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A Dual Band Monopole Antenna for PAN and WLAN Applications

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Abstract*: This paper presents a Dual band monopole antenna which is loaded with open complementary split-ring resonator. The OCSRRs have an arrangement of parallel LC circuits. They behave as high-impedance circuits at their frequencies of resonance. The length of the monopole and the resonance frequency of the OCSRR plays a major role in setting the frequency of operation. The use of OCSRR in the antenna may consist of a slot cut into a rectangular or circular patch monopole which provides a dual band operation and also provides reduction in size. These antennas provide an ease in communication. The prototype can be designed, manufactured and measured using CST Microwave Studio. The antenna proposed here covers the Bluetooth and Wi-Fi (2.40-2.48GHz and 3.60-3.70GHz) bands specifically, IEEE 802.11b/g bands. This antenna has a compact design due to the use of OCSRR.

Keywords: Dual band antenna, High impedance antennas, Omnidirectional, Split ring resonators.

I. INTRODUCTION

With the rise of digitization, wireless communication is playing a prominent role and furthermore acts as a superior remuneration for analog communication. This calls for the making of a wireless antenna with specific frequency bands. As WLANs and PANs are frequently used networks, making an antenna that works on these frequency bands satisfy all the requirements. Moreover, the desired antennas should be cost-efficient and compact so Printed Monopole Antenna with OCSRR's are designed.

In this letter, to satisfy the need of low cost and compact antenna a Monopole antenna is discussed. The presence of a number of strips in the monopole antenna create many distinct electrical pathways, and every pathway individually causes resonance at a different frequency. Hence, a monopole antenna working on many bands can be achieved. However, with the use of this design, there can be an increase in the size of the antenna, the requirement of a ground plane and the antenna complexity may increase and the required frequency range may not be achieved. On the contrary, the dipole antennas receive balanced signals and also signals from various other frequencies. Dipole antennas have a good quality of reception. But the major drawback of the dipole antennas is its size. They are difficult to manage because of their size and at the same time they are difficult to transport, move or install. Considering these factors, a monopole antenna along with an OCSRR has been selected.

OCSRR lies in the category of metamaterials and it has been derived from Open Split Ring Resonator (OSRR) which has two metal rings that are concentric in nature. Extending the metallic strips can open the resonator. OCSRR is implemented by etching a metallic part of the OSRR. OCSRRs are responsible for the change in resonance characteristics and hence produce new frequencies. The OCSRR is a combination of inductors and capacitors and the compact size of the antenna is obtained by reducing the capacitance and increasing the inductance.

There are two current paths in an OCSRR namely, the inductive path that is present at the central strip of the OCSRR and the displacement current that passes through the resonator slots.

There are many properties that are shown by the materials and some of them are even proved by the Maxwell's Equation. In the same way an interesting property is shown by the metamaterials. “Meta” means altered, changed or to go beyond. They are Nano composite structures made up of metals or plastic. Metamaterials can have their electromagnetic properties altered to something beyond what can be found in the nature.

Metamaterials have a negative refractive which is obtained when both of permittivity and permeability are negative. Such materials exist in nature, but not simultaneously. A unit cell of metamaterial is a combination of a circular or a rectangular ring and a wired structure.

Negative Permittivity can be derived from thin wires and negative Permeability can be derived from split rings made of copper.

There are various feeding techniques for the antenna like coaxial cable feed, inset feed, probe feed and coupled feed. A Co-Planar Waveguide feed can be used as it gives less dispersion and better broadband performance.

II. LITERATURE REVIEW

The wide use of WLAN and PAN has led to the development of antennas which operate in different frequency ranges. Due to the drawbacks of the conventional method of antenna design that involved increase in the antenna size, complexity and the need of large ground planes has led to the use of LC resonators to design and manufacture antennas with multiple frequencies [2].

Various kinds of antennas like the monopole antenna, dipole antenna, microstrip antenna, slot antenna, horn antenna, etc. are present. Microstrip patch antenna [5] is amongst the most widely used antennas due to its small size, less weight, ease in manufacturing and fabrication but they have high losses and low gain. The planar or rectangular patch antennas are the most widely used geometries [8].

A Split Ring Resonator is needed for an antenna to work on multiple frequency bands [1]. This SRR gives rise to an Open Complimentary Split Ring Resonator which is constituted by Inductors and Capacitors. Radiation characteristics in the form of radiation pattern, gain and polarization are the outcomes of this structure. In an OSRR, the resonator is left open by means of metallic strips but SRR structure is closed. Thus, the OCSRR can be obtained by opening a CSRR and is the complementary part of the OSRR.

