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CPW Fed Triangular Shaped upper Strip Patch Monopole Antenna for RF Energy Harvesting

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***Abstract:** Worlds are looking for a renewable energy to replace current energy sources. Solar and wind renewable energy has been deployed for some years as one renewable energy in a few countries in a large scale. For a small scale renewable energy, he development in electromagnetic vitality reaping has great potential as one of the wellsprings of sustainable power source since the electromagnetic vitality is accessible constantly and all over the place (e.g., solar, wind, thermal and ocean wave). This paper presents a co-planer waveguide (CPW) fed triangular shaped upper strip patch monopole antenna for RF energy harvesting. It has been found that, the antenna can be used to make operating in multiband mode More than 100% (2-5.6GHz band) impedance bandwidth has been achieved for co-planer waveguide (CPW) fed triangular shaped upper strip patch monopole antenna design for RF energy harvesting. The proposed antenna has been simulated. Simulations have been carried out using commercially available HFSS (High Frequency Structure Simulator) based on finite element method.*

***Index Terms:** Microstrip antenna, Co Planer waveguide, and Wideband antenna, Voltage standing wave ratio (VSWR), Return loss (S11)*

1. INTRODUCTION

A. *Fundamental of RF Energy Harvesting*

Power given to the load and that received by the antenna. While calculating RF to DC power conversion efficiency (η_{PCE}), the efficiency of the antenna (η_A), efficiency of rectifier or voltage multiplier (η_R), and efficiency of impedance matching network (η_M) are considered. PCE is calculated as the ratio of power delivered to the load to the received power.

$$\eta_{PCE} = \frac{P_{load}}{P_{received}} ----(1)$$

Where, P_{load} is power delivered to the load and $P_{erceived}$ is harvested power at the antenna. Factors that decide the value of PCE contains parasitic effects of components used, leakage in the circuits, topologies used for design, and nonlinear cut-off values of electrical components used in rectenna.

B. *Fundamental of RF Energy Harvesting*

To design RF energy harvesting system it is needed to analyze how electromagnetic waves travels in free space, while transmitting in free space these waves having free space path loss & it is required to be calculated [1]. For calculation of free space path loss information about the antenna gain, frequency of transmitting wave, and distance between the transmitter and receiver is needed. For a transmitter-receiver antenna system in far field free space, received power at antenna is be given by Friss transmission equation;

$$P_R = \frac{G_T P_T G_R \lambda^2}{(4\pi R)^2} ----(2)$$

Where P_T is the transmitting power, G_T is the transmitting antenna gain, G_R is the receiving antenna gain, λ is the wavelength signal, and R is the distance from transmitting antenna to receiving antenna, from above equation free space path loss (P_L) can be obtained as;

$$P_L = \frac{P_T}{P_R} = \frac{(4\pi R)^2}{G_T G_R \lambda^2} = \frac{(4\pi f R)^2}{G_T G_R c^2} ----(3)$$

$$P_L(dB) = 20\log_{10}(f) + 20\log_{10}(R) + 20\log_{10}\left(\frac{4\pi}{c}\right) - G_T - G_R ----(4)$$

$$P_L(dB) = 20\log_{10}(f) + 20\log_{10}(R) + 32.44 - G_T - G_R ----(5)$$

IEEE 802.11 standard technology has received considerable attention ever since the Federal Communication Commission (FCC) authorized the unlicensed use of the frequency spectrum ranging from (2 GHz-5.6 GHz). Thus it led to rapid growth in rf energy harvesting applications in this range of frequencies [2]. To meet these demands CPW fed Triangular Shaped upper strip patch Monopole Antenna is the best solution.

