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Design of Active Microstrip Semi-Circular Patch for UWB Applications

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Abstract: In this paper, we have proposed a semi-circular patch antenna with a slot in the patch and a ground plane with a notch. The proposed antenna is designed using FR-4 substrate with a dielectric constant of 4.4 and the height of the substrate is 1.6mm. We simulated the antenna using HFSS and obtained the S11 < -10dB in the range of 3GHz to 15GHz, which covers the UWB range of 3.1GHz to 10.6GHz. An active circuit is designed and simulated using ADS to improve the gain of the antenna when working in a lossy medium other than air.
Keywords: Patch antenna, Bandwidth, Substrate, High Frequency Structured Simulator (HFSS), Advanced Design Systems (ADS).

I. INTRODUCTION

Communication plays a key role in development. With the introduction of antennas, communication has improved in terms of cost and bandwidth. As the free space has an infinite amount of available bandwidth when compared to other wired communication mediums it has added advantage and reduced the cost. Antennas play a key role in the transmission and reception of data wirelessly. It is a metallic device that is capable of radiating in the form of electromagnetic (EM) waves whenever the impedance of the device matches with the medium impedance. These antennas are present everywhere starting from commercial applications like T.V broadcasting and reception, mobile phones, satellite communication, to military applications like missiles, radar application.

With the increase in the population and technology, the requirement of the antenna has increased drastically. To make the devices portable, low cost, and fabrication to be easy, it requires an antenna that of light in weight and the cost of it should be as low as possible. Microstrip antennas have all these advantages of cost, ease of fabrication, low weight. The microstrip antenna has three parts- substrate, patch, and ground. The substrate is made up of dielectric material like Bakelite, FR4 Glass Epoxy, Foam, Teflon, Polystyrene, and RT Duroid can be used. Ground and patch are made up of metals and generally, copper is used because of its conductivity and cost.

The patch antennas were first suggested by Deschamps in the year 1953, but it was practically implemented by Howell and Munson in the year 1970. These patches commonly have a radiator on the top side and ground on the bottom side. There are various shapes of patch antennas that can be used to design the patch antenna some of them are square, rectangular, circular, elliptical, triangular, and semi-circular [5].

Depending on the requirement like gain, radiation pattern, return loss, the shape of the patch is chosen. Matching circuits, feed lines can be fabricated with the microstrip antennas.

Though microstrip patch antennas have many advantages, some of their disadvantages include low bandwidth, low gain, and low power handling capacity. Various techniques are used to overcome these disadvantages. The proposed system is a semi-circular patch antenna that operates in the range of 3-15GHz, thus covering the range of UWB which is approved by FCC (Federal Communication Commission) which is 3.1-10.6GHz. In our proposed antenna for making the antenna operate for a large bandwidth, the ground plane is defected and added with a notch.

Antenna when working in a lossy medium, the gain of the antenna decreases to a very large extend like when the antenna is used in underwater communication. A microwave circuit is an electronic circuit that is used to improve the gain of the antenna when working in such adverse conditions. This circuit can also be used to make the bandwidth precise as for the regulations of the FCC and it reduces the effect of noise and fading effect due to the medium.

The proposed antenna comes under the ultra wideband range and is capable of covering the range of WiMax-3,4 (3.3-3.8GHz; 5.25-5.85GHz), Wi-Fi-2 (4.9-5.9GHz), and satellite uplink and downlink frequencies (3.7-4.2GHz downlink; 5.925-6.425GHz uplink).

The rest of the paper is as follows: section II discusses the background and contributions, section III discusses the simulation of the antenna in HFSS and active circuit in ADS, Section IV discusses the results that are obtained in the simulation.

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II. BACKGROUND AND CONTRIBUTIONS

A. Problem Statement

The problem in microstrip antenna is its bandwidth and gain. The bandwidth of the microstrip antenna can be improved by increasing the height of the substrate but to achieve a compact antenna and get higher efficiencies dimensions of the antenna are to be minimum. The bandwidth of the antenna is to be as per the regulations of FCC and gain to be high, an active circuit is required.

