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Design of a Circularly Polarised Dual Band Notched Ultra Wideband Antenna with Fractal DGS for S-Band and C-Band Applications

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Abstract: A compact circularly polarised (CP) microstrip antenna for satellite communication band of 2.7-3.4GHz and 3.8-4.3GHz is presented.In this antenna, two substrates with air gap is introduced for circular polarisation. Two same size pentagons with 30^0 phase difference are printed on upper substrate, there is a circular ring cut from this combination of pentagons for realisation of CP radiation. To improve the performance parameter of patch antenna such as axial ratio (AR) bandwidth, return loss bandwidth, radiation efficiency and so on a new technique of combination of fractal theory and defected ground structure. Here, 44.54% size reduction in path size, enhancement of 51.26% in AR bandwidth and 72.36 in return loss bandwidth is achieved and compared to conventional patch antenna, after incorporation of Koch curve fractal DGS in the ground plane. The performance of the developed antenna has been compared with other available S band planer antennas in literature, and it is found that improved structure is better one in many aspects. Laboratory prototype of antenna is fabricated and experimentally measured for cross verifying the simulated results.
Keywords: circularly polarised, axial ratio bandwidth, return loss bandwidth, radiation efficiency

I. INTRODUCTION

There is an increase in demand for microstrip, low cost, ease of fabrication, ultra wideband antennas. FCC declared that ultra wideband ranges from 3.1GHz to 10.6GHz. The UWB system has various advantages for transmission of high data rate with low power consumption. The UWB system requires a small size antenna which has characteristics of Omni directional radiation patterns, constant group delay and phase linearity. Many researchers reported UWB monopole antenna have designed on both planer and non planer structures. These antennas possess UWB characteristics with an immense overall size and can't be fluently integrated with MIC/MMIC devices. Few researchers have reported UWB antennas with restricted ground plane microstrip feed and coplanar waveguide feed.

A configurable microstrip antenna provides more functionalities than conventional antennas, improve the link quality and capacity which is extremely important part of wireless communication system. Based on the foundational parameter of the antenna reconfigured, various single parameter reconfigurable antenna designs have been described such as frequency reconfigurable, pattern reconfigurable and polarisation reconfigurable antenna. Lately, various antennas are designed to accomplish multiple reconfigurable which enables polarisation and pattern reconfiguration.

Defected ground structure idea has been used to enhance the desired characteristics of the planer antennas. DGS can be obtained by engravinga particular design in ground plane of the antenna. Because of extra lumped inductance introduced by DGS, The phase velocity of the wave is degraded, As a result of that producing the slow wave effect. The slow wave factor is presented by the proportion of β and k of the transmission line for lossless microstrip line, where β is propagation constant and k is free space wave number.

$$\mathrm{SWF} = \frac{\beta}{K} = \frac{\lambda}{\lambda_g} = \sqrt{\varepsilon_{eff}}$$

So, $\beta = \sqrt{\varepsilon_{eff}}.K = \frac{W}{V_p} = \frac{W\sqrt{\varepsilon_{eff}}}{c}$

Here, V_P is the phase velocity and ε_{eff} is the antenna efficiency.

The SWF of a microstrip line is raised when discontinuities is introduced in the path of EM waves increases the impedance of line. The slow wave effect increases the effective electric length of the antenna or we can say that decreases its resonance frequency leading to a reduction in antenna size for a frequency of operation.

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Different shapes of DGS, such as dumbbell, partial ring, annular ring, spiral etc have been introduced to enhance characteristics of antenna, which is to improve radiation efficiency, to suppress higher harmonics, to lessen the patch size, to decrease mutual coupling, to repress cross polarisation of the antenna.

The traditional shape of DGS suffers from effect of low slow wave, so, maximum benefits of DGS can not be accomplished. Slow wave effect can be embellished by accessing electrical length of the current path.