The most important part for the antenna to work properly is providing it with power supply i.e., by providing excitation with the help of multiple feeding methods. Coplanar waveguide (CPW) is a frequently used feeding approach. Two ground planes and a conductor strip are used. The ground planes are present on the sides whereas the strip is present in the middle. Since all of these lie in the same plane, it is called as coplanar [9].

Metamaterials enhance the resonance in the antenna because of which it is used in dual band [10]. The radiation and matching properties are enhanced by the use of metamaterial coatings of antennas with small electric and magnetic dipole. Metamaterials are those materials which show characteristics which are generally do not exist in nature but its values can be adjusted such that it can match the characteristics. The word “meta” means beyond i.e., the materials with properties beyond existence. Metamaterials are characterized by permittivity and permeability. For exhibiting the metamaterial properties both permittivity and permeability have to be negative i.e. present in the third quadrant and hence they are also known as double negative materials [10]. If the metamaterials are made dispersive, the negative values of permittivity and permeability can be obtained.

III. METHODOLOGY

A step by step approach of the antenna design and manufacture is illustrated in the block diagram of the system as illustrated in the Figure 1.

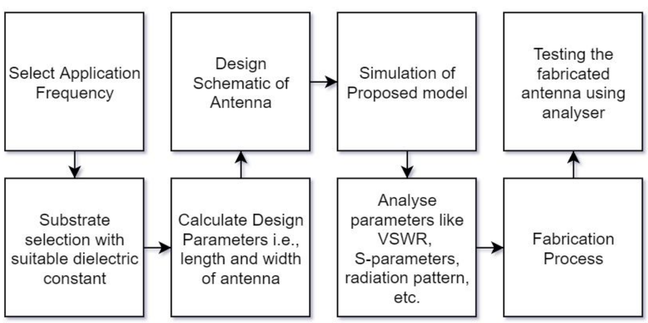

Figure 1 Block Diagram of Antenna Design

1) *Block 1:* Select Application Frequency Before designing any antenna, it is necessary to decide its working frequency. It is necessary to analyse and decide on what frequency range the antenna is going to work. This frequency range can be decided by the application for which we are designing the antenna. Hence the first step is to decide the application and the range of frequency depending on the application.
2) *Block 2:* Substrate selection with suitable dielectric constant Once the application and the frequency is decided the next step is to select the material of substrate. While selection of material certain things like availability of the material, cost of the material, characteristics and features of the materials have to be studied properly. The material should be easily available in the market and cheap at the same time. Moreover, it should be able to withstand any environmental changes. It should be rigid and durable. Many different substrate materials are available like FR-4 (Epoxy Glass), Rogers, Foam, Arlon, Alumina, etc. All these materials have different dielectric constant.

3) *Block 3:* Calculate Design Parameters of Antenna After the calculation of various parameters, the next step is to design the antenna schematic and this is done with the help of appropriate software.
4) *Block 4:* Design Schematic of Antenna After selection of materials for the substrate the next step is to calculate various parameters of antenna like the length and width of the antenna. While designing any project it is important to keep in mind that the design has to be efficient and should meet the given requirements. At the same time the design protocol should be small and compact in size and cost efficient. Proper parameter calculations need to be done like length and width of the antenna. Based on the length and width other parameters are calculated.
5) *Block 5:* Simulation of Proposed Model Once the design of the antenna is ready, it needs to be tested on the software and this process is known as simulation. For this process to yield successful results we need to use feeding techniques like Coplanar Waveguide feeding technique because it provides ease in fabricating the antenna. Various parameters are analysed and conclusions based on them is drawn. There are various graphs of different parameters and each graph explains something different.
6) *Block 6:* Analysis of Parameters Simulation is followed by analysing of parameters like VSWR, S-Parameters, Radiation Pattern, Gain and Directivity. This analysis has been done by the use of CST MWS. For measurement of these parameters on hardware, a device called Vector Network Analyser is used.
7) *Block 7:* Fabrication Process This step involves the fabrication process. A variety of materials are used as a substrate like epoxy glass which is used in this antenna. Selection of a correct substrate is crucial. Many methods are available for fabrication of flexible and wearable antennas which include printing, etching using chemicals and benchmark prototyping.
8) *Block 8:* Testing the Fabricated Antenna The final process is that of testing. It is the process in which the antenna is tested for different conditions in different circumstances and the practical result is verified with the theoretical results. The testing usually takes place with the help of vector network analyser in which there is a test antenna or the reference antenna and the 2nd antenna is the one which is designed by us. A reference antenna is used to compare the parameters of the designed antenna which determines the efficiency of the design.

