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Design and Analysis of MIMO Dual Band Patch Antenna for 5G New Radio Applications in Mobile Terminals

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Abstract: ***This paper presents a dual-band MIMO antenna design with compact size for 5G communication under 6 GHz band frequency. The metallic monopole stub structure is used to miniaturization of antenna. The L-shape monopole antenna is modified by adding semi-circular element in radiating structure of monopole to obtain dual-band resonance. The High isolation is achieved by employing T-shaped stub in ground plane.It has compact size is 45 mm × 25 mm × 1.6 mm^3. The proposed Dual Band MIMO antenna has been design on FR4 material with εr = 4.4 with 1.6 thickness. The proposed antenna has 5G application in the bands of 2.5 GHz (2.34 GHz-2.62 GHz) and 3.5 GHz (3.20 GHz-5.20 GHz). The bandwidth of antenna getting 320MHz and 2500MHz at 2.5GHz and 3.5GHz respectively. The Isolation (S21) of proposed antenna is -31.2 dB at 2.5 GHz and -19.5 dB at 3.5 GHz. VSWR is less than 1.06 for both the bands. The designed dual band MIMO antenna covers 5G bands of 2.3-2.4GHz (n30/n40), 2.4-2.5GHz (n7/n38/n41/n90), and 3.2-5.2GHz (n77/n78/n80). The experimental and simulated results observed good matching except some slight variation. This proposed dual band MIMO antenna is suitable for 5G mobile Communications.***

Index Terms: Monopole, Dual-band, Miniaturization, 5G, ECC and MIMO.

I. INTRODUCTION

The fifth generation (5G) communication has been widely discussed to provide high data-rate communications in the future. The design and testing of the 5G communication system huge on the understanding of the propagation channels [1], and a large body of channel measurements is thus required. In recent development of wireless communication techniques, multiple-input multiple-output (MIMO) technology is attracting solution [2]. Currently, 5G mobile systems are broadening their spectrum to support a high data rate. In the World Radio Communication Conference (WRC) in 2015, the 5G candidate frequency bands below 6 GHz have been widely discussed, and the following frequency ranges have been suggested: 470–694, 2300–2700, 3300–3800, and 4500–4990 MHz Among them, 2.5 GHz & 3.5 GHz has been widely considered, as it can be accepted for most of countries. Therefore this paper was focused on the propagation channel characterizations at 2.5/3.5 GHz bands.

Previously, 2.5/3.5 GHz propagation channel has been studied mainly for the Wireless applications with limited bandwidth & large size [3] [4] [5]. Compact Dual band MIMO antenna is reported in [6] with an orthogonal ground plane to have isolation more than 18 dB The Dual band monopole MIMO Antenna used T-shaped junction to improve the isolation [7]. Also high isolation is achieved by orthogonally arranging the antenna elements [8-11] which is further enhanced by using neutralization line [8], partially stepped ground (PSG) [9] and λ/4 open narrow ground slots [10]. Multiple slits-ground are used in [11] to improve isolation. Few works has been conducted on Dual band MIMO antenna for the 5G NR in mobile terminal applications.

But all this antenna [6-11] having low bandwidth and large size so with the improved bandwidth, isolation & compactness which has been taken as an objective for this research work. In this paper, a compact dual-band MIMO antenna is proposed. In proposed antenna covers 2 frequency bands of 2.5 GHz and 3.5 GHz with excellent impedance bandwidth of 320MHz & 2500 MHz respectively. The high Isolation S12< -28dB and S12< -18 dB over the lower and higher frequency band are achieved.

