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# SQUARE MICROSTRIP PATCH ANTENNA FOR MSS AND WI-FI APPLICATIONS

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***Abstract***— A dual-band, coaxial-feed, square-shaped microstrip patch antenna with the truncated corner is designed. The antenna resonates at 2.21 GHz for Mobile Satellite Service (MSS) and 2.4 GHz for Industrial, Scientific, and Medical (ISM) radio frequency band utilized for Wi-Fi application. The design and simulation are done in CST software with FR4 substrate. Different parameters such as VSWR (1.22&1.09), return loss (-19.99&-27.15) dB, and directivity (5.65&5.89)dBi is enhanced. The fabrication of the design is done and it is tested using Spectrum analyzer. After that, a comparative analysis of simulated and tested results is carried out.

***Keywords***— **Dual-band, microstrip, Square Shaped, Antenna, Wi-Fi, MSS.**

## I. INTRODUCTION

Technological advances in telecommunications, especially wireless technologies, are evolving very rapidly. The rapid development of wireless telecommunication technology requires the use of multiple frequencies in a single device. For this reason, various types of antenna designs have been proposed. Previous people have utilized numerous antennas to cover different frequency bands, but assigning different antennas inside a limited space develop another difficulty of mutual coupling/isolation. Microstrip patch antennas (MPAs) are considered adequate to meet the requirements of present demands. These antennas provide interesting characteristics such as low profile, lightweight, low cost, simple amalgamation with RF circuits, etc. (Balanis.2010). A dual-band square patch antenna is made by truncating the corner of patch at the correct position. Due to the numerous uses in the various ISM bands and in medical disciplines, antenna design for ISM radio bands is a prominent study topic. Among the different ISM bands, the 2.4GHz band is the most coveted, since it contains multiple wireless applications. The study (Kissi et al., 2019) describes a dual-band coplanar waveguide fed double monopole antenna that operates in the 2.4/ 5.8GHz for ISM bands.

In paper (Nitin et al., 2018) a circularly polarized square shaped patch antenna that is etched in all four corners are presented. The design is operating at 2.351 GHz with the reflection coefficient of -30.43 dB and frequency band is 81GHz.The dual wideband textile antenna (Lo et al.,2019)] operating at 2.58 and 5.34 GHz with a bandwidth of 15.9% and 11.4 % respectively for WBAN/WIFI/LTE applications. In (Mapari et al., 2018) a single band rectangular shaped antenna is designed to operate at 2.4GHz for WiFi application with the reflection coefficient of -19.14 dB. In (Pawar et al., 2016) a dual-band circular Microstrip patch antenna (CMPA) with and without DGS for the utilization of ISM (2.4-2.5GHz) and WLAN (5.150-5.350GHz) is presented. The comparison of two implantable patch antenna designs constructed of two substrates, alumina, and Arlon, is provided for the Industrial, Scientific, and Medical (ISM) band (Ali et al.,2018), which is between 2.4 and 2.48 GHz. A small-sized rectangular shaped patch antenna with a change in the feed line is used for operating at the ISM band (2.4 GHz). The antenna is constructed with the use of two substrates, including FR-4 and Arlon and a comparision between the parameter Variation is shown in (Pachigolla et al., 2018)]. In (S.T.T.J et al., 2018) a rectangular microstrip patch antenna for the ISM band of frequencies that propagates at 2.4GHz with a return loss of -42.29 dB is described. A microstrip line feed is used to excite the antenna. A small monopole antenna with a modified triangular form with a return loss of -49dB for the applications of WLAN (2.4GHz), WiMAX (2.3GHz, 2.5GHz, 3.5GHz), and Wi-Fi (2.4, 3.6 GHz) is described in (Yadav et al., 2019). In (Thaher et al., 2018) a dual-band microstrip antenna design for Wi-Max and WLAN applications operating at (3.5 GHz and 5.8GHz) is discussed. The design resonates at 3.5 GHz and 5.8GHz with a return loss of -32.04 dB and -21.5dB. A dual-band microstrip patch antenna with slot pair is explained in (Alsaleh et al., 2016). It operates at the dual frequency of 1.8 GHz and2.4GHz for mobile and wireless LAN applications. In (Yassin et al., 2014), dual-band microstrip using C-slot is designed for WiMax and Wi-Fi. The antenna operates at 3.5GHz and 5.2 GHz with a return loss of -18dB and -31 dB respectively.

