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Dual-Band Square Microstrip Patch Antenna for 4G/LTE and Wi-Fi Applications

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***Abstract:** A dual-band, Square-shaped Microstrip Patch Antenna (SMPA) with two opposite corner cuts is proposed. The presented design is suitable for 4G/LTE and Wi-Fi applications as it resonates at 2.13GHz and 2.41GHz frequencies. The FR4 substrate with co-axial feed is used for fabrication and is simulated using CST software. The simulation result provides enhanced antenna specification of return loss (-42.64&-20.13) dB, bandwidth (62.7&89) MHz and percentage bandwidth (2.94&3.69) % than the conventional antenna prototype. Furthermore, a comparative study of simulated and experimental findings is analyzed in this manuscript.*

***Keywords:** Dual-band, return Loss, Bandwidth, Percentage Bandwidth, 4G/LTE, Wi-Fi.*

I. INTRODUCTION

In the field of wireless communication systems, microstrip patch antennas are essential for various properties such as bandwidth, flexibility, multiband operations, and compressed size. Due to the advantages of a lightweight, easily integrated into microwave circuits, low-priced, and compressed size, these are the basic requirements in wireless communication. The Microstrip Patch antenna offers a good reflection coefficient, high efficiency, and directional radiation pattern. Patch antennas are capable to operate in more than one frequency band. Although these types of antennas have a limitation of limited bandwidth [1]. Various methods are presented to solve this limitation, such as introducing parasitic elements, improving the height of the substrate, defective ground structures [2], choosing the appropriate feeding location [3], changing the dimension of patches, and introducing slots. The technique of introducing a slot at the opposite corner of the patch can reduce the antenna size and make it useful for multi-band operation. It has been studied that, the cutting slot with proper feeding position in the patch realizes dual-band response and is also valuable for the improvement of specification of reflection coefficient, resonant frequency, and bandwidth of the antenna.

In reference [4], [5] Microstrip antennas are being studied for a variety of wireless portable communication system applications. Articles on different types of microstrip antennas, their uses, and the study of frequency bands are presented. A rectangular microstrip patch antenna for LTE mobile applications operating at 2.1GHz and 2.3 GHz is described in [6]. This conventional prototype gives the specification such as return loss of -34.68 dB for 2.1 GHz and -36.39 dB for 2.3 GHz with a frequency band of 50 MHz and 56 MHz. The rapid evolution in the wireless network increases the requirement of a single device operating on multiple frequencies for various applications [7]–[13]. A rectangular patch, trapezoidal slotted PIFA antenna for 4G and Wi-MAX applications. The antenna operates at 2.37 GHz and 3.48 GHz frequencies with a return loss of -13.76dB and -20.09dB. Their corresponding bandwidths are 230 MHz and 300 MHz [7]. In [8] authors proposed a dual-band microstrip patch antenna that resonates at 1.8GHz and 2.4GHz for mobile and wireless LAN applications. Their Return losses are -14 dB and -24 dB respectively. In [9] author explained a dual-band L-shaped slotted square patch antenna with opposite corner cut of length3mm is introduced for circular polarization. The operating frequency of the antenna is 2.45 GHz and 4.81 GHz with a frequency band of more than 100 MHz. In paper [10] a dual wideband monopole antenna is proposed for various wireless applications such as GSM, UMTS, LTE, Wi-Fi, WiMAX, etc. A dual wideband - slot loop textile antenna of 2.58/5.34 GHz with percentage bandwidths of 15.9/11.4 % and gains of 4.21/6.45 dBi is discussed in [11]. The antenna is suitable for WBAN, Wi-Fi, and 4G LTE applications. In paper [12] a dual-band antenna covers a frequency band of 115&928 MHz that operates at 2.4/5.8 GHz. Four slots are inserted on the patch for lower band operation, and a U-slot square patch is for upper band operation. For WLAN application, a dual-band antenna with a defective ground structure is designed to operate at 2.4/5.2GHz [13].

Previously mobile phones work on one frequency only but these days the demands of gadget to function on numerous bands are increasing rapidly. The designing and manufacturing of compressed, multiband single feed antennas for various applications is a strenuous work for antenna researchers. . The purpose of this manuscript is to develop the dual-band microstrip patch antenna resonating at 2.13GHz and 2.41GHz for 4G/LTE and Wi-Fi application with the improvement of reflection coefficient, Bandwidth, Percentage Bandwidth, Gain, and VSWR.

This paper is arranged into four parts, 1st part discusses the introduction and literature survey of antenna design. 2nd part explains the design procedure of the modified antenna for 4G / LTE and Wi-Fi applications. 3rd part performs the simulation outcome of return loss, bandwidth, VSWR, Directivity, and gain. The 4th part concludes the manuscript based on the comparison between the simulated and experimental outcomes.