II. ANTENNA DESIGN AND GEOMETRY

The dimensions and geometry of the proposed dual band MIMO antenna is shown in Fig. 1. The proposed dual band MIMO antenna has been design on FR4 Substrate with εr=4.4 and thickness (h) is 1.6mm. Partial ground plane with T shape stub element is used to improved isolation character tics of dual band MIMO antenna. Each antenna element has an inverted L shape monopole antenna with semi-circle strip attached and is fed by a 50 Ω Microstrip line. The two antenna elements of the diversity antenna are a separation distance of 18 mm in the *y*-axis direction. The inverted L shape monopole operated at high freq 3.5GHz. The total length (L1+L2) of monopole calculated using Eq. (1),

$$L = \frac{C}{4f_1\sqrt{\varepsilon_{reff}}} \qquad (1)$$

Semi-circle Arc is developed to function at a second operating frequency of 2.5 GHz. The radiating semi-circular arc radius is estimated by Eq. (2) where C represents the circumference of the semi-circular and Calculated by Eq. (3)

$$C = \pi R \qquad (2)$$

$$C = \frac{C}{(4f_2\sqrt{\varepsilon_{reff}})} \qquad (3)$$

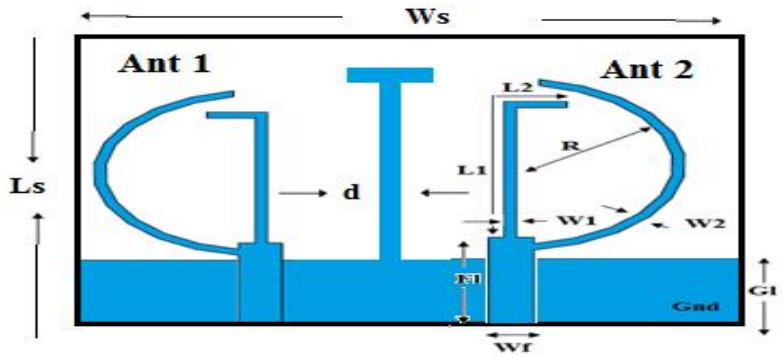
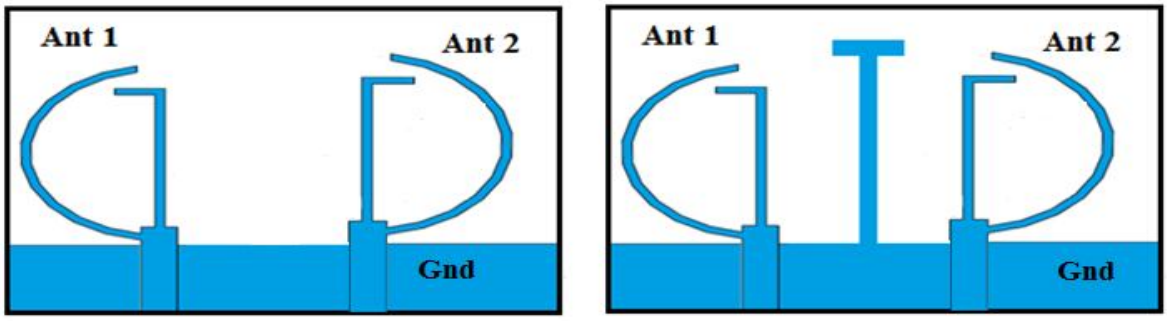


Figure 1. Geometry of the Proposed Dual band MIMO antenna

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
L1	11.0	Ls	25.0
W1	0.5	Ws	45.0
L2	2.5	W2	0.5
R	6.0	Wf	1.8
Gw	14.0	Gl	6.0
Fl	7.2	d	18.0

Table 1: Optimized Parameter Values



(a) Without T stub (b) With T stub

Figure 2. Geometry of the Proposed Dual band MIMO Antenna with and without stub

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III. RESULTS AND DISCUSSION

The proposed dual band MIMO antenna has been design using HFSS software. The mutual coupling reduction process is taken care by the slots in the ground plane and T-shaped ground stub. T-shaped stub as extended ground plane used dual band MIMO antenna acts as a reflector at lower band and reduces space waves and near field coupling.