This manuscript is arranged into four parts. Part I covers the Literature survey of the antenna prototype. Part II explains the Layout of the modified antenna. Part III performs the simulation results of return loss, VSWR, Impedance, Gain, and Directivity. Part IV summarizes the article on the basis of a comparative analysis of simulated and experimental outcomes.

## II. ANTENNA CONFIGURATION

This section elaborates on the design procedure of the proposed microstrip patch antenna. The patch dimension, the permittivity, and the height of the substrate are the factors that determine the characteristics of an antenna.

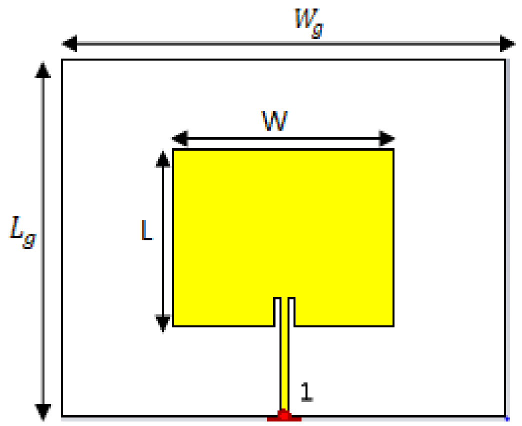



Figure.1Configuration of conventional microstrip Patch antenna

Figure.1 describes the single band conventional microstrip patch antenna which is constructed for ISM band of 2.4 GHz to be used for WiFi application. The substrate used is FR4 with $\varepsilon_r = 4.4$ and the dimension of rectangular-shaped patch antenna is arranged in Table I.

Table I Dimension of conventional antenna

| Antenna parts | Parameters(mm) | Values (mm) |
|---|---|---|
| Ground | Length($L_g$) | 56.76 |
| | Width($W_g$) | 76 |
| | Thickness(Ht) | 0.035 |
| Substrate | Length(Ls) | 56.76 |
| | Width(Ws) | 76 |
| | Height (Hs) | 1.6 |
| Patch | Length(L) | 28.38 |
| | Width(W) | 38 |
| Feed line | Width($w_f$) | 1.42 |

A microstrip patch antenna is made up of a radiating metallic patch on one side of a non-conducting substrate panel and a metallic ground plane on the opposite side. This conventional antenna is designed with a return loss of less than -10dB and VSWR<2 for Wi-Fi applications. The improvement of these parameters along with multiple applications is still required. The structure of proposed antenna is represented in Figure 2. The proposed antenna is a square-shaped patch with all four corners inscribed.

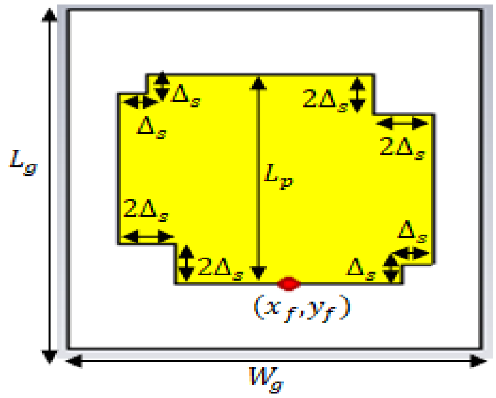



Figure.2 Proposed antenna structure along with co-axial feed

The proposed antenna is a dual-band antenna as it resonates at 2.2GHz and 2.4GHz respectively. There are various methods for realizing a dual-band antenna but the simplest way of getting a dual-band is by inserting or cutting a slot at a suitable position

in the patch. The design formula used to estimate the dimension of the square patch antenna is discussed in [14].

$$L_P = \frac{c}{2f_{r\sqrt{\varepsilon_r}}} - 2\Delta l \qquad (1)$$

Where, $f_r$ is resonant frequency, $\Delta l$ is the increment in patch length, c is velocity of light $3 \times 10^8 m/s$, $\varepsilon_r$ is dielectric constant of substrate used. The $\Delta l$ can be evaluated by using equation (2) and (3).

$$\Delta l = 0.412h \frac{(\varepsilon_e+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_e-0.258)(\frac{w}{h}+0.813)} \qquad (2)$$

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12\frac{h}{w}}} \qquad (3)$$