B. Literature Survey

Many different shaped antennas were studied in literature such as circular monopole antenna with a frequency range of 2-12GHz for WPAN applications [1], a rectangular microstrip patch antenna with orthogonal crossed slits in the ground plane for higher bandwidth[2], rectangular microstrip patch antenna in the frequency range of 3.1-10.6GHz for UWB applications[4], various manufacturing technologies, comparison of materials, numerical techniques for designing of wideband and ultra wideband were discussed[6], Dual band patch antenna for UWB applications[7], compact rectangular aperture antenna for UWB applications[8], UWB printed monopole antenna with notch filter[9], novel UWB circuit using MESFET [3].

In literature, many methods were proposed and each method has its advantages and disadvantages. For the proposed antenna all the advantages are collected and the antenna and Ultra short pulse generator circuit were designed.

C. Contributions

1) The proposed antenna bandwidth is improved and the bandwidth is in the range approved by FCC for UWB applications.
2) The proposed antenna is made up of FR-4 substrate so it is cost-effective.
3) The proposed microwave circuit provides a high gain in this bandwidth.

III. SIMULATION PROCEDURE

A. Structure of the Proposed Antenna

The antenna is designed using FR-4 substrate shown in Fig (1) with a dielectric value of 4.4 and the height of the substrate is 1.6mm. The proposed antenna has a semi-circular patch with a slot and ground plane dimensions of 11.5mmX27mm and a notch of 1.5mmX3mm as shown in Fig (1).

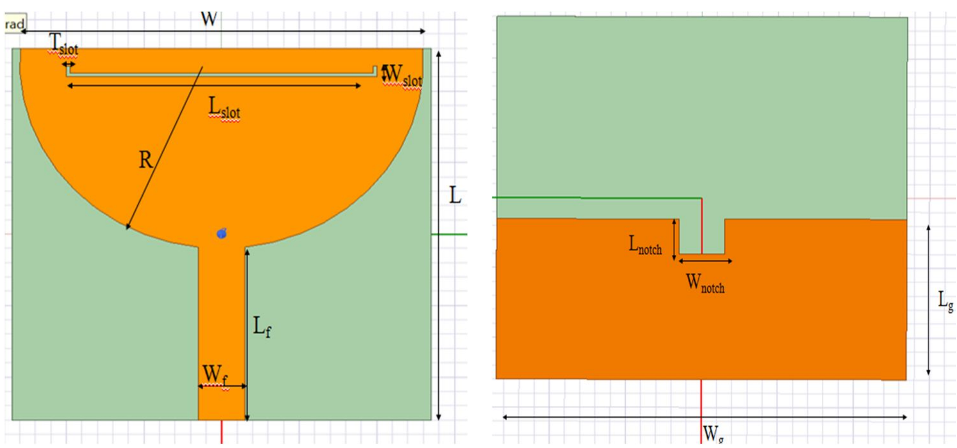

Fig 1: Proposed antenna dimensions (a)Top view, (b)Bottom view

Table 1: Dimensions of proposed antenna

L	W	L_g	W_g	L_{notch}	W_{notch}	R
26mm	27mm	11.5mm	27mm	1.5mm	3mm	13mm
L_f	W_f	H_s	L_{slot}	W_{slot}	T_{slot}	ε_r
13mm	3mm	1.6mm	20mm	1mm	0.5mm	4.4

The substrate length, width, and height are denoted by L, W, and H_s respectively, ground length, width is denoted by L_g, W_g, length, and width of notch in ground plane are represented using Lnotch, Wnotch, length, width, and thickness of slot are represented using L_{slot}, W_{slot}, T_{slot}, length and width of feed are L_f, W_f and all the dimensions are represented in the Table (1) and simulation is done using HFSS.