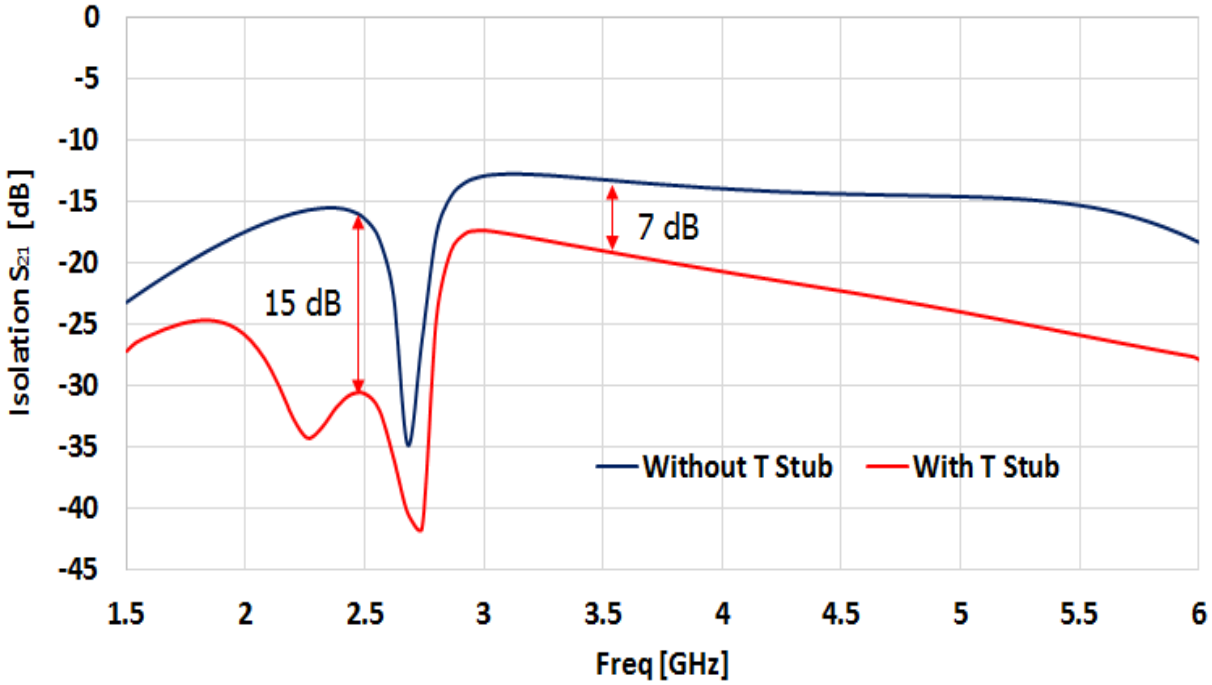
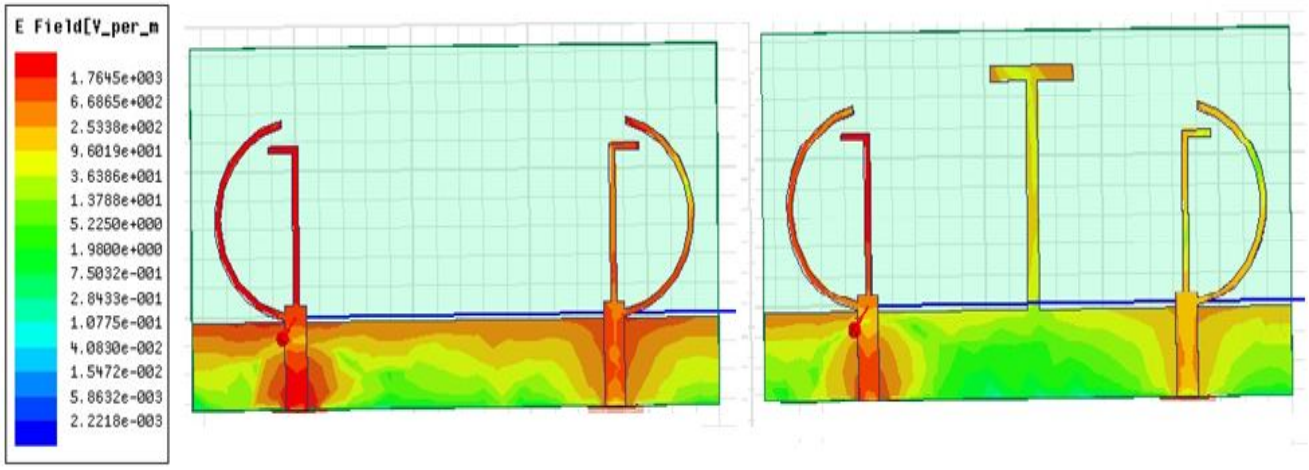


