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# Circular Slot-Loaded Square Ring Microstrip Patch Antenna for IOT and ISM Band Application

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## ABSTRACT

Annually 14.7% demand is increasing for IoT devices & Wireless technologies projecting a rise in market to $22.3 billion till 2030, thus efficient and compact antennas operating at Industrial Scientific and medical [ISM] Band are widely needed. Wireless technologies like Wi-Fi, Zigbee, and Bluetooth uses 2.4GHz ISM band. Microstrip patch antennas are most oftenly used in these technologies, Microstrip patch antennas have characteristics like simple structure, low profile and easy to integrate with microwave circuitry. Yet, conventional microstrip antennas have low bandwidth and comparatively less radiation efficiency. This research work present the analysis and design of Circular Slot-Loaded square ring microstrip patch antenna functioning at 2.4GHz. The designing of the antenna is made by FR-4 dielectric substrate and examined using ANSYS HFSS electromagnetic simulation software. The current distribution is modified by introducing a circular slot in square ring patch resulting in improved impedance matching. The simulation result signify a VSWR of 1.3, gain of 3 dB, return loss of -32.8dB and bandwidth ranging from 2.3GHz to 2.6GHz. The proposed antenna have a compact design while delivering improved performance making it right for IoT devices.

**Keywords:-** ISM Band, Wireless technologies, Microstrip Patch antenna, FR-4 Substrate, ANSYS HFSS, slot loaded.

## I. INTRODUCTION

In the world full of enhancing wireless technologies which created a necessity of downsized & effectual antenna's which could cover frequency bands accepted all over the globe. From these frequency bands, one is the 2.4 Ghz Industrial, Scientific & Medical (ISM) band. ISM Band are being widely utilized in intermediate ranged wireless communication technologies, such as Wi-Fi, Zigbee, Bluetooth, BLE and many more used in IoT. This is possible because of the small size, compact design and Low powering feature in IoT devices, for these kind of application Designing of Antenna needs to be smaller, stable radiation pattern, and effective & efficient matching of impedance.

One of the most well known types of antenna for wireless communication system is Micro Strip Patch Antenna in view of the fact that it is of planar structure, light weight, low cost fabrication and it's ability to incorporate with Integrated Circuit Technologies. These advantages provide them to a large extent in small wireless devices & IoT branches. However, traditional Microstrip patch antennas usually have low bandwidth & limited radiation power, therefore, their performance is not suitable for nowadays wireless system's . In the literature, Through different methods it is been proposed to improve the performance parameter of microstrip patch antenna, such as parasitic elements, slot loading, stacked patch, and defected ground structure [1].

One of the most effective strategies is Slot Loading to enhance the working of the antenna by adjusting the ongoing distribution on the surface of patch and by increamenting the effective electrical length of antenna but the structural size of the antenna should remains unchanged. This technique is very beneficial for improving the radiation pattern, bandwidth and impedance matching. Some scholar have researched that adding the slots to radiation pattern like square, rectangular, round or ring shaped can generate new modes of resonance and performance enhancement of antenna in the wireless system[2].

The antenna design proposed in the research paper is Circular slot-loaded square ring Microstrip Patch Antenna, which operates at 2.4Ghz ISM Band. The antenna is designed with FR4 Dielectric substrate material and Simulation software used for analyzing which is ANSYS HFSS. The proposed design focuses on optimizing the bandwidth, gain and impedance matching with a compact structure which could work for IoT application.

## II. LITERATURE REVIEW

A considerate amount of research on Microstrip Patch Antenna has been done which operates at ISM Band. The traditionally designed Circular or rectangular patch antenna are used because it is easy to design and simple to fabricate. The antenna are basically are classified by narrow bandwidth properties and it restrict their functionality in modern-day wireless communication system.

A slot section has been introduced in the radiating patch it is been recognized as one of the most accepted ways for enhancing the antenna performance. Due to singal loading, a Significant change may take place in the surface distribution and different resonating frequencies are introduced which improve impedance bandwidth and enhances radiation properties. To cite an instance, Rao. Et al. Designed a Dual Band Circular Microstrip patch antenna with Slot for WLAN Application, The designed findings was that the design is capable of providing both Dual Band Operation with a rational return loss and stable radiation pattern with FR-4 substrate having a dielectric constant of 4.4[3].