IV. ANTENNA DESIGN AND WORKING

The proposed antenna has been designed with a monopole feeding approach and has an OCSRR mounted on it. The transmission line used here is the coplanar waveguide (CPW) whose frequency response is very high and it can be mounted anywhere in the circuit similar to a microstrip patch antenna. Also a high level of isolation is attained with the use of CPW.

This is the best technique for the manufacturing of compact circuits. The layout of t proposed antenna is as shown in Fig.2. which shows a CPW feed.

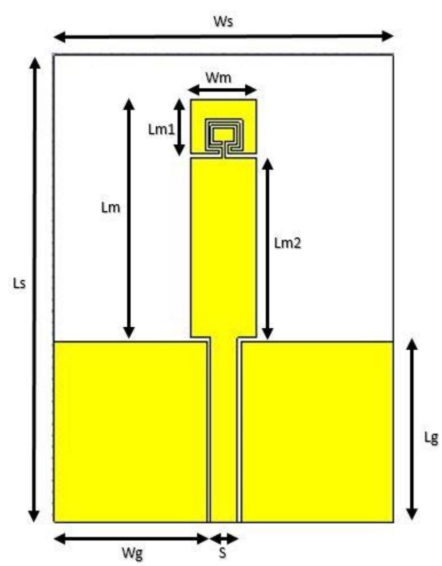

Figure 2 Proposed antenna layout

This principle focusses on using LC circuits in parallel with the monopole. As the designed antenna consists of two bands, the frequency of each band is dependent on the length of the monopole and the resonance frequency which takes place at λ/4. The position of the inductor-capacitor circuit with respect to the feeding point is a deciding factor in choosing the radiating frequency. At the resonant frequency, the circuit has a very high impedance and hence the Open Complementary circuitry is vital. Hence, a dual band antenna is achieved.

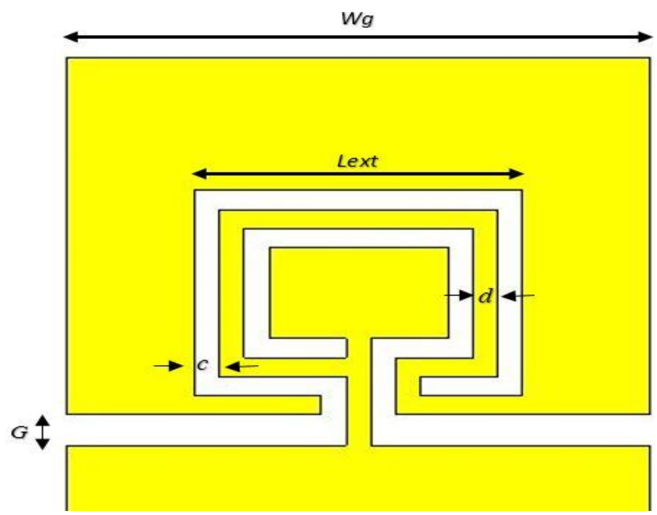

Figure 3 OCSRR layout

For obtaining the correct frequency band, it is necessary to set the total length of the monopole to λ/4. This gives the first resonance frequency. Another important factor that needs to be taken into consideration is the distance where the OCSRR is placed. The distance between the OCSRR and the feeding point should be λ/4. For the second frequency band the parameters like inductance and capacitance have to be varied as the resonant frequency is dependent on them.

The length and the width of the patch, substrate and the ground plane need to be engineered well in order to get a proper result. The bandwidth of the antenna is enhanced by simply loading the OCSRR. The dimensions of the OCSRR are a deciding factor in the output frequency. The frequency band also changes depending on the gap between the OCSRR. Smaller the gap is, better is the performance of the antenna. Table I shows the dimensions of the proposed antenna.

Table I: Antenna Design Specifications

Parameter	Value(mm)	Parameter	Value(mm)
Ws	30	Wm	5.85
Lm	21	G	0.40
Ls	41.23	Lg	16
Wg	13.48	S	2.44
W	0.30	Lm1	4.70
Lm2	15.90	Lext	3.30
c	0.25	d	0.25

V. RESULTS

A. Simulated Voltage Standing Wave Ratio

The proffered dual band antenna is simulated using CST MWS simulator. Figure 4 shows the simulated Voltage Standing Wave Ratio of the antenna which is in the range of 2.40-2.48 GHz. At 2.425 GHz, the minimum value is obtained which is in the required frequency. The normal range of an ideal antenna should be 1<VSWR<2. After simulating the proposed design, the VSWR obtained is 1.03dB at 2.425 GHz.