Figure 3: Simulated Isolation (S21) of Dual Band MIMO antenna structures

Figure 3 shows the isolation S21 of Dual band MIMO antenna with & without T shape stub it can see that S21 value is -31.34 at 2.54 GHz and is -19.58 at 3.66 GHz.This is indicate that significant improvement in isolation S21 in MIMO with T shaped stub element. It can be seen that antenna without stub has poor isolation about 15 dB in the whole 2.5 GHz band when the conventional partial ground plane is used. Mutual coupling between the proposed MIMO antennas is reduced up to 15 dB at lower band 2.5GHz and 7 dB at upper band 3.5GHz by modifying the ground plane with stub techniques.



(a) Without T stub (b) With T stub

Figure 4. Surface current distribution (a) without T stub (b) with T stub.

Table 2. Comparison table of Dual band MIMO Antenna with and without T Stub.

Sr. No.	Results	Frequency (GHz)	S11_S22 (dB)	S12_S21 Isolation (dB)	VSWR	BW (MHz)	Gain (dB)
1.	Dual band MIMO without Stub	2.50	-21.30	-16.42	1.18	320	2.9
		3.50	-25.42	-13.45	1.14	2000	4.7
2.	Dual band MIMO with T Stub	2.50	-31.50	-31.34	1.05	320	3.0
		3.50	-26.59	-19.58	1.11	2400	4.8

When one of the two elements is excited, a strong current is induced in the other element in the absence of the T stub which shown in fig.4.a. After added the T shape stub element in gnd plane, the induced current in the non-excited element weakens. A very low current on second element antenna 2 which shown in fig. 4.b.

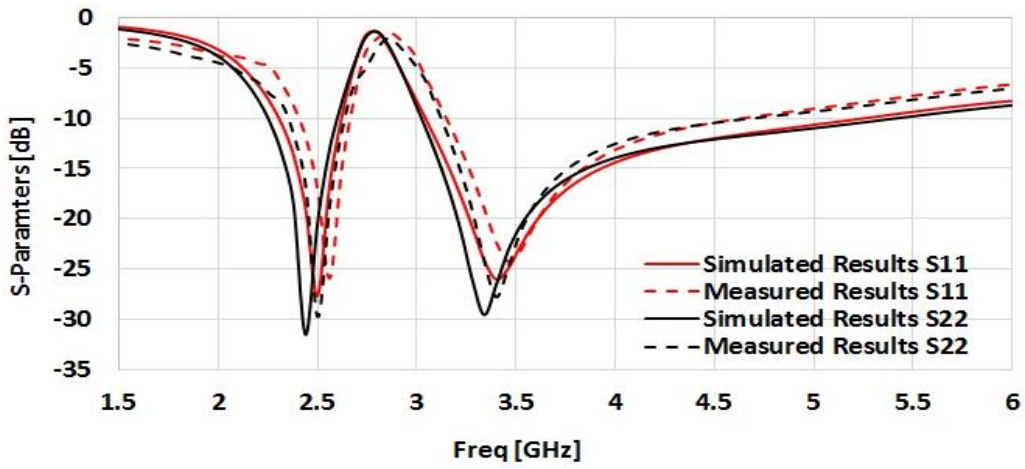


Figure 5. Simulated vs. Measured S-Parameters of proposed dual band MIMO antenna.

Figure 5. Conclude that simulated and measured S11 & S22 observed good agreement except some slightly variations. The proposed dual band MIMO antenna offers bandwidth of 320 MHz at 2.5 GHz and 2500 MHz at 3.5 GHz.