Similarly, some other authors also proposed the use of WLAN with rectangular slotted microstrip patch antenna. Anita and Jayanti research stated that the slot-loaded rectangular patch antenna designed with microstrip which managed to work on both the frequency bands i.e. 2.4 GHz and 3.6 GHz in accordance with the Wireless System. Simulation software CST microwave studio is used to simulate the designed antenna and display better characteristics of impedance matching and gain parameter in comparison with traditional patch antenna[4].

Another Study based on Dual Band Patch Antenna of Microstrip which were actually designed for the application of Wi-Fi Communication system. It was presented that slot structure covered on the surface of the patch which could operate by producing 'N' number of resonant frequencies permits dual band functioning of wireless communication protocol e.g. IEEE 802,11 a/b/g [5].

In past few years, the compact multiband antenna, that could provide simultaneous operation to different types of wireless standards, has been analyzed by researchers. Significantly, it's been suggested that coupled resonant element and microstrip feed designs to generate compact planar antenna operating on a frequency of 2.4GHz, 5.2 GHz and 5.8 GHz which hold up the application of WLAN. In the radiating patch some of the structural changes have been recommended which could become very helpful in enhancing the functionality of antenna with a compact size.

It's been noticed that the Technologies like Wireless Sensor network and Radio Frequency Identification [RFID] are more likely in using slot antenna's. Abdelmounim et al. proposed that by embedding slots in the radiating element can unlock operation with two bands and reduction of size in slotted microstrip antenna. Designed antenna by them signify constant radiation properties and improved impedance matching at the frequency of operation[6].

Based on literature survey, it establishes that slot loading is one of the most prominent methods for enhancing the working of antenna's especially related with the impedance and bandwidth matching. Nonetheless, currently various designs have unique geometries or multi layered designs which are the source of complexity rising in fabrication. Thus, the evolution of an simple but efficient and effective slot loaded antenna structure is also a applicable research goal.

## III. ANTENNA DESIGN

The proposed antenna designed made is a square ring patch of microstrip with circular patch hole cut on a square patch. The antenna is based on FR-4 Substrate material with a dielectric constant of 4.4 and a thickness of 1.6mm.

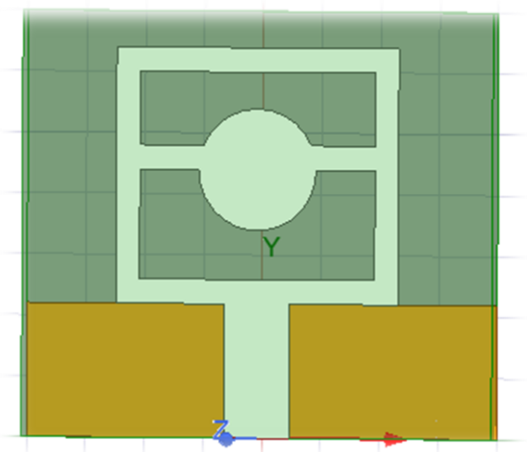


**Figure 1:- Front View of Proposed Antenna**

The antenna is excited by a microstrip feeding line.

The length of path is been changed by a circular cut in the square ring patch through which the flow of current occurs, along with adjustment is made on antenna surface for distribution of current. This guides to a improved Impedance matching and enhanced bandwidth characteristics.

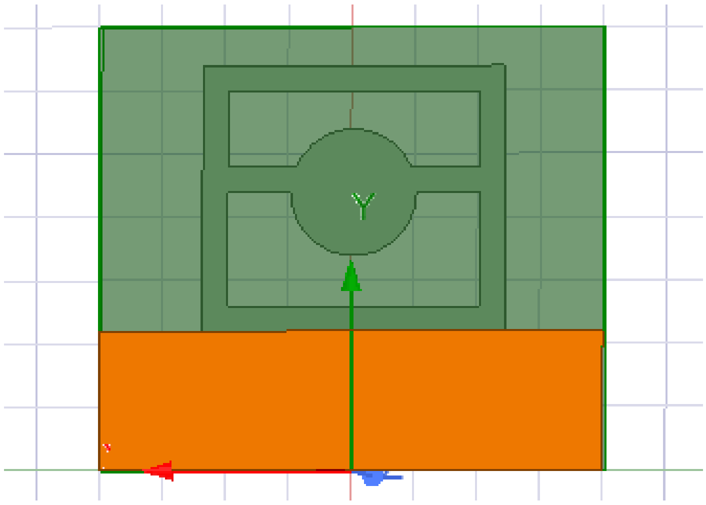


**Figure 2:- Back View of Proposed Antenna**

The proposed antenna is simulated by using ANSYS HFSS software to evaluate it's performance characteristics in accordance with it's potential to operate in consideration with VSWR, Return Loss, Gain & Radiation Properties.

