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A Reconfigurable Microstrip Patch Antenna for Various Wireless and Cognitive Radio Applications

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Abstract: Cognitive radio is an apparent technology for coherent use of the radio spectrum where, the spectrum can be used by the unlicensed users without interference with the licensed users. Reconfigurable antennas provide a potential solution to solve the antenna problems related to the cognitive radio system using the ability to switch frequency, radiation patterns and polarization. In this paper a reconfigurable microstrip patch antenna for possible applications in cognitive radio systems is presented. This work provides a methodology to design reconfigurable antennas with PIN diode switch. The reconfigurability is achieved in the frequency ranges from 4.3 GHz to 8.3 GHz respectively. To switch between the frequencies in the cognitive radio, the frequency reconfigurability is done. The PIN diode switch is used to change the dimensions of the patch and to make the antenna to resonate at various frequencies. The proposed antenna is simulated using Ansoft HFSS software. The results show with only two switches 9 different transmitting frequencies are available which are useful to implement cognitive radio applications.
Keywords: Cognitive radio, Ansoft HFSS, PIN diode, Reconfigurable antenna, microstrip patch antenna, reflection coefficient.

I. INTRODUCTION

The main goal of cognitive radio system is to determine the spectrum holes using an ultra wide band sensing antenna and to transmit using a narrow band frequency reconfigurable antenna in the identified free channels [4], [8], [9]. The main feature of cognitive radio is to sense the communication environment to maximize the quality of service for the secondary users and to minimize the interference with the primary users. Reconfigurable antennas can be achieved by many techniques that alter the electromagnetic fields with respect to antennas aperture by redistributing the currents by electrical, optical, and mechanical means.

Reconfigurable antennas are needed to cover different wireless services over a wide frequency range. So in order to be able to transmit at any frequency a frequency reconfigurable antenna is required for a cognitive radio system. By altering the frequency of operation a cognitive radio is able to communicate efficiently across channel. To meet this requirement a rectangular patch antenna can be used. It has light weight, planar structure, low cost and ease of design. Hence it is more useful as a communicating antenna. Reconfigurability can be achieved by using different types of switches like FET, PIN-Diode and varactor diode, among them PIN – Diode is being mostly used due to its high switching speed [2], [5]-[7].

A rotatable reconfigurable antenna design has been proposed in [1]. Two different triangular shaped patches that are separated by 8mm are used. Two different positions are identified by which each of triangular shaped patches can be fed one at a time. To go from one position to the other the assembly of two patches has to be rotated by 180 degrees. The antenna can be tuned between 5.3 - 9.15 GHz in one position and 3.4 – 4.85 GHz in the other position. The problem of coupling between two antennas and the suppression is difficult, in using this approach [1], [2]. In [3] an arc shaped slot ground with circular patch antenna controlled by PIN diodes is presented. With five PIN diodes as switches, along with the radius of antenna being 40 mm, and with three capacitors of 47 pF per slot with a total of 6 slots of width 0.3 mm, to provide independent DC biasing for PIN diodes, the circular patch antenna has been designed. The band is limited to a band of 1.84 GHz – 2.46 GHz. For similar dimensions that we have in our design we identify more transmitting frequencies over a much wider band.

In this paper three reverse L-shaped patches are used which are connected by two PIN-Diode switches in order to attain reconfigurability. Frequency reconfiguration is achieved by changing the switch condition based on our requirement.

II. ANTENNA DESIGN

The proposed antenna is etched on the FR4 substrate material that has relative permittivity 4.4 and loss tangent 0.02. The proposed antenna structure comprises of central patch known as the driven patch and the adjacent patches called wing patches. PIN diodes are introduced for frequency reconfiguration. The geometry of the proposed antenna is shown in Figure 1 and the red colour in the figure represents the PIN diode switch (S1 and S2). The dimensions for the design are shown in table 1 and the substrate thickness is taken to be 0.8 mm. Transmission line is used as a feed to the antenna with an input impedance of 50 ohms. The length and width of the patch are calculated using the equations (1) and (3) and the effective dielectric constant of the substrate is calculated using the equation (2).