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B. Structure of Proposed Microwave Circuit

The proposed microwave circuit is designed using HEMT (High Electron Mobility Transistor) with microstrip lines are used to match the impedance and minimize the reflections. 1nF, 1uF, 1pF are used as blocking capacitors and 1nH inductor is used as shown in Fig (2). A PIN diode and a resistor are used to allow one pulse per cycle. The input pulse specifications are Vlow=-0.15v, Vhigh=-2.5v, pulse rate of 30MHz. The circuit generates short pulses that are ~0.5ns implies the frequency of generated pulse in the GHz range. The circuit is simulated using Advanced Design Systems (ADS) software. The obtained results are converted from the time domain into the frequency domain using MATLAB using Fast Fourier Transform (FFT).

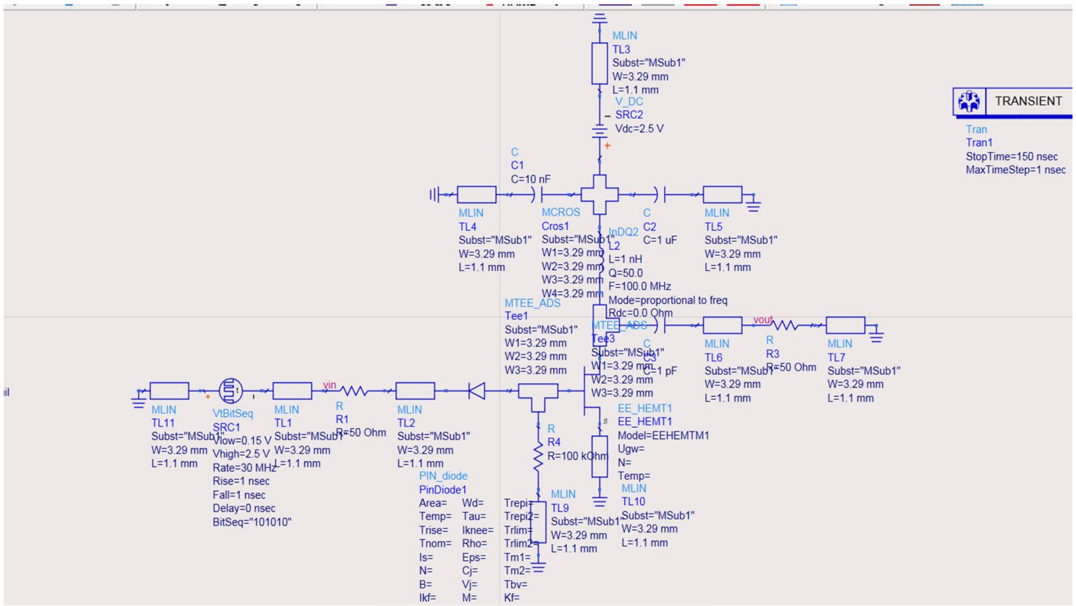

Fig (2): Ultra short pulse generation circuit

IV. SIMULATION RESULTS

A. Simulation Results Of Proposed Microstrip Patch Antenna

1) *Return Loss:* Simulation of antenna with different lengths of ground planes, the proposed antenna with ground plane length of 11.5mm, a notch in ground plane and a slot in patch gave a very low return loss. The inclusion of slot in the patch further reduced the return loss and achieved -35dB at 4GHz. In the 3.1-10.6GHz the return loss was less than -12.5dB as shown in Fig (3).