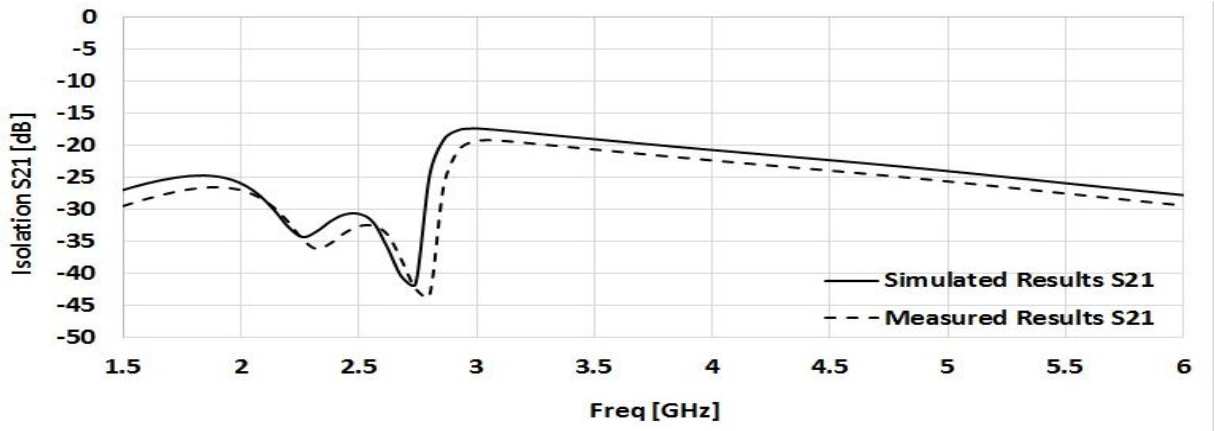


Figure 6. Simulated vs. Measured Isolation (S21) of proposed dual band MIMO antenna.

The simulated vs. measured Isolation (S21) plot is displayed in Fig. 6. Isolation S21 > 28 dB in the lower band at 2.5 GHz and S21 > 18 dB in the upper-band at 3.5 GHz.

Figure 7(a)-(b) shows simulated & measured radiation pattern in E-plane & H-plane of proposed dual band MIMO antenna at 2.5 GHz, and 3.5 GHz. The good matching observed between simulated and measured radiation patterns.

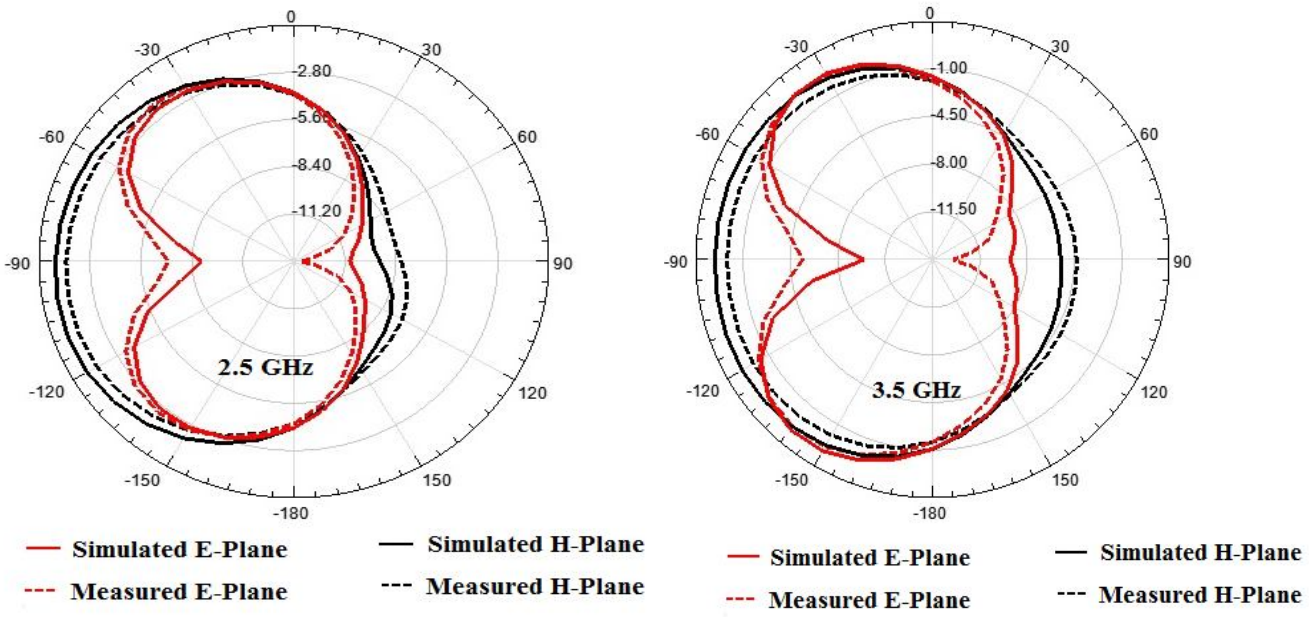
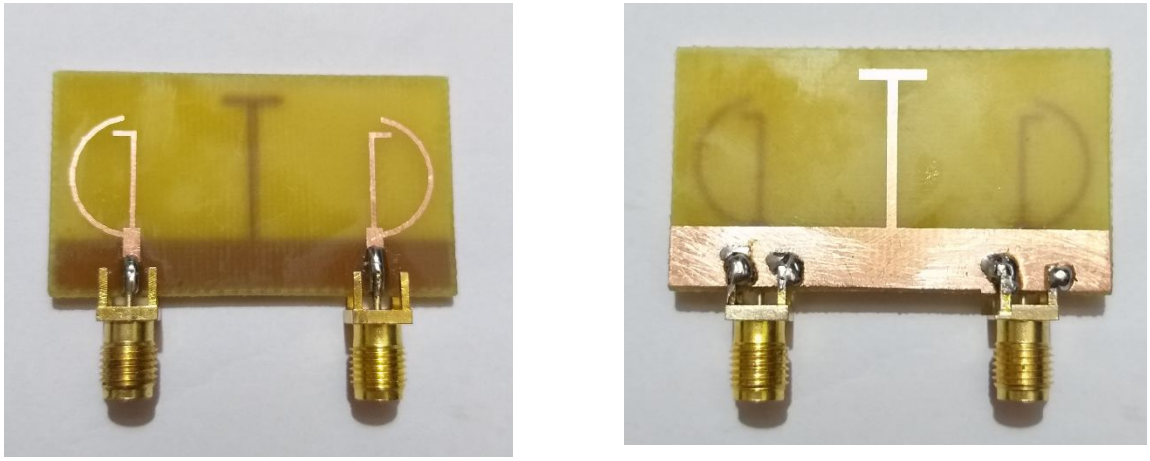