This paper reviews different parameters needed to be optimized which are used for improvement in PCE of rectenna. The section 1 describes fundamental of RF energy harvesting system. The section 2 describes related prier research. Design of antenna and their shape characterization are described in section 3. Simulation are summarized in section 4 & finally conclusion is drawn from these discussions

D. Related Prior Research

A narrowband rectenna was presented to harvest ambient cellular signals at 1.96 GHz [1-9].The proposed rectenna also included a smart power management system and maximum power point tracking (MPPT) unit to capture around seven times more energy in comparison to using a direct battery connection. An efficiency of 60% was achieved with input power levels over 30 μW (10∼ −15dBm) at a location 50 m away from the RF source.

However, for lower power levels of 10 μW (−20 dBm), 10% efficiency was reported. Another single band rectenna has been designed to harvest ambient digital TV signals at 540MHz [10]. The sensing rate was improved by considering the storage capacitor leakage and using an adaptive duty cycle control scheme. Hence, an efficiency of 30% was reported for−10 dBm input power for a 50 KΩ load.

Highest sensitivity of −20 dBm was also reported with very low efficiency of ∼5%. However, more sensitive RF harvesters are required for more realistic ambient harvesting cases. A compact single band RF energy harvester was designed and optimised to capture ambient medium wave signals at 909 kHz, taking the advantage of high transmit power and desirable signal propagation in contrast with higher frequencies [11]. It has been shown that a DC power of ∼0.24 mW was delivered to a 1KΩ load at a distance of up to 20 km from a150 kW transmitter, powering a wireless sensor. However, the sensitivity of the energy harvesting system was not identified.

A medium wave relatively sensitive single band rectenna was proposed operating at1.27 MHz [12] and it was demonstrated that the scavenger can operate 10 km away from a 50 kW AM broadcasting station. However, the reflection properties of the antenna and rectifier were not provided to clarify their findings and the efficiency was almost zero at low input power (<2 μW [−27 dBm]).Single band rectennas that operate in the UHF band are an efficient and cost-effective solution to power passive RFID systems.

These passive systems typically require small amounts of power (microwatts) which can be efficiently and continuously captured from the reader. Extensive research has been conducted to enhance the RFID system performance [4, 14, 15]. Based on the published works, complementary metal-oxide-semiconductor (CMOS) technology has been widely utilised to harvest RF power for RFID applications, having the advantage of a compact design.

However, it is very challenging to optimise CMOS-based rectifiers at different input powers and frequency bands [3].In recent years, fully integrated CMOS technology rectifiers for passive RFID systems have been proposed, operating at 900 MHz [13]. An RF-DC conversion efficiency of 13% was achieved with −14.7 dBm received RF energy. Another fully integrated long-range RFID tag chip was fabricated in 0.35-μm CMOS using titanium–silicon Schottky diodes [14].

E. Design Of Proposed Anteena

Fig. 1 shows the design composition of the antenna. The shape is basically a CPW fed Triangular Shaped upper strip patch Monopole Antenna [14]. The substrate used for design and analysis is a FR4 material whose properties are chosen as listed in Table 1. Effective dielectric constant (ε_r) can be calculated from the design expressions listed in [6, 7]. The antenna parameter upper strip patch width (W1) and length (L1), also ground length (Gl) and ground width (Gw) was optimized using the Ansoft HFSS [16] which is the commercially available electromagnetic software based on finite element method. The physical dimension of the antenna has been listed in Table 1. Detailed of compositional studies on this shape can be found in [14].

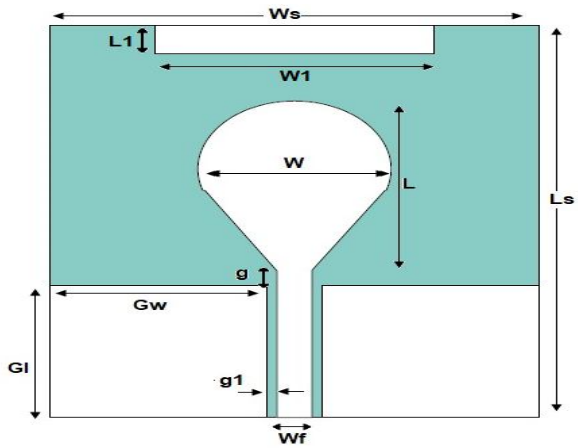

Fig 1: Geometry of proposed CPW fed triangular shaped upper strip monopole antenna.