In equations (2) and (3), h denotes the height of the substrate, w is the width of the patch, and $\varepsilon_e$ signifies the effective dielectric constant of the substrate. The computed length of the patch is $L_P = W_P = 32mm$ and the dimension of ground plane is $L_g = 52mm$ and $W_g = 42mm$. The opposite corners of the patch are truncated in square shape having an appropriate measurement of $\Delta_s = 3mm^2$ and $2\Delta_s = 6mm^2$. Co-axial feed is used to excite the antenna at $(x_f, y_f) = (1.5, -16)$mm. The FR4 substrate ($\varepsilon_r$ =4.3, $h$ = 1.6 mm, tan$\delta = 0.02$) is used for simulation and fabrication of design. The CST Software tool is used to model the design.

## III. RESULT AND DISCUSSION

Some parameters have changed while designing the antenna, and the outcomes have been studied to adjust the antenna's operating frequency. To obtain the desired simulation outcome, several iterations are done by modifying the size of the patch by keeping the dimension of the cutting slot, $\Delta_s$ fixed. The working frequency of the antenna based on the size of the patch, if the size of the patch increases then the frequency will decrease and vice versa. The iteration process of the dimension of $L_p$ side length of the patch is displayed in Table II.

Table II Variation in size of $L_P$

| Iteration | Size of $L_p = W_p$ |
|---|---|
| **Iteration 1** | 28 mm |
| **Iteration 2** | 30mm |
| **Iteration 3** | 31 mm |
| **Iteration 4** | 32 mm |
| **Iteration 5** | 34 mm |

The desired results of S11, VSWR, and directivity of the designed antenna are achieved after numerous iterations as represented in Fig.3, Fig.4 and Fig.5.