Figure 7. Simulated vs. Measured Radiation Patterns of proposed dual band MIMO antenna at (a) 2.5GHz and (b) 3.5GHz.



(a) TOP View (b) BOTTOM View

Figure. 8. Shows the Fabricated Prototype Proposed Dual band MIMO antenna with top view and bottom view.

Antenna	Size(mm^2)	Frequency (GHz)	Isolation (S21) (dB)	Gain [dB]	ECC
Ref [6]	43 x 38	2.7 /5.3	12 / 15	NA	0.001
Ref [7]	140 x 70	1.9 / 2.5	13 / 14	3.8	0.5
Ref [8]	40 x 34	2.4 / 5.2	10 / 15	2.5	0.004
Ref [9]	70 x 70	2.5 / 5.2	17 / 18	4.0	0.004
Proposed Work	45 x 25	2.5 / 3.5	31 / 19	4.8	0.001

Table 3: Performance comparison of the proposed dual band MIMO with reference antennas.

It is showing that the overall size of the proposed dual band MIMO antenna are smaller as compared to [6-9]. Also seen that we achieved high isolation (S21) up to 30 dB at 2.5 GHz.

IV. CONCLUSION

A compact dual-band MIMO antenna is presented for 5G NR in mobile terminal applications. The overall size of antenna is very small 45×25×1.6 mm3. In design steps of dual-band antenna started with simple L-shape monopole for 3.5 GHz is designed and then and adding half semi-circle strip in radiating monopole patch structure to obtain dual-band band resonance. The frequency and bandwidths of the bands can be adjusted by tuning the lengths of the attached L-strip & Semi circle of monopole. The isolation S21 of proposed dual MIMO Antenna without stub element is -15.2dB and -13.4 dB at 2.5 GHz & 3.5 GHz respectively. Using with T stub element isolation enhanced by 15 dB at 2.5GHz and 7.2 dB at 3.5 GHz.The proposed Dual band MIMO antenna has very high isolation -31.5 dB at 2.5GHz and -19.5 at 3.5 GHz achieved. The Radiation pattern is stable both dual frequency bands with maximum gain of 4.8 dBi.The experimental and simulated results observed good matching except some slight variation.