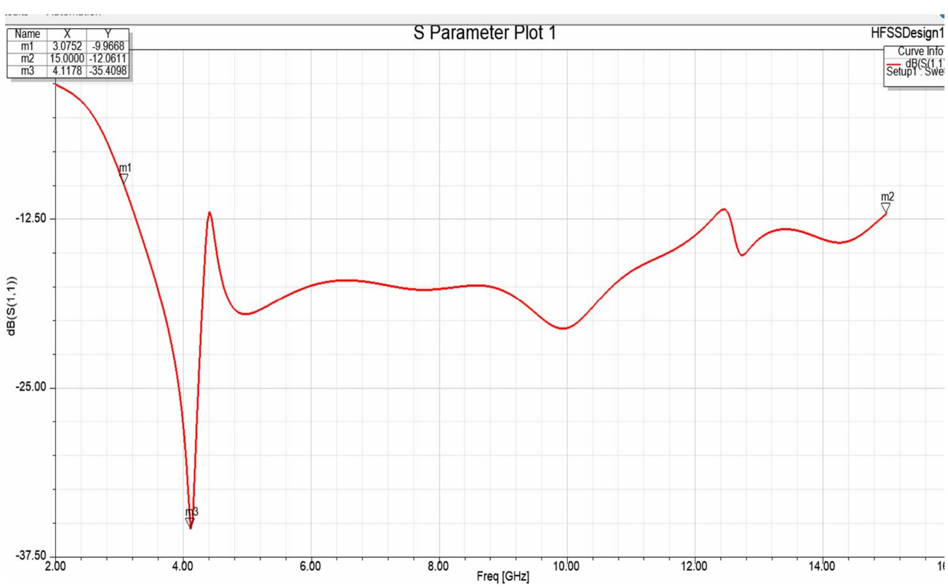

Fig (3): Return loss in dB against frequency

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2) *Radiation Pattern of Antenna:* Gain is one of the important factors in transmission and reception of message. As the gain bandwidth product is always constant, and bandwidth of antenna is large so gain is low, the gain of the antenna is observed to be 3.8dBi, gain plots for frequencies of 3GHz, 5GHz, 8GHz, 10GHz are shown in the Fig (4). The gain plot shows radiation of signal and at low frequencies there are no minor lobes, as frequency of operation increases the minor lobes gradually develops. In the frequency range of 3.1-10.6 there are very few minor lobes and radiates in all directions.

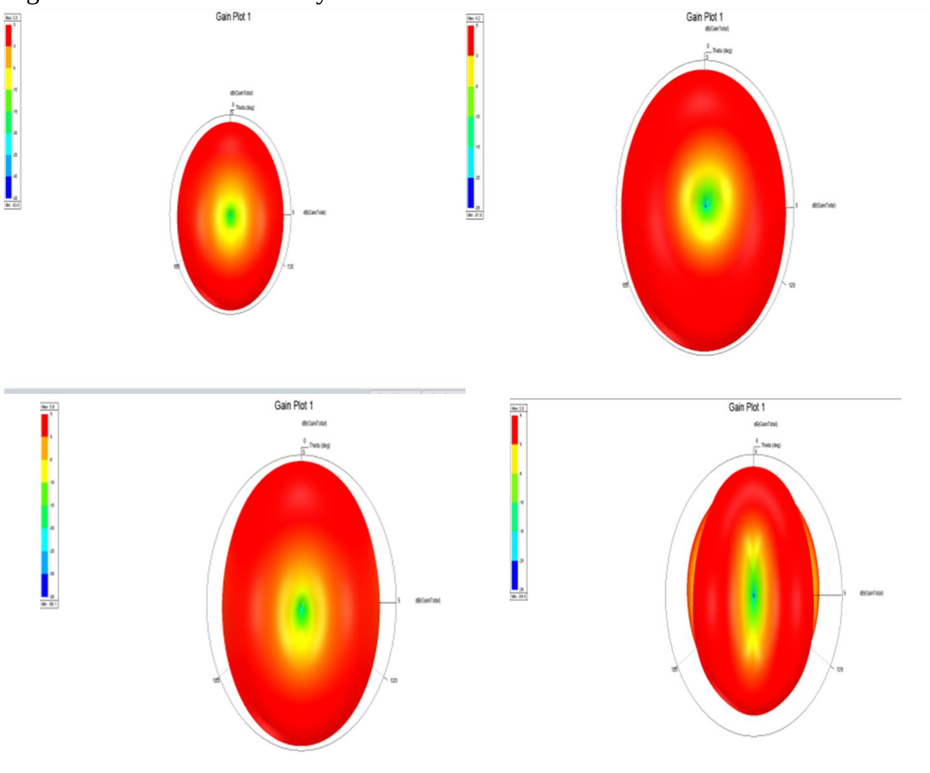
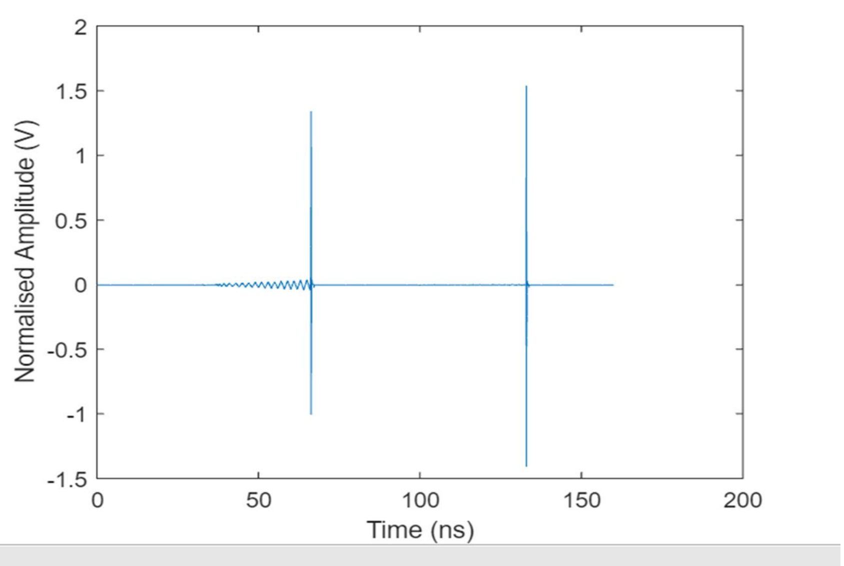