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{\frac{-1}{2}} \tag{2}$$

$$L = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 0.824h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{3}$$

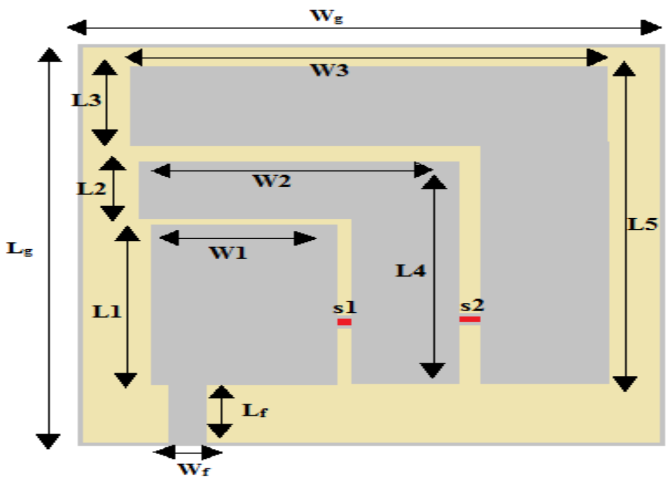

Fig. 1: Geometrical view of proposed antenna design

Table I shows the dimensions of lengths and widths of different sections of Figure 1.

TABLE I
DIMENSIONS OF THE PROPOSED DESIGN

L3	L_g	W_g	L1	L2	L4	L5	W1	W2	W3	L_f	W_f
8.5mm	45mm	38mm	16mm	7mm	20.5mm	33.5mm	12.45mm	20mm	25mm	9mm	2mm

III. SIMULATION SETUP AND RESULTS

The antenna is simulated using Ansoft HFSS software. Figure 2 shows three dimensional view of proposed structure. Reconfigurability of the antenna is implemented by using two switches S1 and S2 which incorporated between the driven and wing patch.

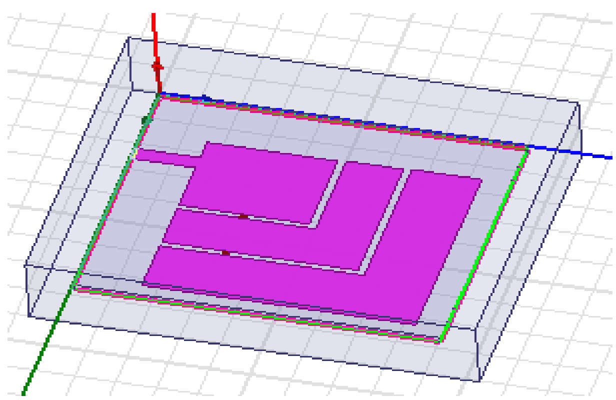

Fig. 2: 3 Dimensional view of proposed antenna

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The circuit model for on and off state of the PIN diode is shown in Figure 3. In case of on state both resistor and inductor are in series connection and in case of off state resistor and capacitor are parallel to each other and in turn series with the inductor.