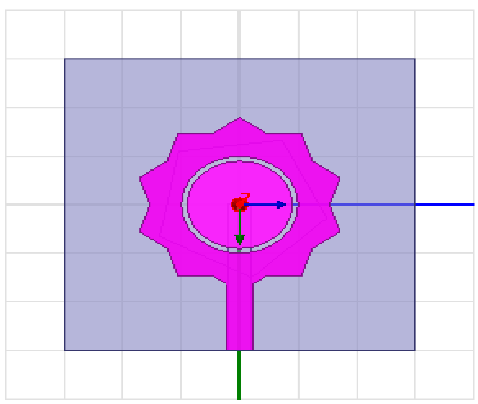
To acquire maximum slow wave effect, the blend of DGS and fractal theory has been done with the work. This causes use of self similar structures to carve the ground plane, which in turn behaves as DGS and therefore the name ‘Fractal DGS’. The complete equivalent electric length boosts because of a mixture of Koch curve and DGS and other increment in corresponding electrical length takes place with the enhanced iterations of Koch curve fractal DGS, which go along with maximum size reduction of patch antenna.

II. PROPOSED ANTENNA DESIGN

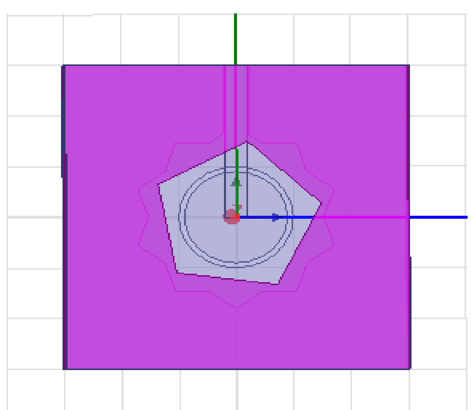
The patch of proposed antenna is made up of by adding twopentagons which is 90 degree phase shift between them. The radius of these pentagons are 15 mm a microstrip line are adding to side of antenna from patch,By attaching microstrip line at the top of bottom substrate. The position of the strip attachment to the substrate provides the impedance matching and to provide the dual band characteristics.

The overall size of the antenna is $60\times60\times9mm^3$. The dual frequency behaviour is obtained by cutting a circular ring from the patch.

In this work,the proposed antenna is optimised by using HFSS(high frequency structure simulator). The proposed antenna is done by adding air gap between two substrate,at the bottom substrate a pentagon cut is made out of ground plane of radius 15mm, which operate at frequency of 3.09GHz. The proposed antenna is etched on a 1.6mm thick FR4 substrate with relative permittivity of 4.4 and dielectric loss tangent of 0.02. All the results have been verified through simulations as well as experimentally by designing laboratory prototype structures as shown in fig. 1.



(a)



(b)

Fig.1 Design of Proposed Antenna (a) Top view, (b) Bottom view

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III. RESULT AND DISCUSSION

This approach includes the implementation of inspired optimization techniques in conjunction with curve fitting, for making these fractal antennas work at required frequencies. Fractal geometries such as new fractal design and hybrid fractal tree were taken as the candidate structures to check the validity of the developed methodology.

A. Bandwidth

Band is defined as the characteristic for which the antenna is designed to operate. Fig shows the simulated result of return loss vs. frequency of multi band characteristics which is an excellent result of bandwidth of 657.2MHz. In this result, the first band (m1 to m2) from 2.679 to 3.374 GHz which is 695MHz and second band (m3 to m4) from 3.8182 to 4.3636MHz which is 545.5MHz and total of 1.897GHz.