Fig (4): Gain plots for frequency (a) 3GHz, (b) 5GHz, (c) 8GHz, and (d) 10GHz

B. *Simulation of Microwave Circuit*

When the antenna works in different medium other than air the gain reduces and return loss increases so to improve the gain in this frequency range a microwave circuit is designed as shown in the Fig (2). The obtained results are visualized in frequency domain plot using MATLAB as shown in Fig (5).



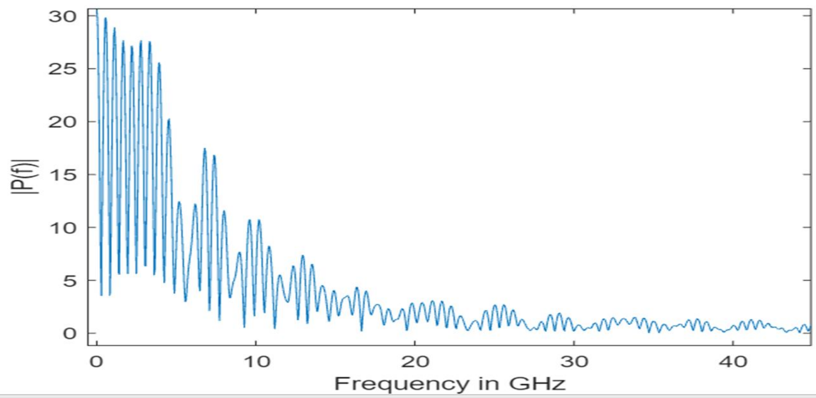


Fig (5) MATLAB simulation results (a) Time domain plot, (b) Frequency domain plot

V. CONCLUSION

This paper presents the design of semi-circular patch antenna for UWB applications with strip line feeding. The antenna is designed with dimensions of 26mmX27mm, and is made up of dielectric material FR-4 with dielectric constant of 4.4. Minimum return loss of -35dB was obtained at 4GHz. The microwave circuit designed is able to produce reliable amount of gain in this frequency range. The proposed antenna with the microwave circuit can also be used in underwater communication. The inclusion of antenna array can make the antenna radiate Omni-directionally.