## MATHEMATICAL EXPRESSION DEPENDING ON BALANIS BOOK[7]

### 1. PATCH HEIGHT:-

The patch's height (h) is determined as follows:-

$$h = \frac{0.3c}{2\pi\, f\sqrt{\varepsilon_r}}$$

### 2. PATCH WIDTH:-

The patch's width (W) is calculated as follows:-

$$w = \frac{c}{2f}\sqrt{\left(\frac{2}{\varepsilon_{r+1}}\right)}$$

### 3. EFFECTIVE DIELECTRIC CONSTANT:-

The effective dielectric constant($\varepsilon_{eff}$) is calculated as follows:-

$$(\,\varepsilon_{\mathrm{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$$

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## 4. PATCH LENGTH:-

Extension of the patch length (ΔL) is calculated as follows:-

$$\Delta L = 0.412\frac{[\varepsilon_{eff}+0.3][\frac{W}{h}+0.264]}{[\varepsilon_{eff}-0.258][\frac{W}{h}+0.8]}$$

## 5. EFFECTIVE LENGTH:-

Effective length of the patch ($L_{eff}$) is calculated as follows:-

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}}$$

## 6. PATCH REAL LENGTH:-

Calculation of the patch's real length (L) is calculated as follows:-

$$L = L_{eff} - 2\Delta L$$

## 7. GROUND PLANE DIMENSION'S:-

Calculation of the ground plane dimensions is calculated as follows:-

Lg= L + 6h

Wg=W+6h

### ANTENNA DESIGN PARAMETER

**Table 1:- Measurement of the Proposed Antenna**

| S.NO. | DESIGNED ANTENNA PARAMETER | VALUE(MM) |
|---|---|---|
| 1. | $L_f$ | 11 |
| 2. | $W_f$ | 5.5 |
| 3. | $L_p$ | 21 |
| 4. | $W_p$ | 24 |
| 5. | $L_s$ | 35 |
| 6. | $W_s$ | 40 |
| 7. | $H_s$ | 1.6 |
| 8. | $W_g$ | 40 |
| 9. | $L_g$ | 11 |
| 10. | $R_a$ | 5 |

## IV. METHODOLOGY

- The proposed Circular slot loaded square ring microstrip antenna design pursue a systematic and recursive approach beginning with an profound literature review. Research on microstrip and slot loaded antenna for ISM band application has been analyzed throughly which consists of gain, bandwidth, return loss, and compactness. The identified constraints in prior designs helps in the selection of an improved antenna design. Based on this analysis, a circular slot with a square ring patch is chosen to enhance distribution of current, proper impedance matching and compactness for IoT application.
- After reviewing the literature, the performance of designed antenna is based on commonly used microstrip antenna design equation and principles of transmission line theory.
- Mathematically, initial dimensions of substrate, patch and feed line are firstly calculated and simulated in ANSYS HFSS afterwards.
- The analysis and simulation part will demand the analysis of some of the key parameters such as Voltage standing wave ratio [VSWR], Radiation pattern, Gain, Return Loss [S11] and Bandwidth.