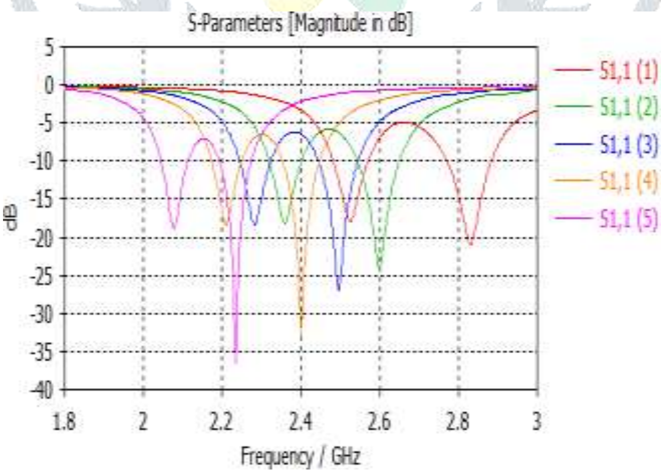



Fig.3 Return Loss plot from variation in $L_p$

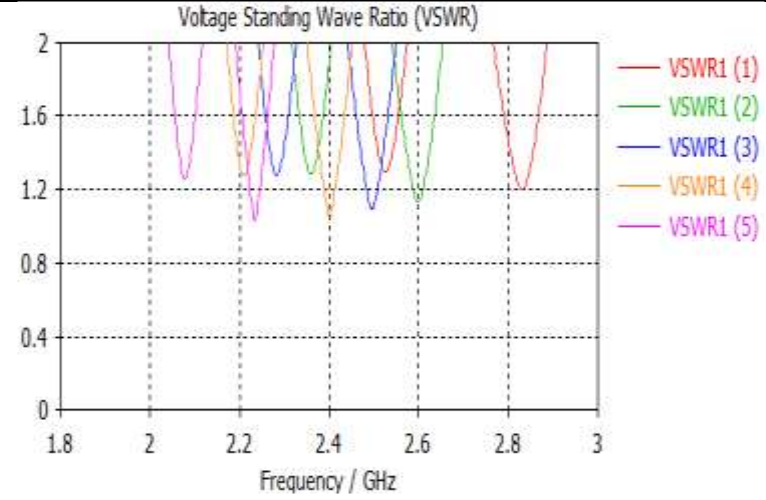



Fig. 4 VSWR plot from variation in $L_p$

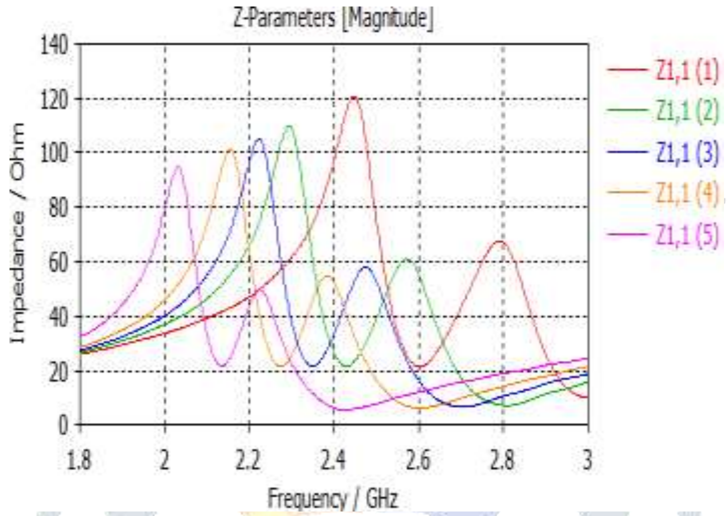



Fig.5 Impedance at different patch dimension of $Lp$

Figure.3, Figure.4, and Figure.5 represents that the patch size affects the operating frequency, S11, VSWR, and impedance of the modified antenna. The overall outcome in the iteration process is arranged in table III.

Table III Simulation outcome from variation in the value of $L_p$

| Iteration | Operating frequency(GHz) | S11 (dB) | VSWR |
|---|---|---|---|
| **Iteration 1** | 2.52 and 2.83 | -17.85 and -20.92 | 1.293and 1.19 |
| **Iteration 2** | 2.36 and 2.6 | -18 and -24 | 1.289and 1.138 |
| **Iteration 3** | 2.28 and 2.49 | -18.26 and -26.91 | 1.276and1.094 |
| **Iteration 4** | 2.21and 2.4 | -19.97and -27.15 | 1.223and 1.09 |

Figure.3 and table III show that the optimize outcome is achieved in iteration 4 with a return loss of -19.97dB and -27.15dB in the working frequency of 2.21GHz and 2.4GHz. From the above discussions, it is noticed that the optimized size of $L_p(i.e. L_p = 32mm)$ modifies the S11 parameter as presented in Fig.6.The bandwidth of the proposed design is quite appropriate for the use of mobile satellite service and Wi-Fi. At 2.21 GHz the bandwidth is 76.5 MHz and 96.8 MHz at 2.4GHz frequency.

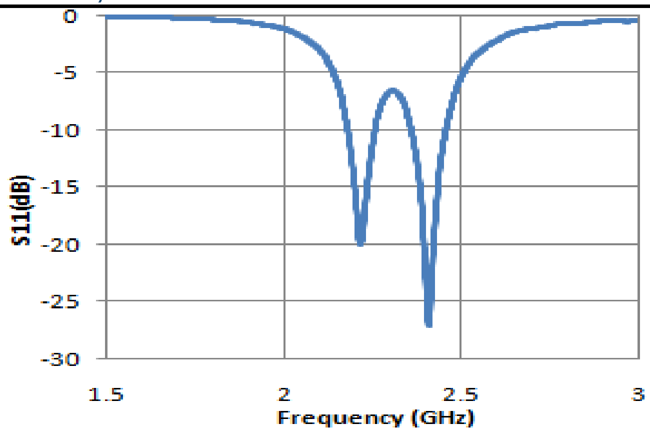



Fig.6 Return loss of proposed antenna

Fig. 6 shows that the antenna operates at a dual-frequency that is at 2.2 GHz and 2.4 GHz respectively with S11< -10dB at the required frequencies. The Specification of VSWR, impedance, gain, and directivity are depicted in Fig.7, Fig.8, Fig.9, and Fig.10. Figure.7 depicts that the VSWR value is very close to 1 which is good for impedance matching. Where:

$$VSWR=\frac{1+\gamma}{1-\gamma} \quad (4)$$

In equation (4), $\gamma$ represent the reflection coefficient and the value of return loss, S11=10 log ($\gamma$).