In order to achieved ISM and WiMax band operation, upper strip patch dimensions (L1 & W1) of the antenna have been varied and optimized for the ISM and WiMax band operation. It may also be noted that the ground dimensions length (Ls) and width (Ws) can be varied and optimized for ISM and WiMax band operation.

Table 1: Optimized dimensions of the proposed antenna

Parameters	Dimensions (mm)
L	10.3
W	15.4
Ls	35.0
Ws	28.0
L1	2.5
W1	16.0
Gw	12.4
Gl	11.8
Wf	2.0
g	1.3
g1	0.6
Dielectric constant (ε_r)	4.4
Loss tangent (tanδ)	0.001
Height of substrate (h)	1.6

II. SIMULATION RESULT OF PROPOSED ANTEENA

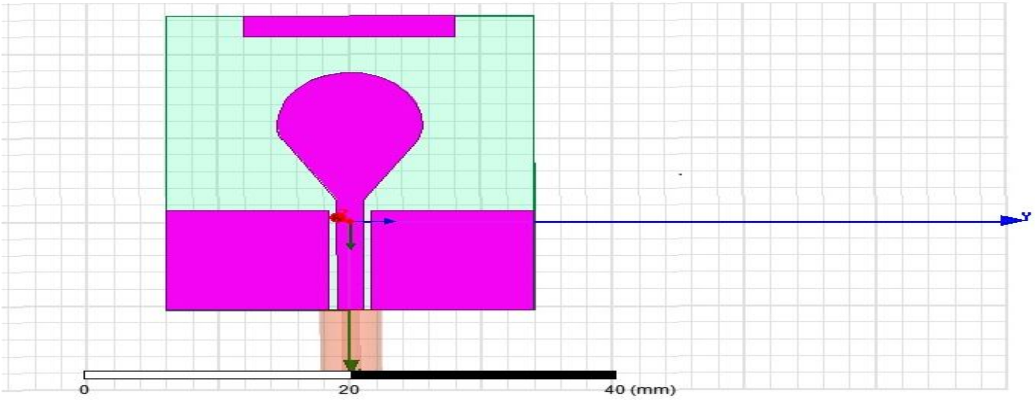

Fig 2: Geometry of CPW fed triangular shaped upper strip monopole antenna using HFSS.

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Figure 2 shows simulation setup of the antenna. The simulation was carried out by using commercially available EM analysis HFSS software. In Fig. 2 the centered triangular patch separated by two monopole ground plane shown by using magenta color. Above of triangular patch upper strip patch is shown. The substrate material is shown by stunt color and SMA connecter is shown by using pink color.