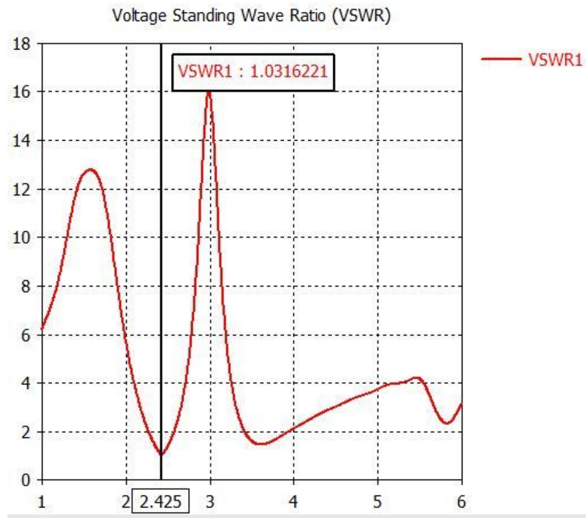

Figure 4 Simulated VSWR (2.40-2.48GHz)

Figure 5 shows the simulated VSWR of the proposed antenna at 3.60-3.70 GHz. After simulating the proposed design, the VSWR obtained is 1.46dB at 3.6039 GHz which is in the desired frequency range.

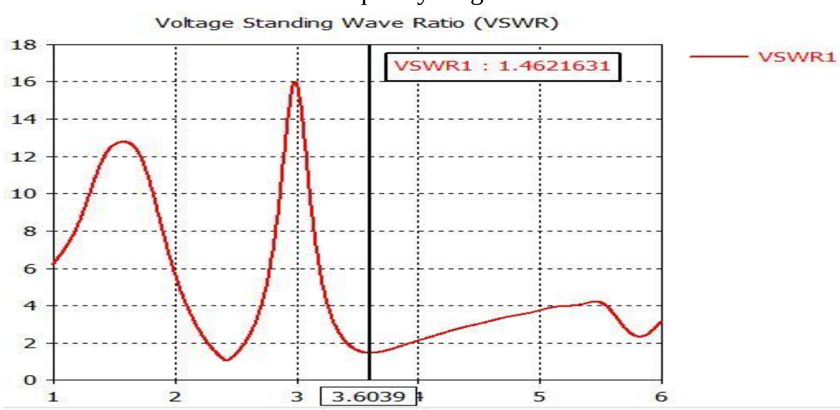

Figure 5 Simulated VSWR (3.60-3.70GHz)

B. Antenna Directivity and Gain

The simulated antenna farfield directivity and gain i.e., the radiation efficiency is present in Fig. 6. at 2.45 GHz & Fig. 7 at 3.65 GHz frequency which show proper suppression. The farfield is an important parameter as it shows the region of operation for the simulated antennas.