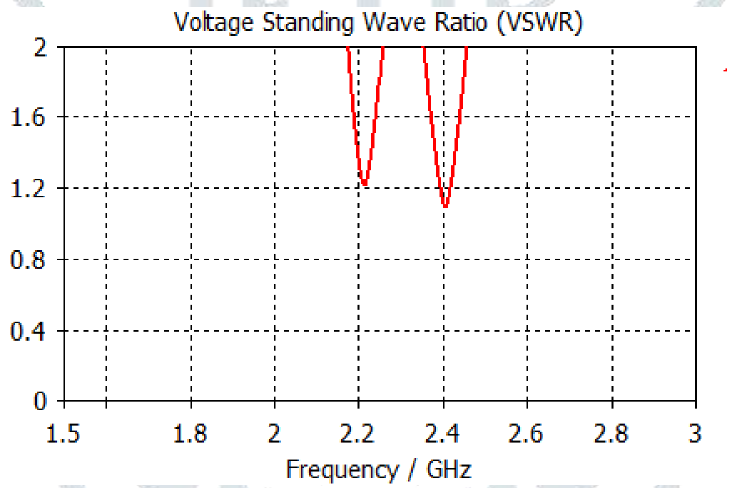



Fig.7 VSWR of proposed antenna versus frequency

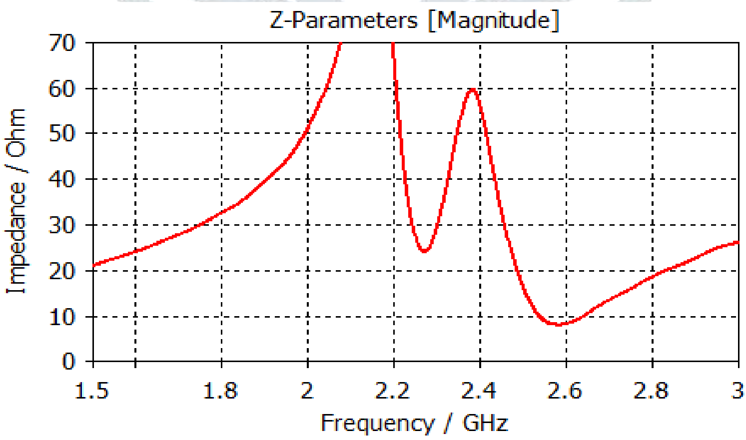



Fig.8 impedance of antenna with respect to frequency

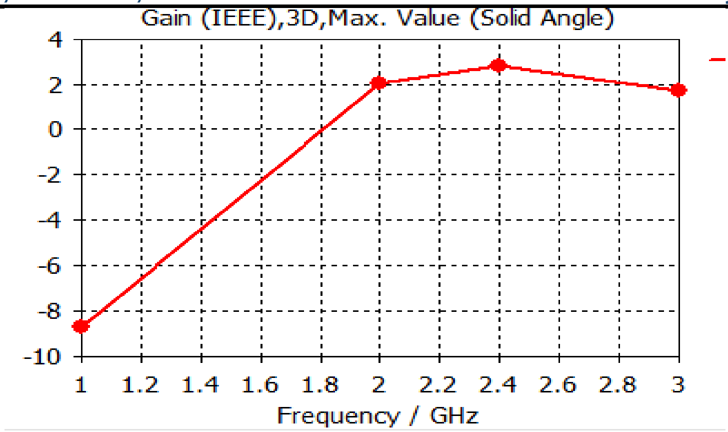
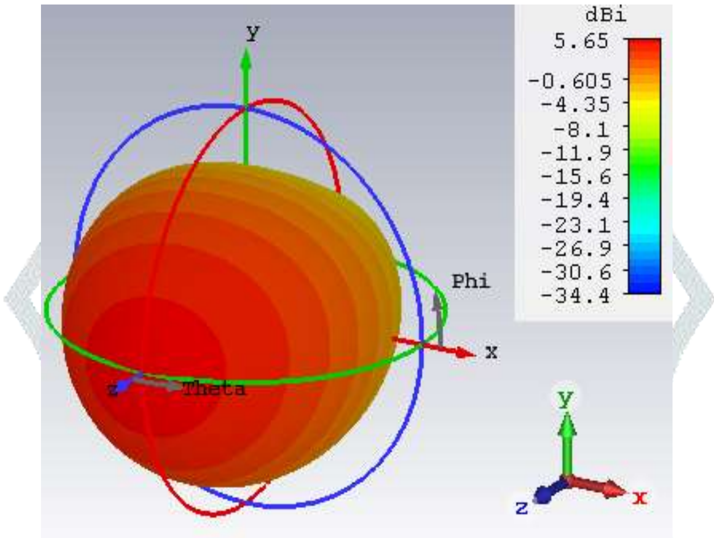
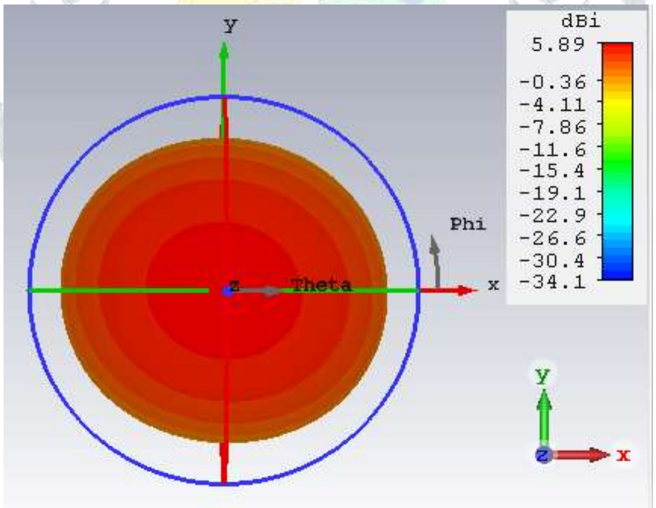