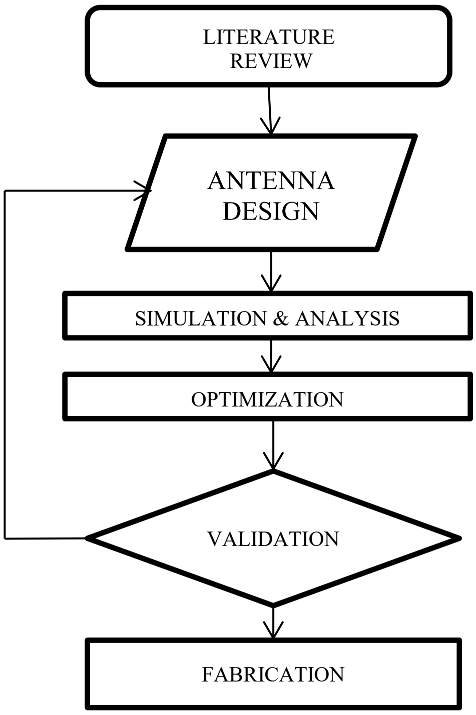


**Figure 1:- Methodology Flow Diagram**

- From the findings, an optimization is applied to critical design parameter such as patch dimension, slot radius and feed position are varied to gain a resonance at 2.4Ghz with improved impedance matching and adequate radiations.
- The final steps of the methodology includes the validation and fabrication as well as documentation. The designed antenna optimization is verified against the required standard performance during the validation like when VSWR is below 2 and the return loss is under -10dB.

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- When the specifications are not met, the designing process is repeated so that a process is been formulated for improvement which is made by feedback. After the successful validation of antenna is found valid, it is ready for fabrication, with PCB methods on an FR-4 substrate, so further it can be used in practice.

## SIMULATED RESULTS

### A. RETURN LOSS

The power reflected by the antenna input port is known as return loss. The proposed antenna has a return of -32.8dB at a frequency of 2.4GHz known to a proper impedance matching.

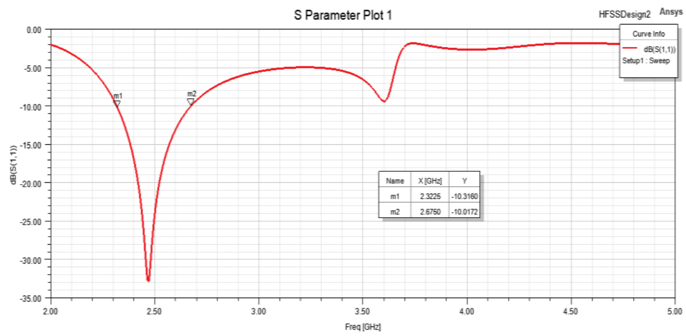


**Figure 4:- Simulated Result for Return Loss**

### B. VSWR

VSWR is the ratio of the voltage between the transmission line and the antenna showing transfer efficiency of power between them. The simulated antenna is having VSWR value of 1.3 which is smaller than the acceptable parameter [VSWR<2]

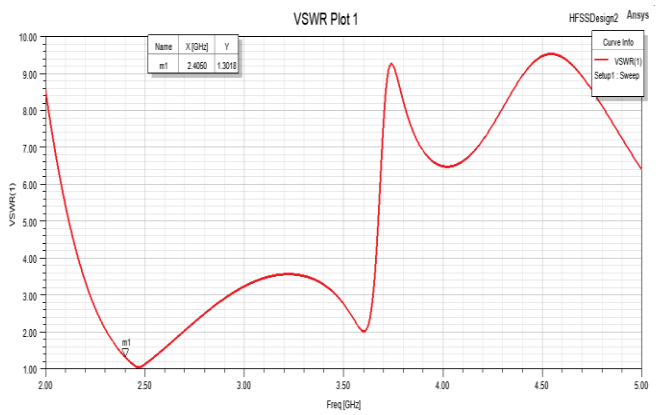


**Figure 5:- Simulated Result of VSWR**

### C. RADIATION PATTERN

Radiation pattern shows the directivity of the antenna energy transmission into the space. The simulation result's shows that the radiation pattern has a high area coverage properties, which is needed for wireless communicationsystem.

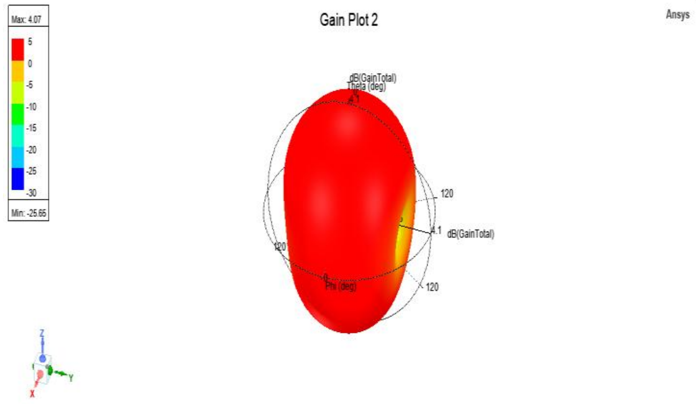


**Figure 6:- Simulated Result for Radiation Pattern**

### D. GAIN

The simulated antenna has a gain of about 3.02dB for antenna functioning at 2.4Ghz in ISM Band.