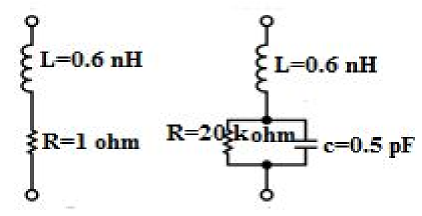


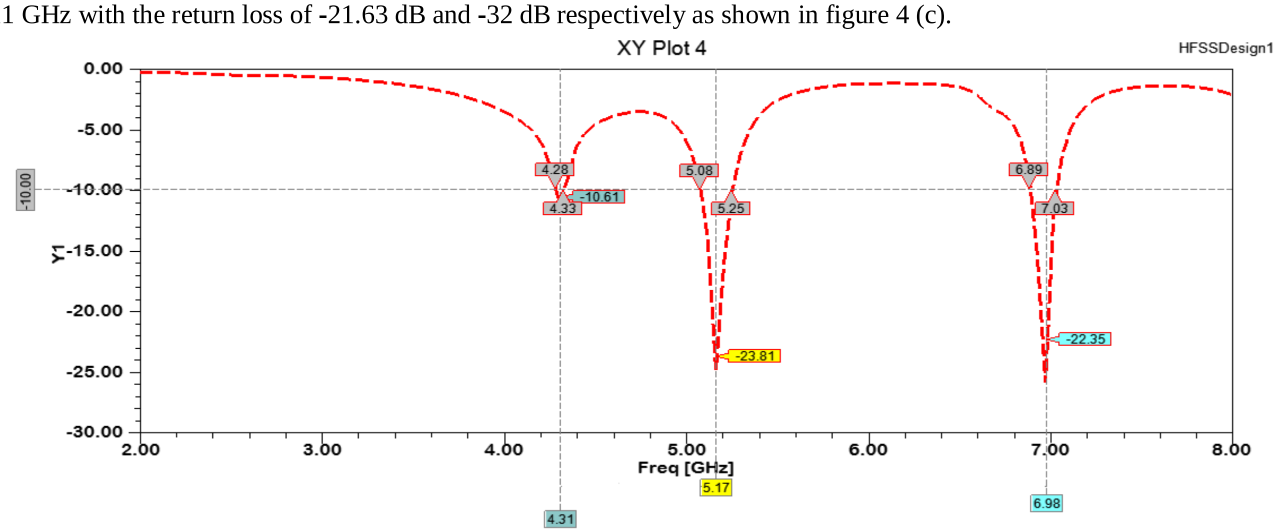
Fig. 3: On and off state circuit model of PIN diode switch

The obtained reflection coefficient result shows that proposed antenna is able to resonate at different frequencies with switch conditions as summarized in Table II.