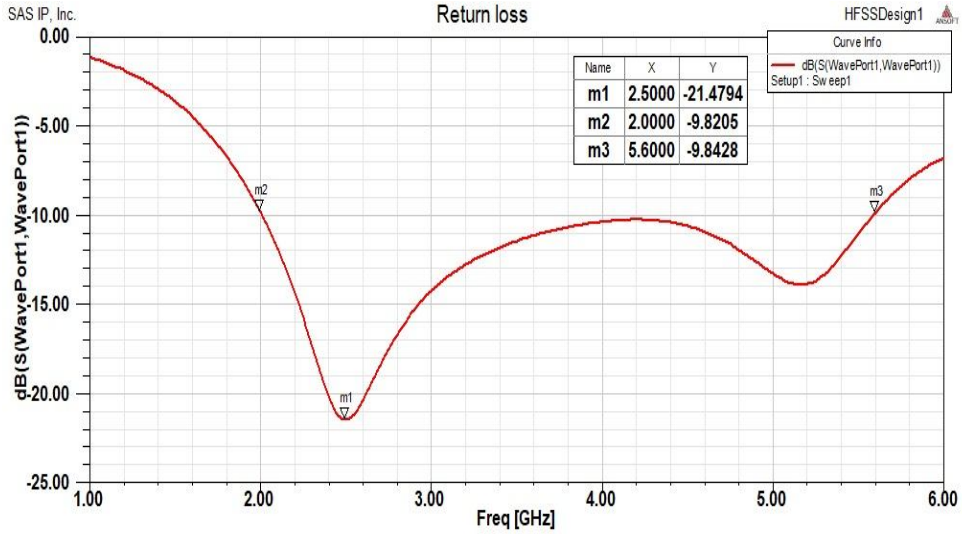

Fig 3: Return loss (S11) of antenna shown in fig. no. 2.

There are several other parameters associated with a patch, which define various performance measures of the antenna , e.g., some of these parameters are return loss, gain, impedance, VSWR, etc. Considering the return loss as the first parameter, the performance of the triangular patch is evaluated at (2 GHz-5.6 GHz) bands. This return loss gives an idea about the impedance matching between the micro strip patch and the feed line. It not only depends on the dimensions of the metallic patch, substrate, ground plane, but also on the position of the feed and feed dimensions. The Fig. 3 shown Return loss (S11) of antenna shown in Fig. 2 the antenna can be used to receive from (2 GHz -5.6 GHz) with slight crunch at 4 GHz. As antenna should have less than -10 dB for any band to work. Where ever it is decreasing below -10 dB we can say as much as efficiency as much as it decreased.

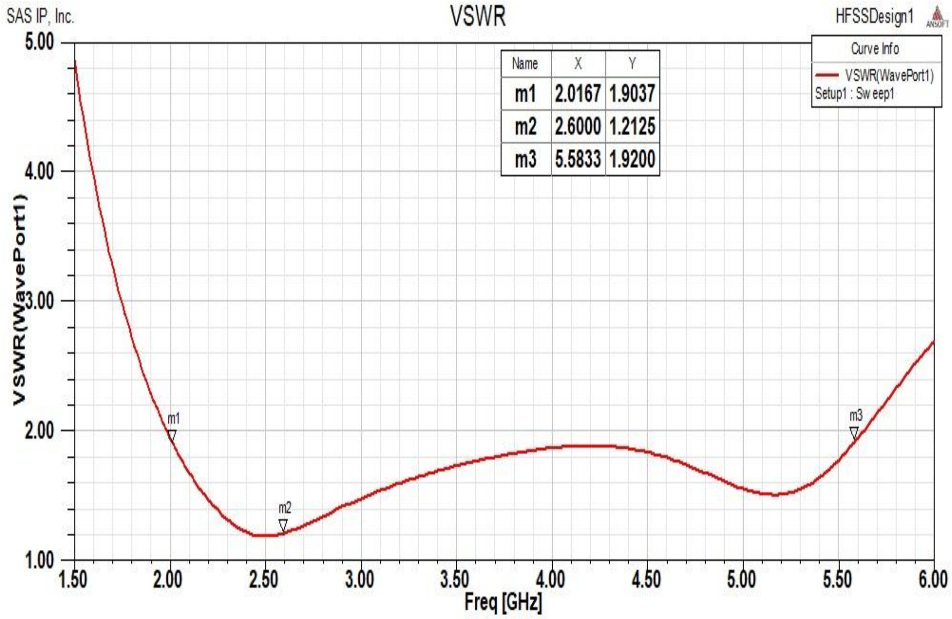

Fig 4: VSWR of antenna

Fig. 4 shows VSWR plot of the antenna. The maximum value of VSWR is 1.21 at 2.4 GHz. These low VSWR values suggest that most of the input power is transferred to the antenna at the desired frequencies and less power is reflected back