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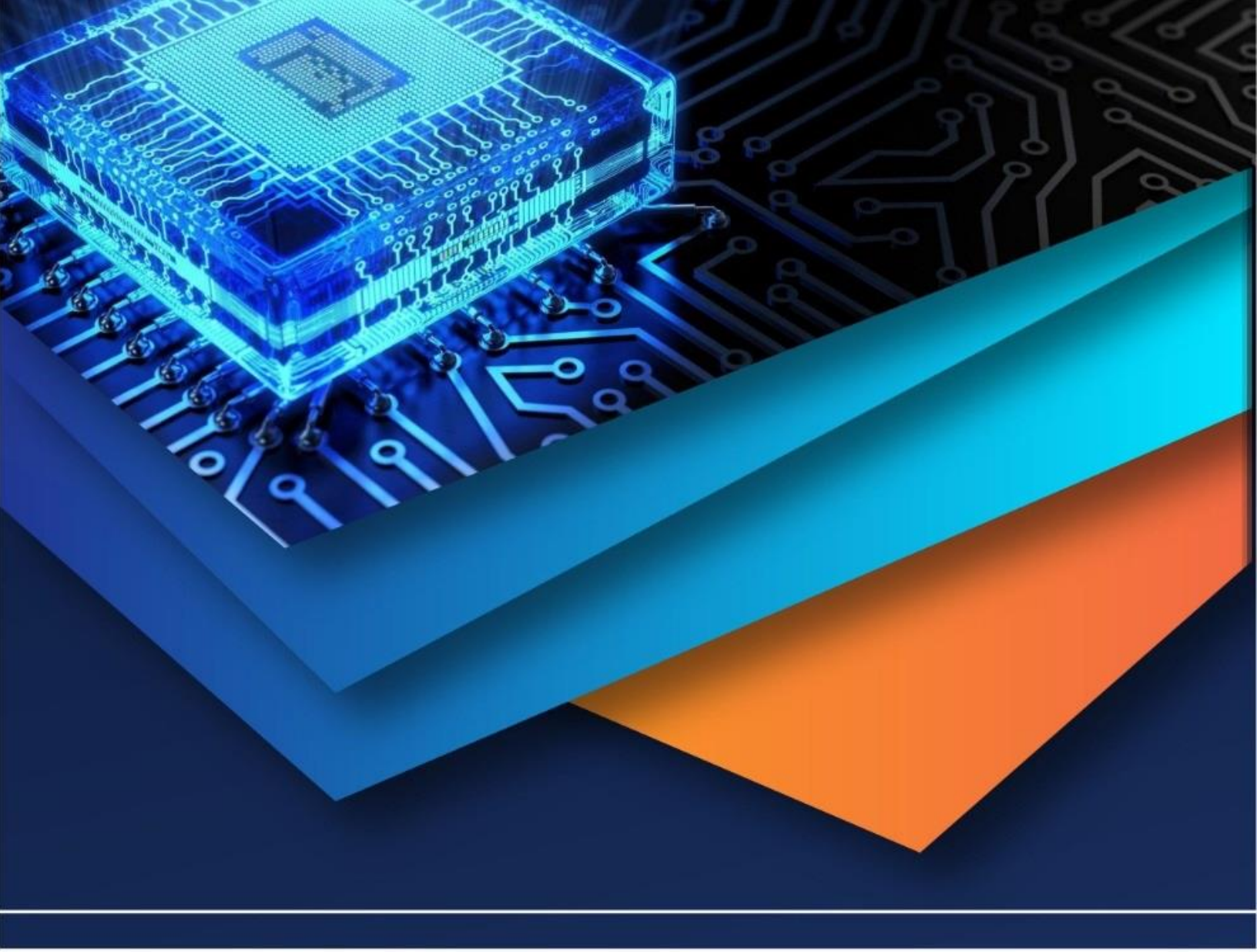

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