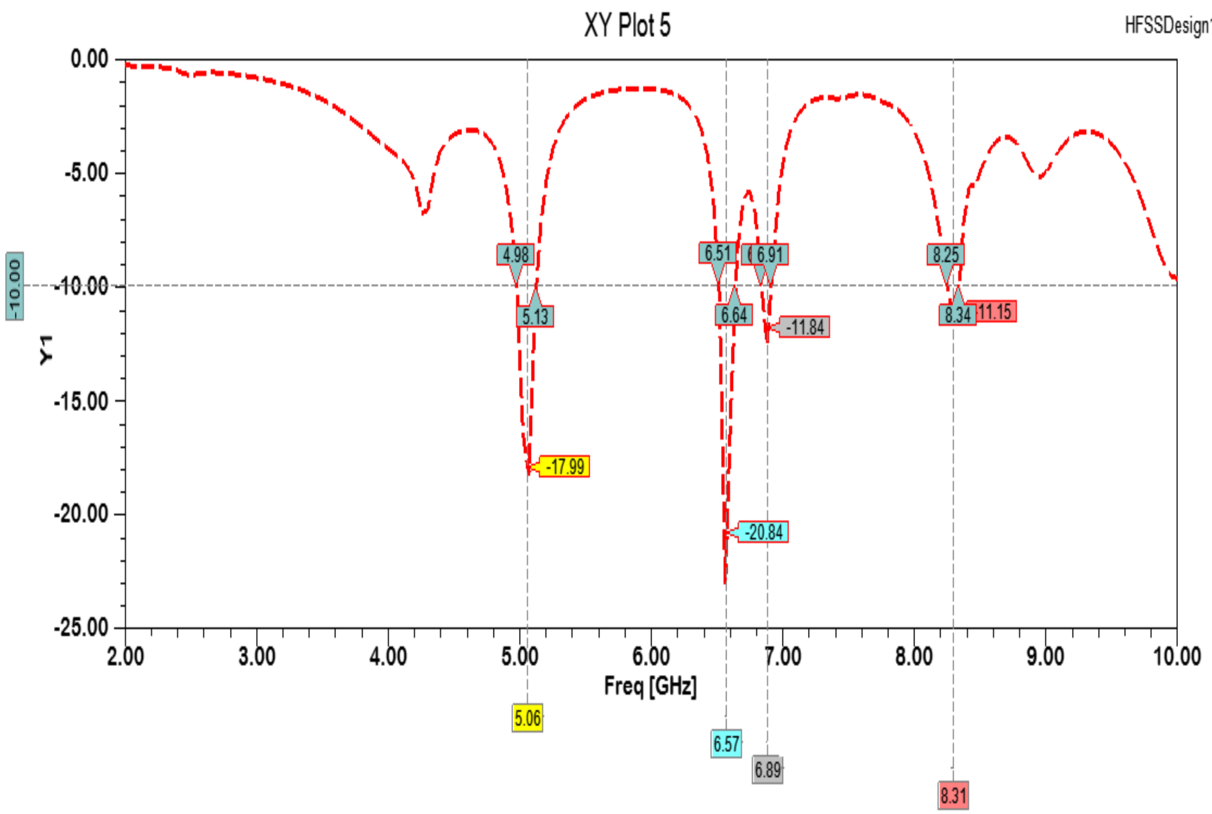
TABLE III
SWITCH CONDITION AND TRANSMIT FREQUENCY

SWITCH CONDITION	TRANSMIT FREQUENCY
All switches closed	4.31 GHz, 5.17 GHz ,6.98 GHz
All switches open	5.06 GHz, 6.57 GHz, 6.89 GHz, 8.31 GHz
S1 ON and S2 OFF	. 5.30 GHz, 7.11 GHz

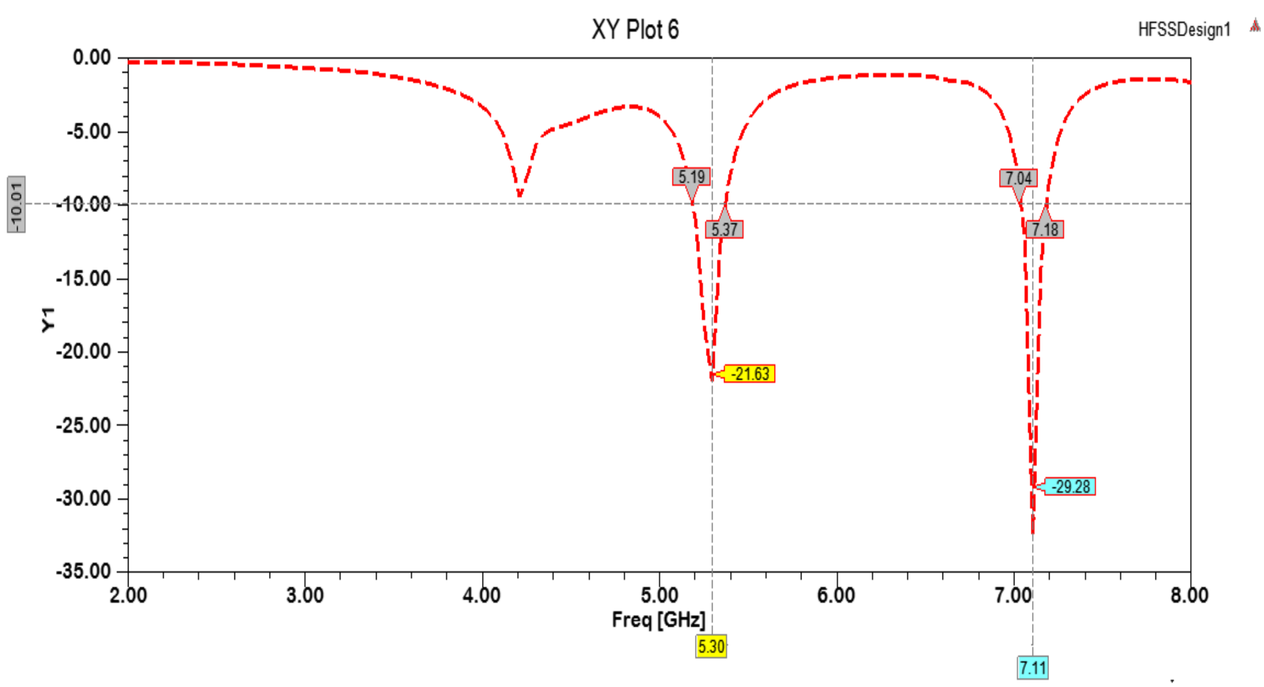
Figure 4 shows the reflection coefficient results at different switching conditions. When all the switches are closed the transmit frequency can be at three frequencies i.e. 4.31 GHz, 5.17 GHz and 6.98 GHz with return loss of -10.61 dB, -23.81 dB and -25 dB respectively as shown in Figure 4 (a). When all the switches are in 'ON' state the transmit frequency can be at four frequencies i.e. 5.06 GHz, 6.57 GHz, 6.89 GHz and 8.31 GHz with the return loss of -17.99 dB, -23 dB, -11.84 dB and -11.15 dB respectively as shown in figure 4 (b). When S1 is in 'ON' state and S2 in 'OFF' state the transmit frequency is at dual frequencies i.e. 5.30 GHz and 7.11 GHz with the return loss of -21.63 dB and -32 dB respectively as shown in figure 4 (c).



