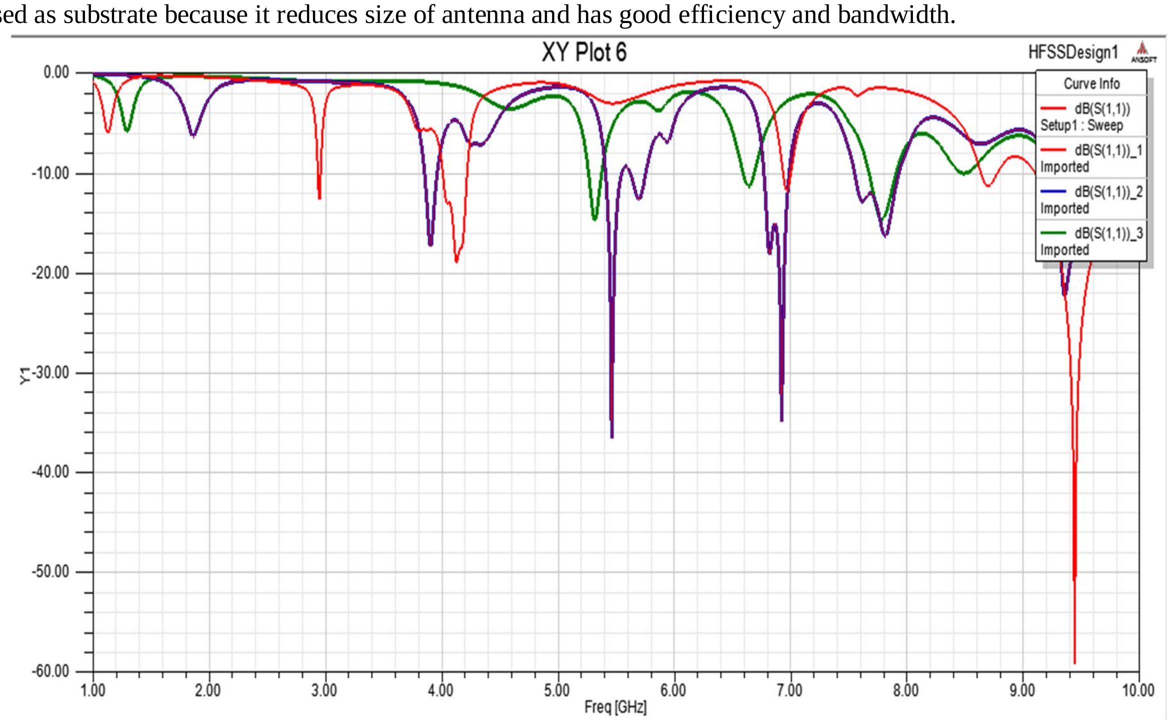


Figure 5: Return Loss Vs Frequency of Antenna for different fractal iteration of Duroide substrate

By changing substrate the antenna resonates at 7.8, 9.34 GHz with return loss -16.36,-22.25 dB and gain of 9.48, 7.34 dBi having B.W. 385 and 615 are obtained for 0^{th} iteration. When Duroide substrate applied for 1^{st} iteration gain up to 9.96 has been obtained. For 1^{st} iteration antenna resonate at 5.30,7.7 with return loss of -14.75,-14.7db and gain of 9.96,9.03 dBi having B.W of 128 and 239

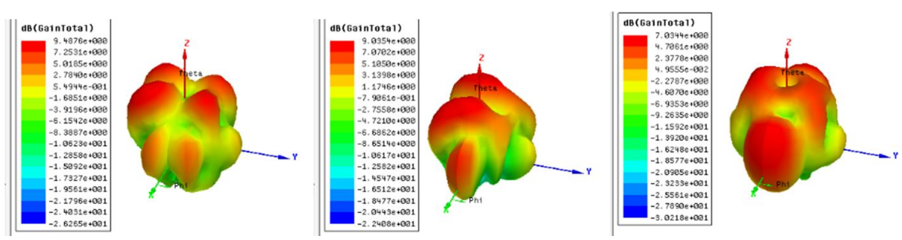
MHz For 2nd iteration when substrate has been changed antenna resonate at 4.11,6.95 GHz with return loss -18.8,-11.7 dB and gain of 2.78,7.03 dBi having B.W of 211 and 64 MHz

Table 3: characteristics of square-shaped patch antenna using Duroide substrate

Iteration number	Resonant frequency(GHz)	Return loss (dB)	Gain (dBi)	Bandwidth (MHz)
0th	3.89	-17.40	3.64	120
	5.45	-36.46	5.20	150
	6.91	-34.98	4.40	220
	7.8	-16.36	9.48	385
	9.34	-22.25	7.34	615
1st	5.30	-14.75	9.96	128
	6.62	-11.39	8.37	101
	7.7	-14.7	9.03	239
	9.35	-16.57	7.90	201
2nd	2.93	-12.6	-2.65	36
	4.11	-18.8	2.78	211
	6.95	-11.7	7.03	64
	9.43	-59.03	1.05	753

The gain results at different frequencies are:

When Duroide material is used as substrate antenna has maximum gain up to 9.96 db and bandwidth up to 753 has been obtained.