Fig. 9 Simulation result of antenna gain versus frequency




(a) 2.21 GHz




(b) 2.4 GHz

Fig.10 3D view of Directivity at (a) 2.21GHz (b) 2.4 GHz

The structure of conventional design is represented in Fig.1. The design resonates at 2.4GHz and the structural dimension of the patch antenna is arranged in Table 1. The comparison of return loss of conventional antenna with the designed antenna is illustrated in Fig.11. Figure 12 depicts the VSWR of the conventional antenna. The outcome after the comparison of different specifications is listed in Table IV. Return loss, VSWR, Impedance, and Directivity of the modified design (Fig. 2) are improved than the reference design [5].

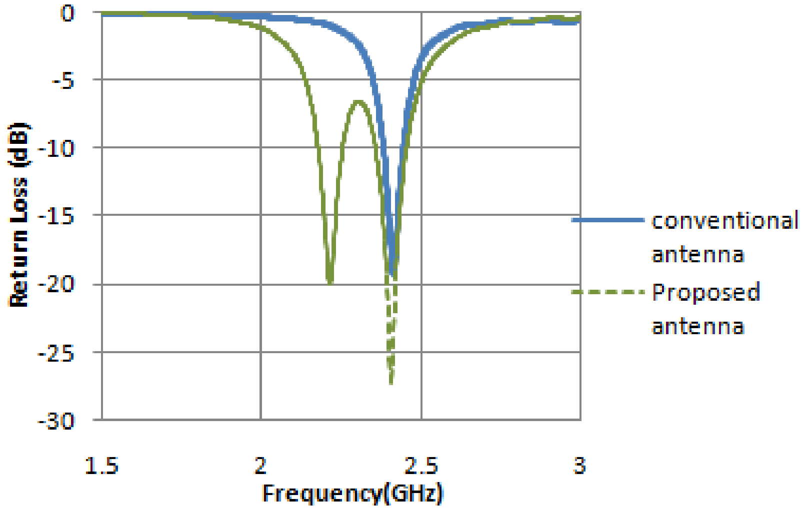



Fig.11 comparison of return loss

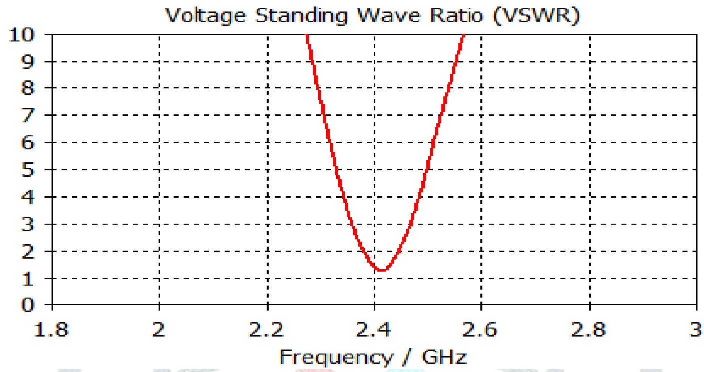



Fig.12 Simulated VSWR of conventional antenna

Table IV Comparison of conventional antenna with proposed antenna

| **Parameter** | **Conventional Antenna**[5](Fig.1) | **Proposed Antenna** (Fig.2) | |
|---|---|---|---|
| Structure | Single band | Dual band | |
| Patch size | $28.38 \times 38mm^2$ | $32 \times 32mm^2$ | |
| $f_0$ (GHz) | 2.4 | 2.21 | 2.4 |
| Return Loss (dB) | -19.14 | -19.99 | -27.15 |
| VSWR | 1.8 | 1.223 | 1.09 |
| Directivity | 4.5 dBi | 5.65dBi | 5.89 dBi |
| Application | Wi-Fi | MSS and Wi-Fi | |

Table IV demonstrates that the designed antenna has improved characteristics than the conventional antenna at the working frequency of 2210 MHz and 2400 MHz.

## IV. HARDWARE DESIGN AND TESTING

### A. HARDWARE DESIGN

Firstly, the design of antenna is transferred from the CST software to ZWCAD software for printing it onto the glossy paper and then the process of photo exposure is done. The Etching process is carried out and finally the co-axial feed is inserted by soldering the prototype at the appropriate position. The fabricated proposed antenna prototype is illustrated in fig. 13.

(a) Front view

(b) Back view