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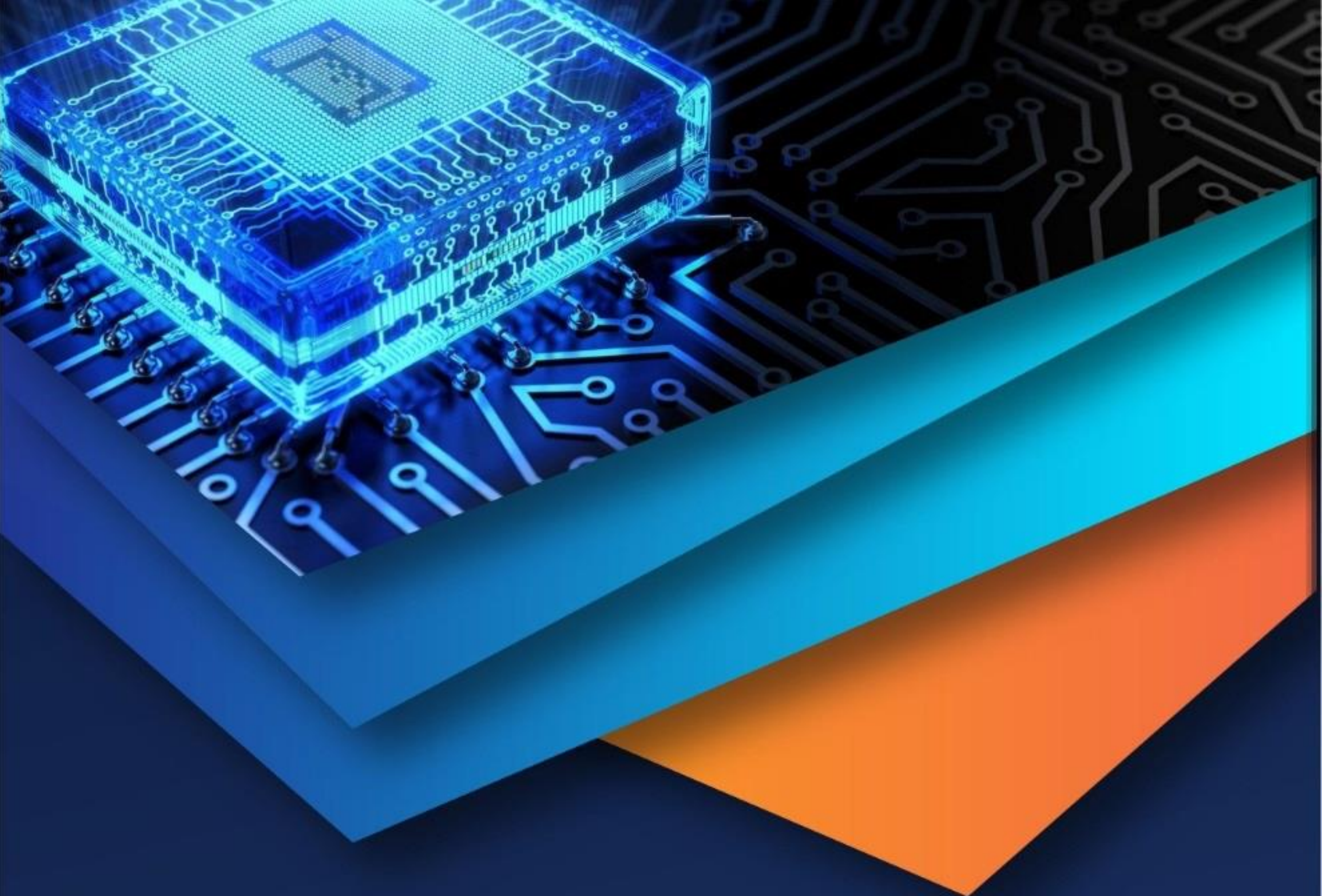

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