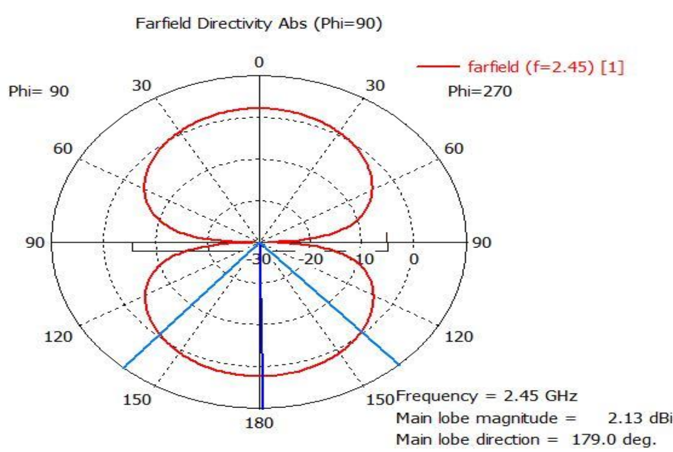

Figure 6 Radiation pattern & Farfield Gain at 2.45GHz

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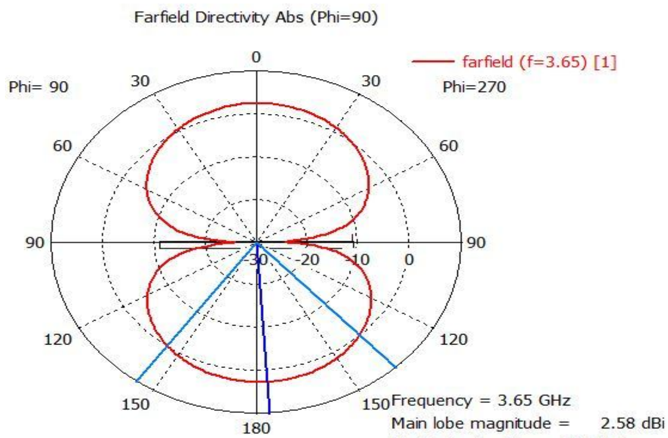

Figure 7 Radiation pattern & Farfield Gain at 3.65GHz

Antenna gain on the other hand is the product of antennas efficiency and directivity. It shows the directions in which the antenna radiates i.e., converts its power into radio waves in specific directions. The proposed antenna is an example of an omnidirectional antenna. Higher gain results in a more directional behavior of the antenna.

C. Parametric Study

S-parameters vary as a function of frequency and hence change with the change in frequency. S-parameters are defined only for a specific frequency at a time for any non-ideal network. They describe electrical behavior of the networks. Fig. 8. shows the simulated results of Scattering Parameters at 2.45 GHz. The simulated results are obtained at -36.15dB.

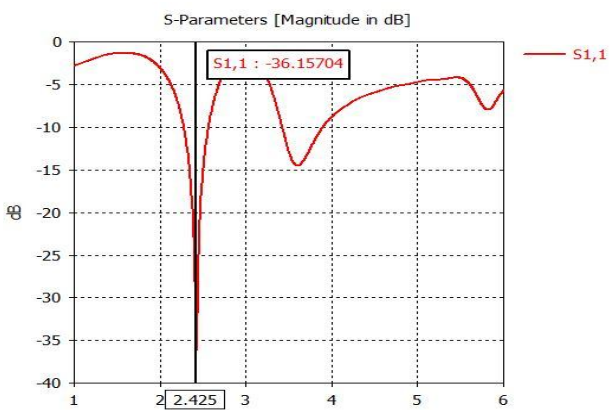

Figure 8 Reflection Coefficient at 2.45GHz

Fig. 9. shows the simulated results of Scattering Parameters at 3.6 GHz. The simulated results are obtained at -14.36dB.

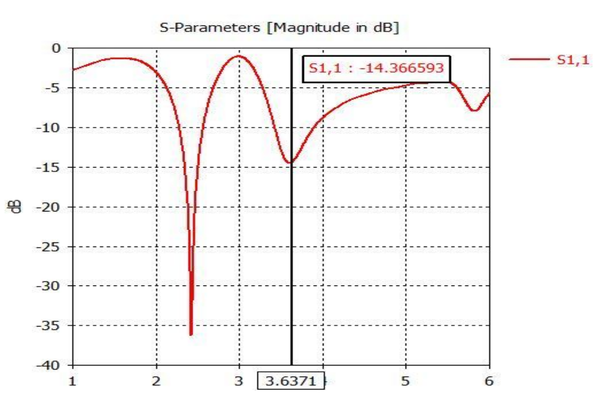

Figure 8 Reflection Coefficient at 2.45GHz

VI. CONCLUSION

An antenna for PAN and WLAN applications that works on two bands has been proposed. The frequency of operation is dependent on the resonance frequency of the OCSRRs and also to the length of monopole. By simply adjusting the dimensions of the OCSRR the frequencies in the desired band can be achieved. This is possible because an OCSRR comprises of inductors and capacitors, so as the distance is changed, the capacitance changes and hence the resonant frequency changes. Moreover, due the use of OCSRR the antenna manufactured is compact in size. The antenna also possesses an omnidirectional radiation pattern with ideal VSWR and return loss in the proposed frequency bands. The theoretical and software results of the proffered antenna match in the range of 2.40-2.48 GHz and 3.60-3.70 GHz. Hence the proposed antenna can be used for Personal Area Network and Wireless LAN i.e., it is befitted for Bluetooth and Wi-Fi applications.

A. Applications

The antenna that will be fabricated will cover the Bluetooth and Wi-Fi range (2.40–2.48 GHz and 3.60-3.70 GHz). This antenna will be a high gain antenna.