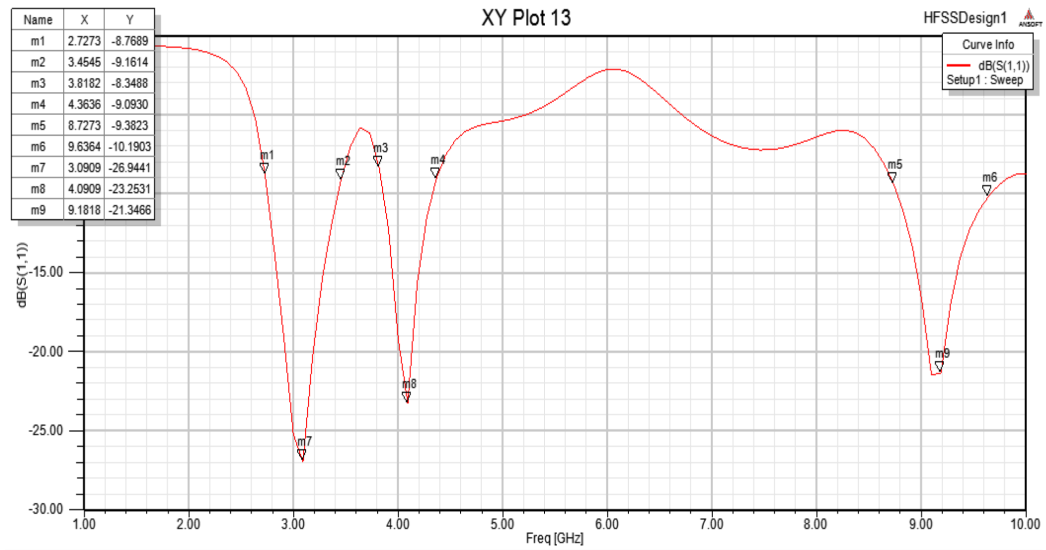

Fig.2 Bandwidth of proposed antenna

B. Axial Ratio

The Axial Ratio (AR) is defined as the ratio between the minor and major axis of the polarization ellipse. Recall that if the ellipse has an

equal minor and major axis it transforms into a circle, and we say that the antenna is circularly polarized. In that case the axial ratio is equal to unity (or 0 dB).

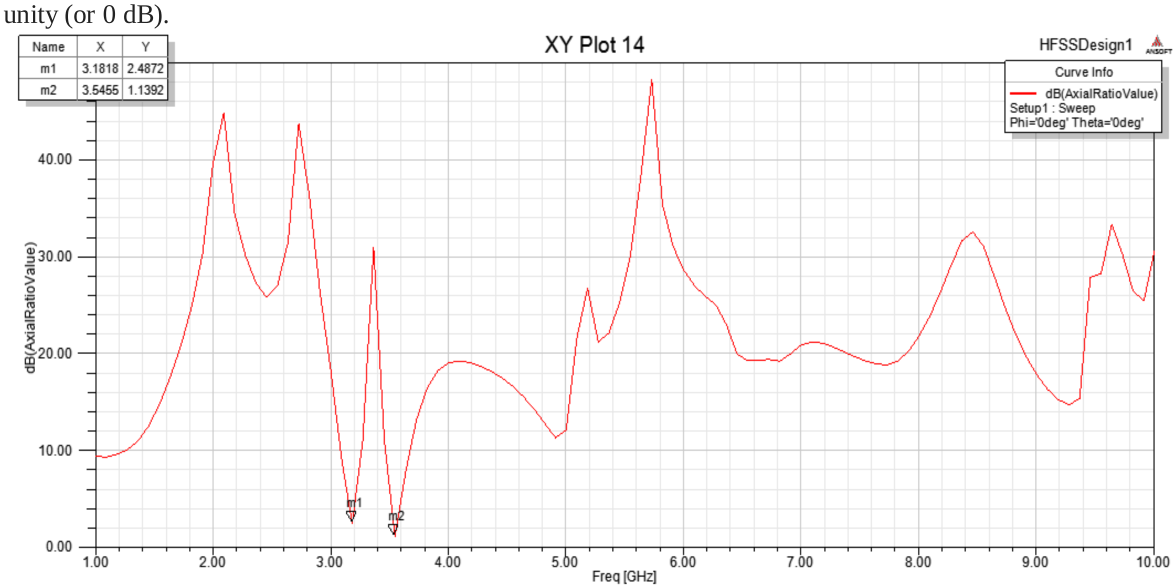

Fig.3 Axial ratio of proposed Antenna

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C. GAIN

Gain is a key performance number which combines the antenna's directivity and electrical efficiency. As a transmitting antenna, the gain describes how well the antenna converts input power into radio waves headed in a specified direction. Here, we achieve the gain 3.32dB and 4.59dB at 3.09GHz and 4.09GHz respectively.