(a) All switches are in 'OFF' state.



(b) All switches are in 'ON' state.



(c) S1 is in 'ON' state and S2 is in 'OFF' state

Fig. 4: Simulated return loss plot (a) all switches are in 'ON' state (b) all switches are in 'OFF' state and (c) S1 'ON, and S2 'OFF'.

Figure 5, shows the current distribution when all switches are in 'ON' state.

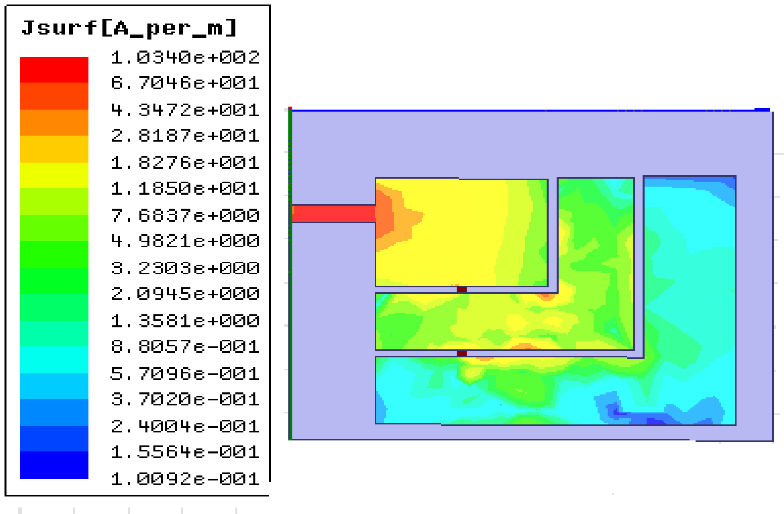


Fig 5: Current distribution on the proposed patch antenna

IV. CONCLUSIONS

The Reconfigurable microstrip patch antenna is designed and simulated in ANSYS HFSS simulation tool. The antenna achieves reconfigurability at various frequencies with use of switches between the radiating patch. The frequency reconfigurability is achieved between the frequencies 4 GHz and 8.3 GHz with good reflection coefficient. The results show a good agreement with frequency reconfiguration for various wireless applications. The proposed antenna can be utilised for WIMAX, WLAN, Satellite, Radar applications and cognitive radio applications.