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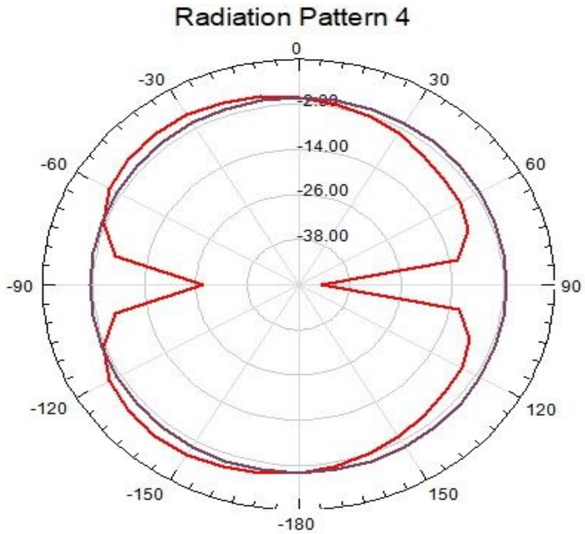

Fig 5: radiation pattern of antenna at 2.4 GHz

The mirrored radiation plans are presented in fig 5. The E-and H-plane radiation structures reproduced at 2.4 GHz. The radiation structures are bidirectional in the E-plane and H-plane. It should be seen that cross polarization levels are all around controlled in E-plane and H-plane. Receiving antenna is straightly invigorated. The reproduced zenith radio wire gain is 2.5 dBi at 2.4 GHz.

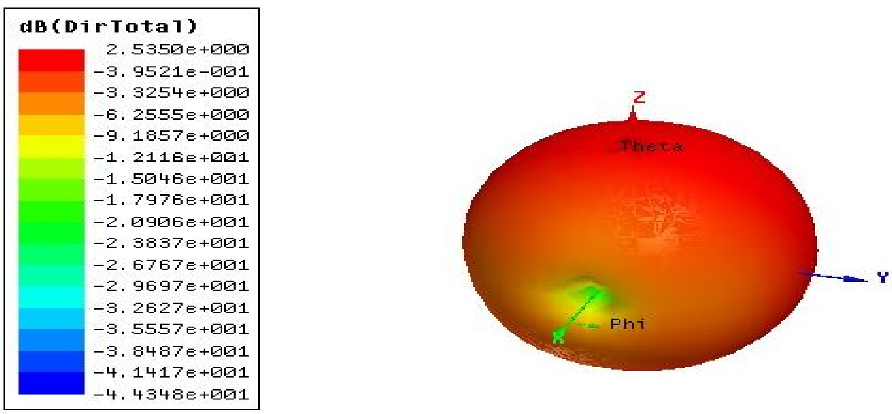

Fig 6: Gain of antenna at 2.4 GHz

The directivity and gain of antenna are related closely to each other, directivity measures the directional capabilities of radiation and gain represents the efficiency of antenna as in fig. 5. The gain of the antenna is 2.5 dB. The directivity obtained for the proposed antenna elements are 5.7dB.

III. CONCLUSION

A CPW fed triangular shaped upper strip patch monopole antenna has been proposed. Upper strip patch length (l1) and Ground (g1) dimensions of the CPW feed have been deviate to obtain ISM & WiMax band operation. The simulation results indicate the ISM & WiMax operations with good radiation characteristics. For wideband operation more than 100% (2-5.6 GHz) impedance bandwidth with good gain throughout t he band of operation was obtained. To the best of our knowledge, the antenna presented here is one of the best configurations for ISM & WiMax RF Energy harvesting operation especially capable for receive power from Wi-Fi router, cell towers etc. All the results of presented antenna are based on the simulation. Hence proposed future work will be the fabrication of antenna and validation of hardware results with simulation results. Further, computational approach for antenna with matching circuit may also be investigated in future.