Bluetooth devices use the 2.4 GHz band, in addition to some cordless phones and radio controlled toys. Also, this antenna covers the range of Wi-Fi of 3.60-3.7GHz.

B. Future Scope

The proffered antenna can be used in a variety of active devices which can be used for services including that of Bluetooth and Wi-Fi. A structure called as MIMO antennas can be implemented. These structures have multiples inputs and multiple outputs. Thus, a structure with multiple frequency bands can be designed and analysed.

VII. ACKNOWLEDGMENT

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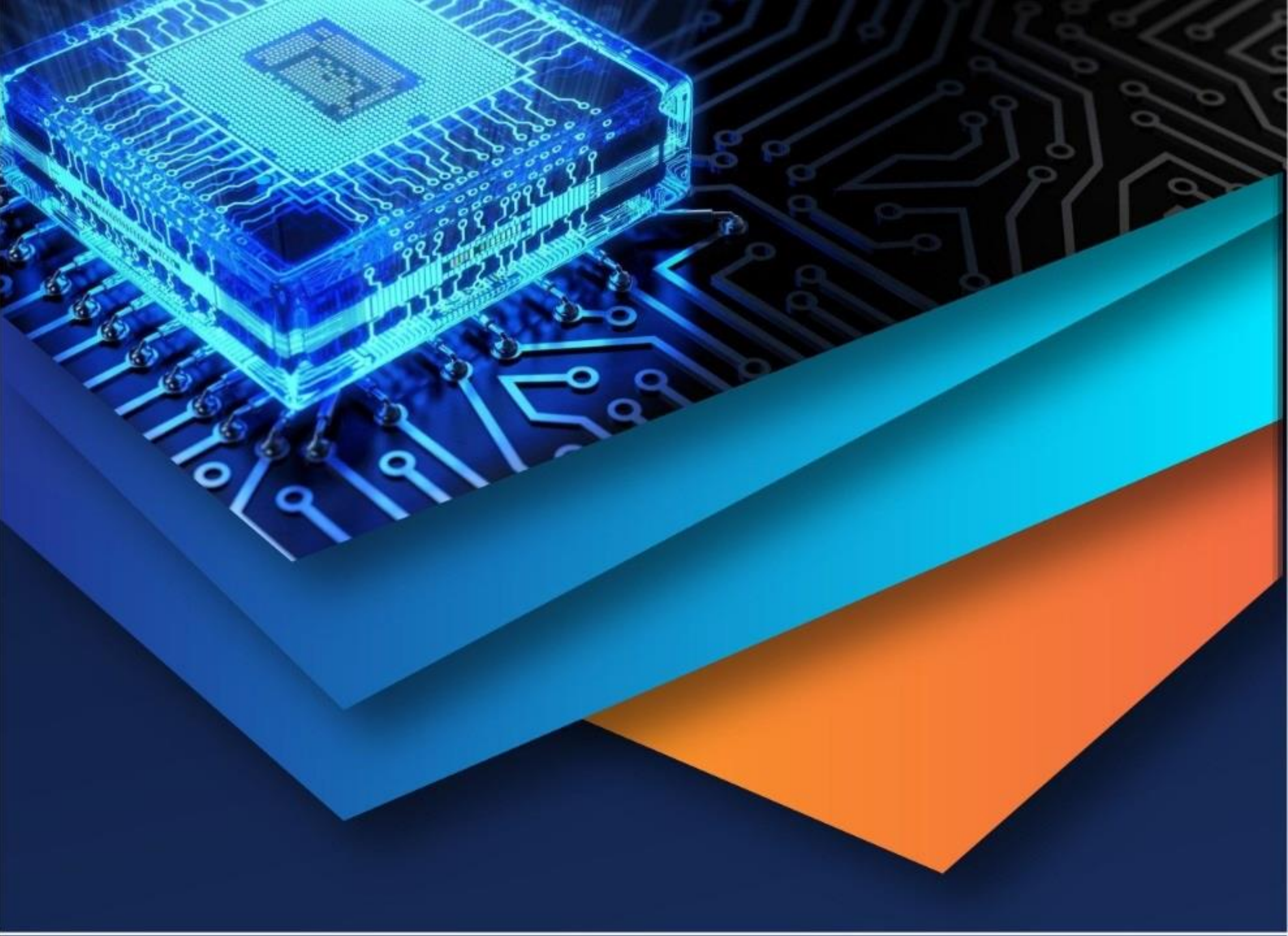

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