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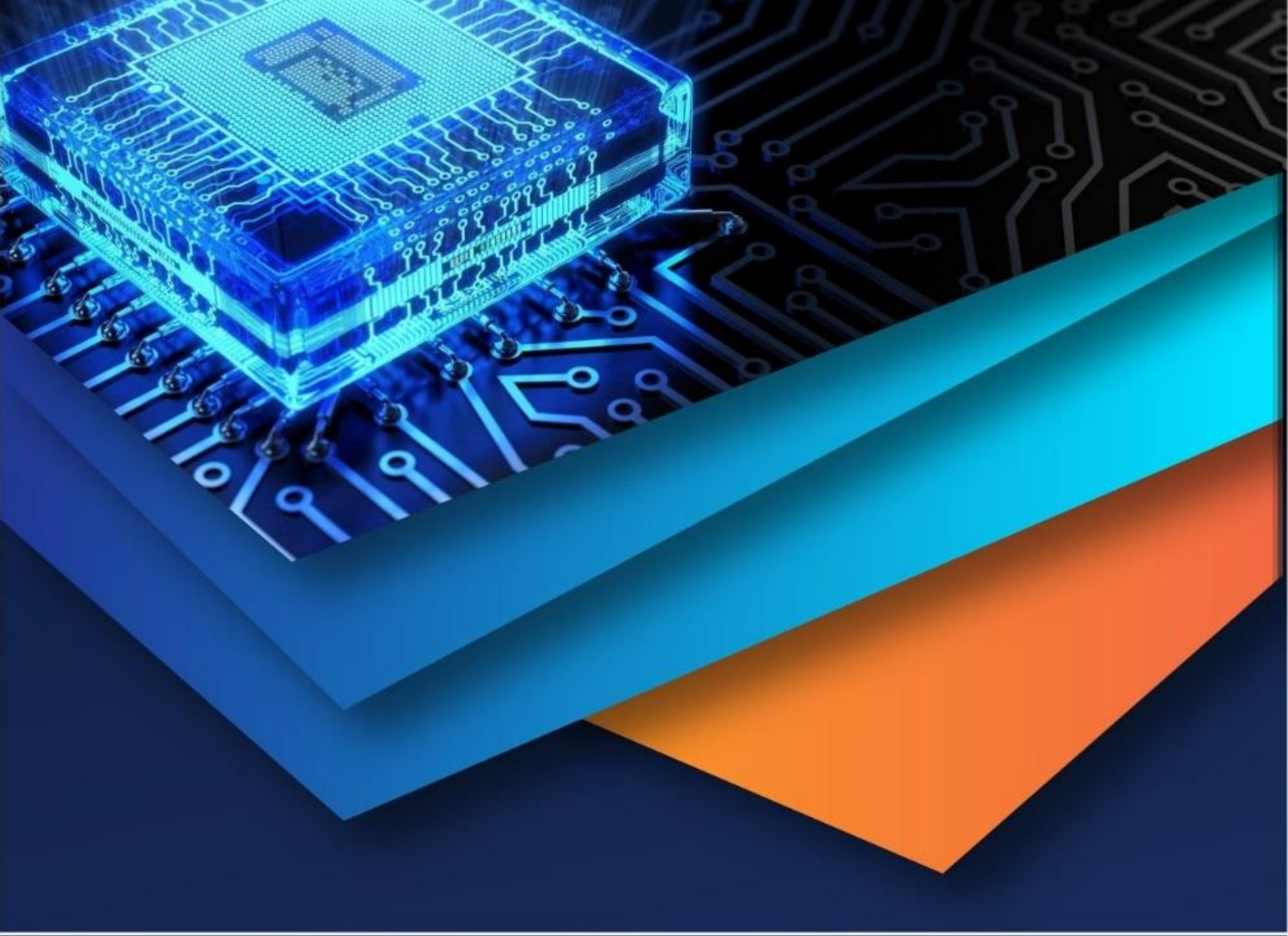

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