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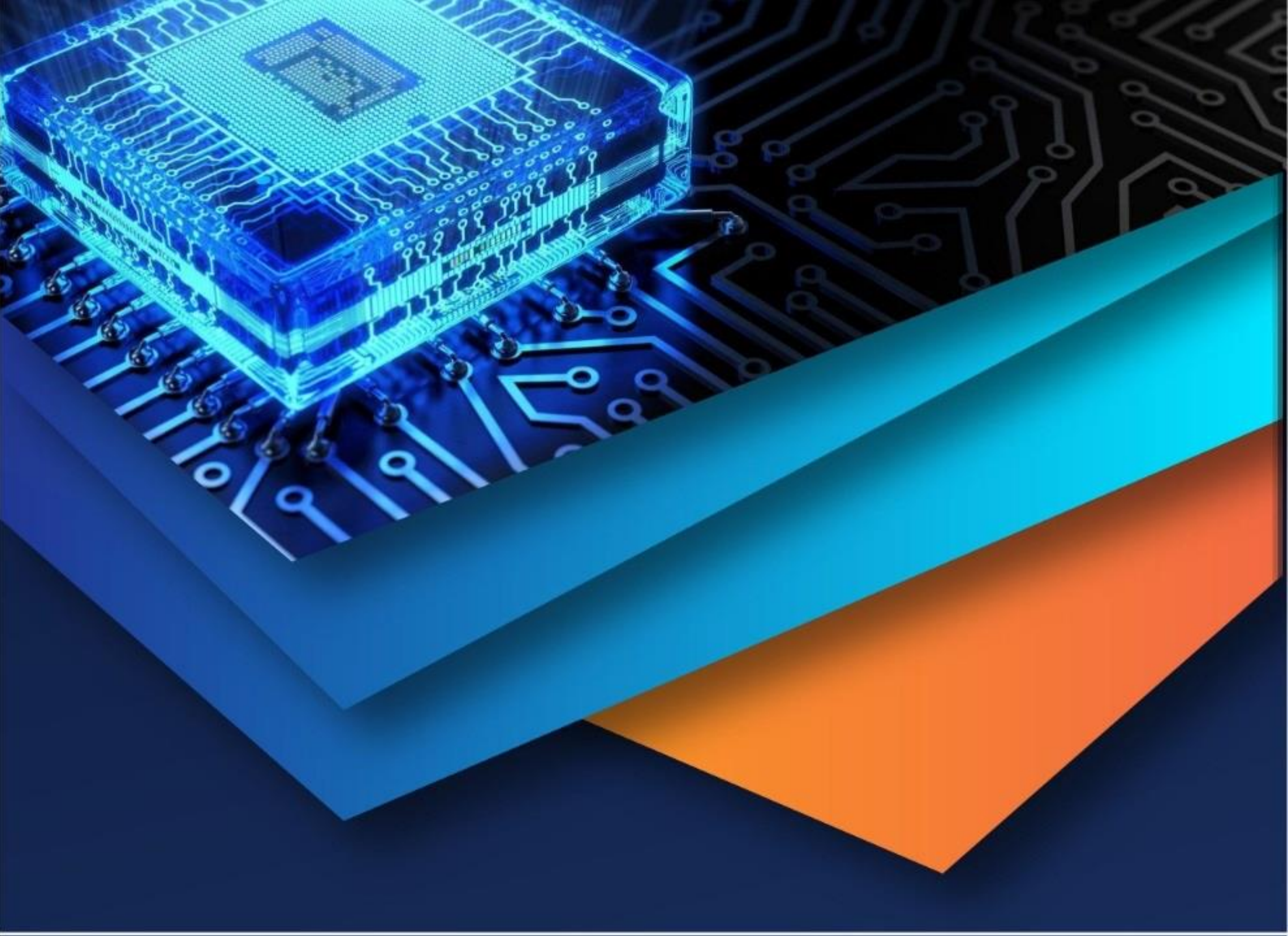

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