(a) (b) (c)

Figure.6: Radiation pattern of patch antenna using Duriode for (a) 7.8GHz (b) 7.7GHz and 6.95GHz.

V. EFFECT OF ROGERS MATERIAL

When we are using Roger as a substrate, antenna resonate at frequencies 6.49,8.09 GHz with return loss of -22.87 and -26.43 dB having Bandwidth of 280 and 600 MHz.For 1st iteration antenna resonate at 7.44,8.9 and 9.8 GHz with return loss of -23.72,22.28 and -12.87 having bandwidth of 480,380 respectivelt. For 2nd iteration antenna resonate at 7.56,8.20 and 8.56 Ghz with return loss of -23.67,-11.02 and -22.97 having bandwidth of 140,100 and 810 MHz.

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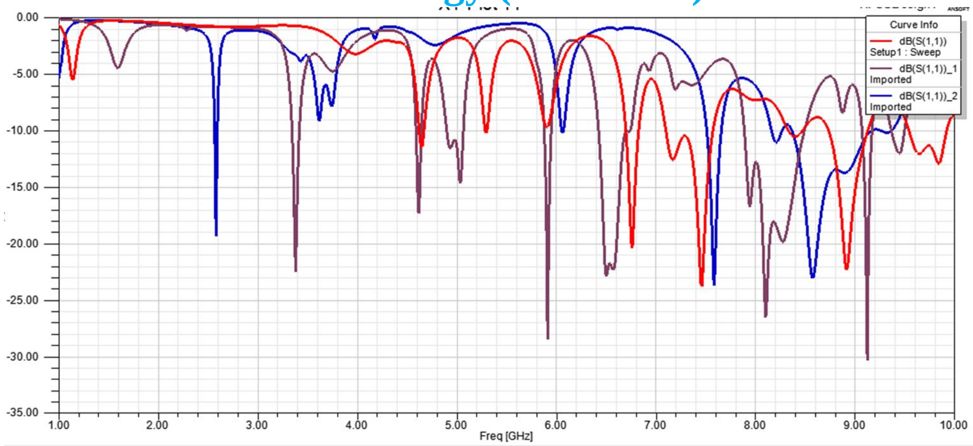

Figure 7: return loss vs. frequency Antenna for different fractal iteration of Rogers substrate

Table 4: characteristics of square-shaped patch antenna using Rogers substrate

Iteration number	Resonant frequency (GHz)	Return loss (dB)	Gain (dBi)	Bandwidth (MHz)
0^{th}	3.36	-22.47	1.18	70
	4.6	-17.21	2.56	60
	5.02	-14.54	5.66	180
	5.89	-28.45	2.45	80
	6.49	-22.87	8.33	280
	8.09	-26.43	8.23	600
	9.11	-30.31	6.86	80
1^{st}	4.63	-11.48	8.22	50
	5.28	-10.21	7.90	40
	6.75	-2032	9.32	90
	7.44	-23.72	6.21	480
	8.9	-22.28	9.68	380
	9.8	-12.87	9.59	380
2^{nd}	2.56	-1934	-2.84	20
	7.56	-23.67	8.60	140
	8.20	-11.02	7.26	100
	8.56	-22.97	7.00	810

The radiation pattern at different frequencies are shown below:

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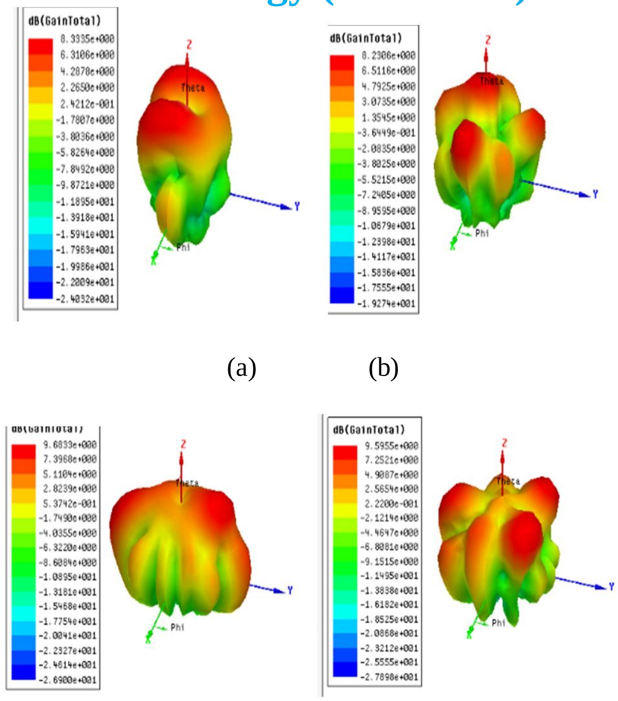

(a) (b)

(c) (d)

Figure8: Radiation pattern of patch antenna using Rogers for (a) 6.49GHz (b) 8.09GHz (c) 8.9 GHz and 9.8GHz.