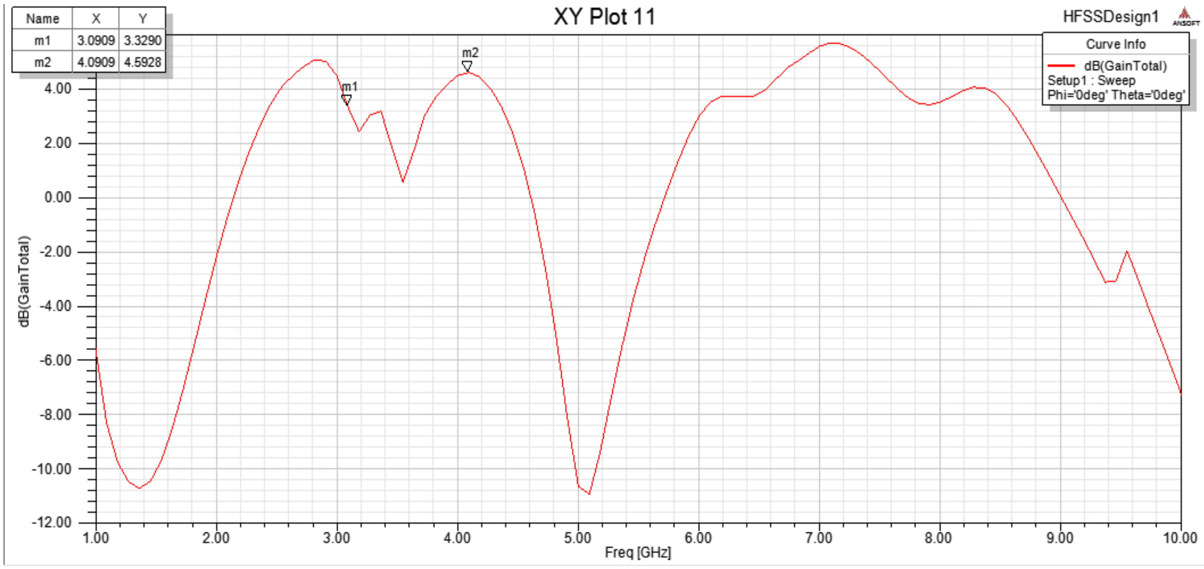

Fig.4 Gain of the proposed Antenna

D. Vswr

Impedance mismatches in a radio-frequency (RF) electrical transmission line cause power loss and reflected energy. Voltage standing wave ratio (VSWR) is a way to measure transmission line imperfections. Fig shows the