Fig.13 Design of the fabricated proposed antenna (a) Front view (b) Back view

B. HARDWARE TESTING

The measurement setup of prototype with spectrum analyzer is displayed in Fig.14. The ROHDE & SCHWARZ Spectrum Analyzer of version FS315 is used for the testing purpose. The limit frequency of this spectrum analyzer is from 9 kHz to 3GHz.

Fig.14. Testing set-up of design with spectrum analyzer

The comparison of simulated and fabricated outcome of return loss is shown in Fig.15 and the numerical value of return loss, bandwidth and the resonant frequency of simulated and measured are listed in table V.

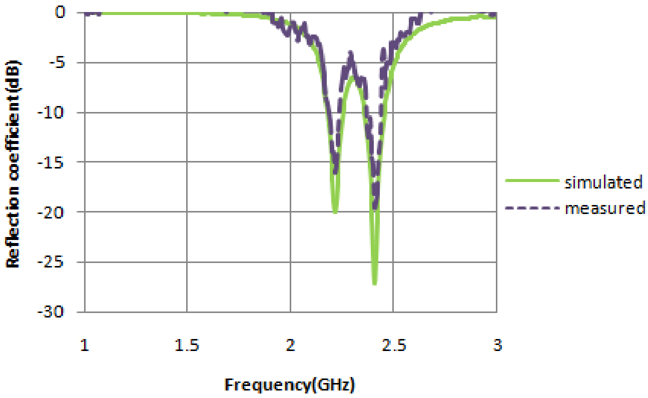



Fig.15 Simulated and measured result of S11 parameter

Table V Comparison of Simulated result with experimental work

| Results | Simulated | | Measured | |
|---|---|---|---|---|
| Resonant Frequency(GHz) | 2.21 | 2.4 | 2.19 | 2.39 |
| Return Loss(dB) | -19.99 | -27.15 | -15.98 | -19.91 |
| Bandwidth(Hz) | 76.5 | 96.8 | 75.89 | 95.9 |

Fig.15 and Table V show that simulated and measured results are comparable with each other while a minute reduction in the value of return loss is may be due to fabrication tolerance, material purity, use of lossy substrate and testing environment.

## V. CONCLUSION

In this paper, a dual-band co-axial feed square microstrip patch antenna with all of its four corners is etched is presented and the results are simulated using CST software. The modified design provides the parameters such as return loss of -19.99 dB for 2.21GHz and -27.15 dB for 2.4GHz and the VSWR is1.22 for 2.21GHz and 1.09 for 2.4GHz. Also, the bandwidth of the antenna is quite good which is76.5 MHz at 2.21 GHz frequency and 96.8 MHz at 2.4 GHz frequency. This paper also concludes that the simulated and experimental outcomes are comparable to one another. Consequently, the suggested antenna offers favorable characteristics for use in mobile satellite service and Wi-Fi applications.

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