By using Rogers as a substrate antenna resonates at different frequencies as mentioned in the table having different gain shown above having maximum gain up to 9.68 db has been obtained by using Rogers.

VI. CONCLUSION

A Square shaped fractal patch antenna has been designed and the simulation results have been produced. The antenna is designed to operate at higher multiband applications. Different iteration produces the result which uses in different applications such as used forWi-MAX, WLAN and defence and secure communication application. The main parameters at the operating band such as return loss, gain and bandwidth have been studied.

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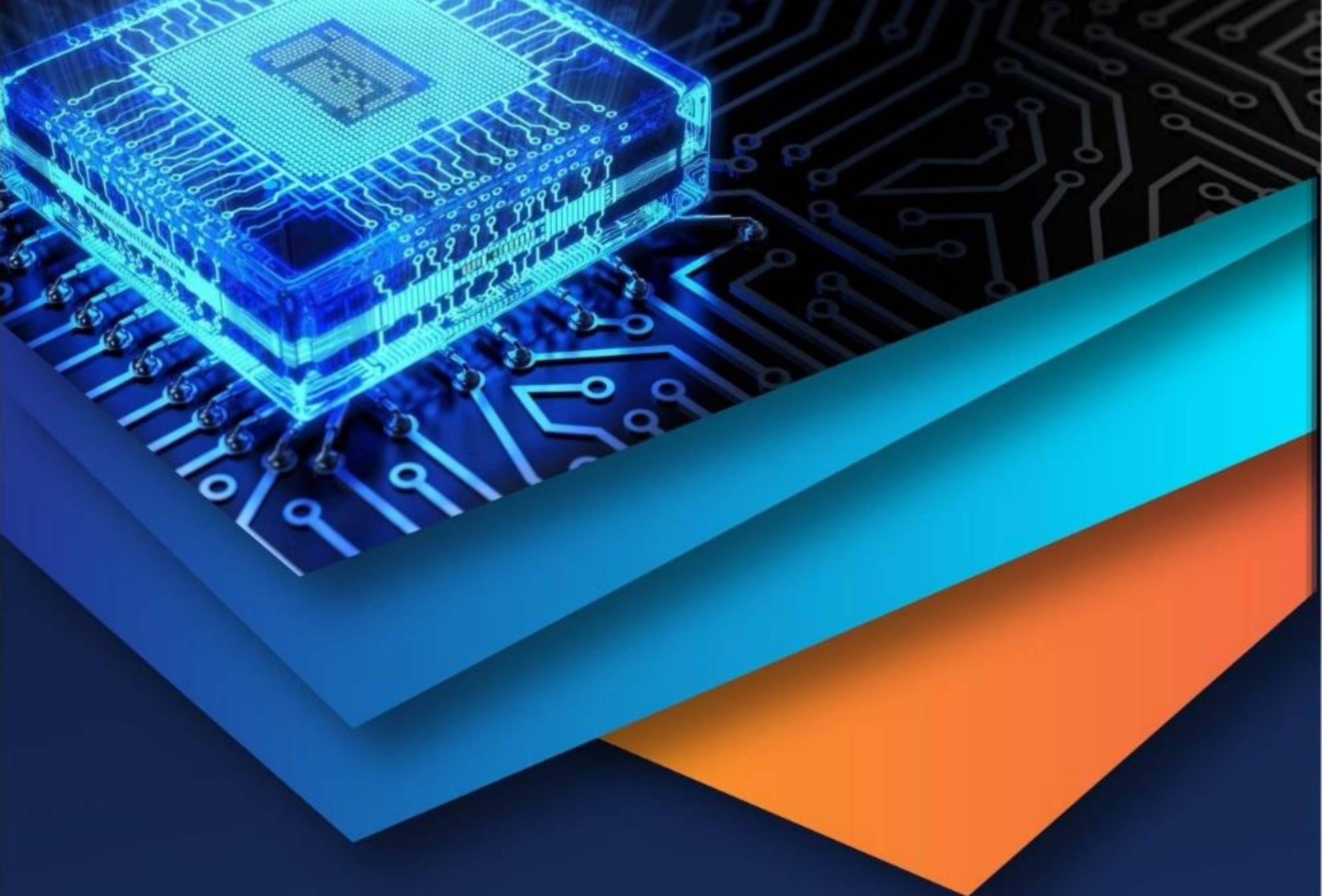

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