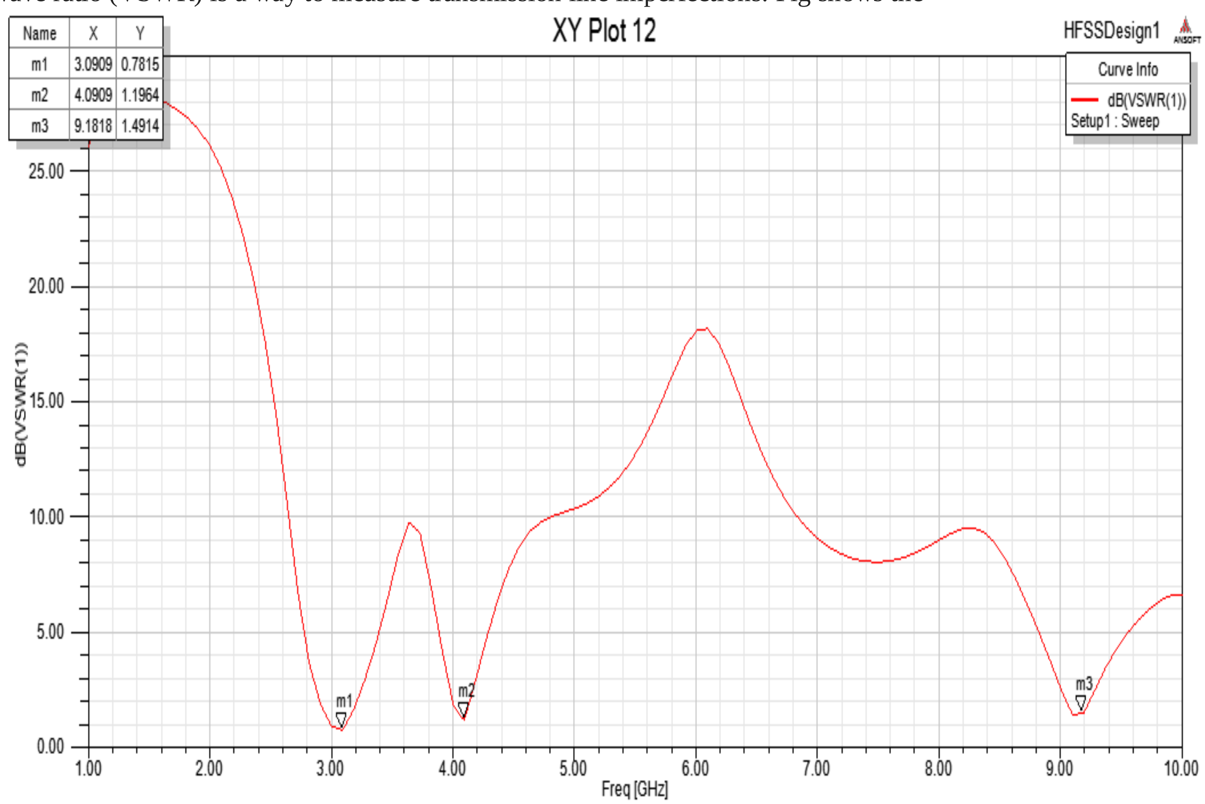

Fig 5 VSWR of proposed Antenna

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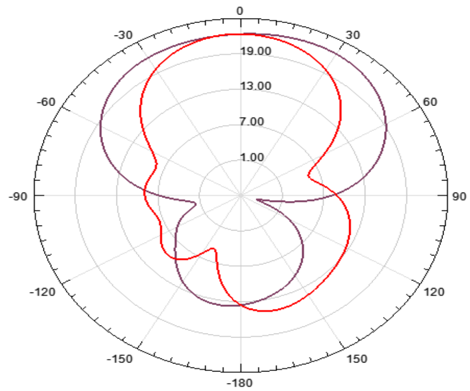
E. Radiation Pattern

The radiation pattern shows the variation of the power radiated by an antenna is a function of the direction away from the antenna. This power variation function of the arrival angle has observed in the antenna's far field. The design antenna shows a directional radiation pattern, in other words, an antenna radiates in a particular direction and operate its own center frequency at 3.09GHz



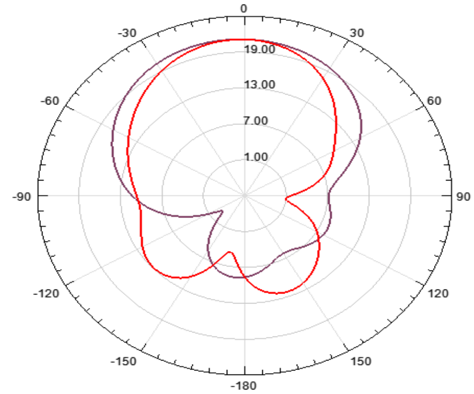


Fig.6 Radiation pattern of the E and H plane directional pattern at 4.09GHz

Fig.7 Radiation pattern of the E and H plane directional pattern at 3.09 GHz

IV. CONCLUSION

This paper presents the design of a dual notched band UWB DGS fractal antenna of size of 60×60×9 mm^3 with 1.6mm thickness on FR4 substrate. The antenna has designed for HFSS 13.0 tool. The proposed antenna is able to cover the entire UWB spectrum except at dual-notched band at 3.45 GHz, and 4.36 GHz has been obtained by acircular ring cut from the patch. This paper explores the use of fractal DGS in the design and development of S-band planar antennas. The proposed technique of fractal DGS gives better antenna performance. Antenna performance in terns of compact radiating patch, optimum gain, optimum return loss bandwidth and AR bandwidth are obtained and variefied experimently.