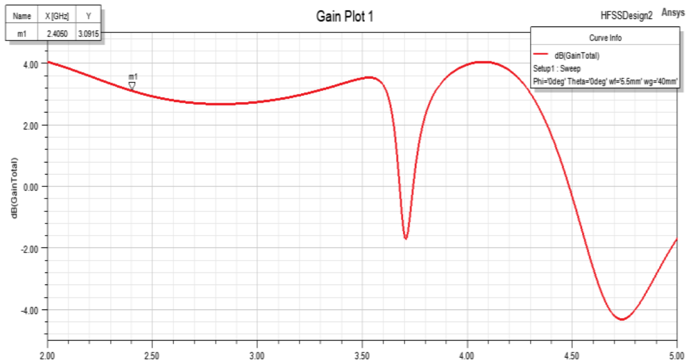


**Figure 7:- Simulated Result for Gain**

## V. RESULTS AND DISCUSSION

The simulation performed using ANSYS HFSS antenna software demonstrate that the proposed antenna has a significant level of resonance at a frequency range of 2.4GHz. Return loss shows the reflection of power from the antenna input. The Proposed design has a return loss of -32.8dB, showing good impedance matching between feed line and the antenna. The Design principle of antenna states that the value of return loss less than -10dB is generally acceptable in today's wireless communication system.

An another important parameter is VSWR which determine that how efficiently power is transferred between the antenna and the transmission line. The VSWR simulated is about 1.3, which verifies that the antenna has an effective impedance matching and has minimum reflection of power.

The simulated antenna having a gain of about 3.02dB, in comparison with the standard values which have been cited about compact antenna operated in IoT systems. Furthermore, the simulated antenna is having a bandwidth upto 2.6GHz, covering the 2.4GHz ISM Band for operation of wireless communication technologies.

The radiation pattern shows the broader radiation property which is mostly desried in wireless system, covering a wide area. Enhanced impedance matching, moderate gain and appropriate bandwidth are the grounds to believe that the proposed antenna will be adequate for the operation of IoT and WLAN applications.

## VI. CONCLUSION

The paper presents the design and analysis of a circular slot loaded square ring patch antenna operating at 2.4GHz ISM band, based on microstrip patch theory. The antenna has been designed on FR-4 substrate and simulated on ANSYS HFSS electromagnetic simulation software. When a hole is cutted of square geometry at the center of the radiating patch was introduced at the patch, which is circular in shape, by altering the surface distribution of current the bandwidth properties and impedance matching were enhanced to a great extent. The simulation result shows VSWR of 1.3, return loss of -32.8dB and bandwidth between 2.3GHz and 2.6GHz. The developed antenna design could be used in wireless network like Bluetooth devices, IoT devices and wi-fi networks which are been suggested through these findings. More work to be done in future is fabrication and validation of antenna for comparison of experimental and simulated results.

## REFERENCES

[1] David M. Pozar, "Microstrip Antennas," *Proceedings of the IEEE*, 1992.
[2] Sanjay Singh et al., "Design of Rectangular Microstrip Patch Antenna for WLAN Application," *International Journal of Engineering Research and Technology*, 2015
[3] L. Nageswara Rao et al., "Dual Band Circular Microstrip Patch Antenna with Slot for WLAN Applications," *International Journal of Engineering and Technology*, 2018
[4] Anita R., "Design of Slotted Microstrip Patch Antenna for WLAN Application," *International Journal of Engineering Research and Applications*, 2022
[5] Pon. Keerthana, "Compact Rectangular Microstrip Antenna for WLAN and WiMAX Applications," *IJERT*, 2014
[6] Elhassane Abdelmounim et al., "Compact Microstrip Slotted Antenna for Dual-Band RFID Applications," *International Journal of Technology*, 2018
[7] Antenna Theory: Analysis and Design, Constantine A. Balanis, Wiley, 2016