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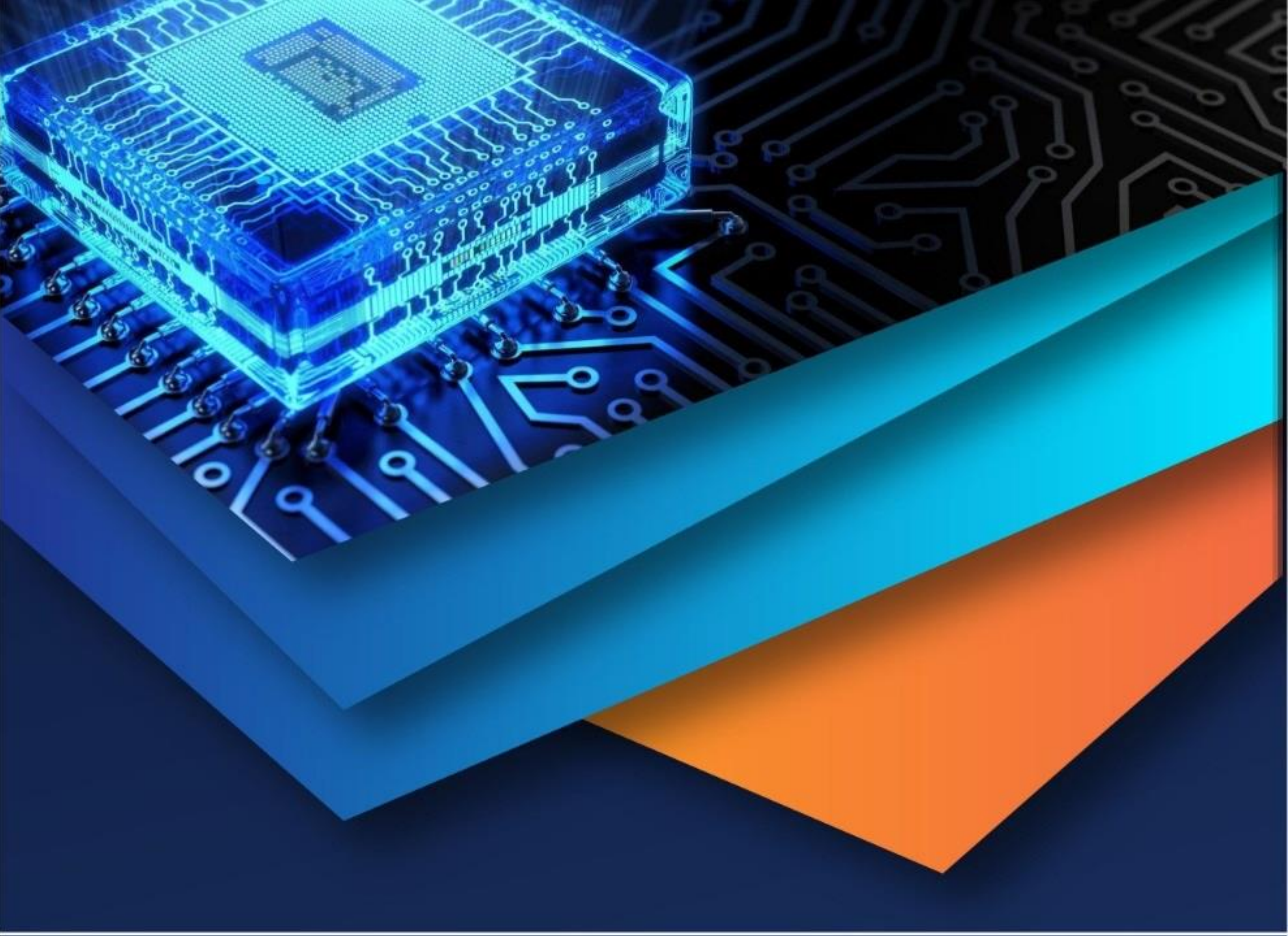

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