II. ANTENNA CONFIGURATION

This section elaborates on the design procedure of the proposed microstrip patch antenna. Generally, the patch antenna is a resonant type antenna that works on a single frequency. So, people used multiple antennas to use distinct frequency bands for various applications. But the limitations of mutual coupling, compact size, and to reduce the cost of the antenna, the demand for a single device resonating at multiple frequencies is increasing rapidly.

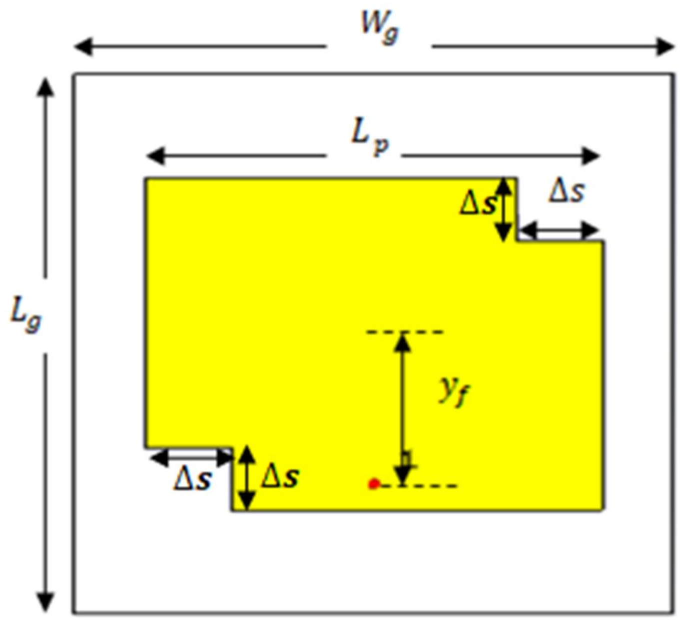

Fig.1. Design of Proposed antenna

The structure of the square shaped patch antenna with opposite corner cut is shown in Fig.1.The dimensions of the side length (L_P) of the square microstrip patch antenna is determined by using equation (1).

$$L_p = \frac{c}{2f_{r\sqrt{\epsilon_r}}} - 2\Delta l \tag{1}$$

Where, f_r is resonant frequency, Δl is the increment in patch length, c is the velocity of light in free space and the value is $3 \times 10^8\ m/s$, ϵ_r is dielectric constant of substrate. The incremental length of the patch Δl can be calculated by using equation (2) and (3) [14].

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

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{\sqrt[2]{1+12\frac{h}{w}}} \tag{3}$$

In equation (2) and (3), h is the height of the substrate, w is width of the patch and ε_e is the effective dielectric constant of substrate and is evaluated by using equation (3).The dimension of L_p of the optimized square- shaped patch antenna is 32 mm. To obtain a dual-band antenna, a square shape slot is cut in the opposite corner of the patch so that the antenna will operate at the desired frequency.

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As shown in Figure.1, the opposite corners of the patch are cut into a square shape having appropriate measurements of $\Delta s = 6mm^2$. The location of co-axial feed is at y_f = -13.5 mm. The FR4 substrate (ε_r= 4.3, h = 1.6mm, tan δ= 0.02) is utilized for simulation and fabrication of design. Firstly, the structure of the dual-band antenna is designed and then simulated using the CST microwave studio suite of version 2018 [15]. To simulate the design an infinite ground plane is examined. Although for the manufacturing procedure limited ground plane is considered. The dimension of the ground plane to design the proposed antenna is L_g = 52mm and W_g = 42mm respectively.

III. RESULTS AND ANALYSIS

The CST microwave studio of 2018 model has been used to determine the design specification.

A. *Proposed Antenna Characteristics*

1) *Return Loss and Bandwidth:* the proposed antenna resonates at dual frequencies of 2.13 GHz and 2.41 GHz with a frequency band of 62.7 MHz (2.1015 to 2.1642 GHz) and 89 MHz (2.372 to 2.461GHz) respectively. The return loss at 2.13GHz and 2.41GHz is -42.64 dB and -20.13 dB as shown in Fig. 2.
2) *VSWR:* The VSWR at 2.13 GHz and 2.41 GHz is 1.01 and 1.22 which is quite good for impedance matching. Figure 3 shows the variation of VSWR with frequency.
3) *Gain:* The Variation of gain with frequency for the modified design is shown in Fig. 4. At 2.1GHz and 2.41GHz Gain is1.54 dB and 2.91 dB as shown in Fig. 5 and Fig.6.
4) *Directivity:* The Directivity value of the proposed antenna is 5.43 dBi and 5.87 dBi at 2.13GHz and 2.41GHz respectively is shown in Fig.7.

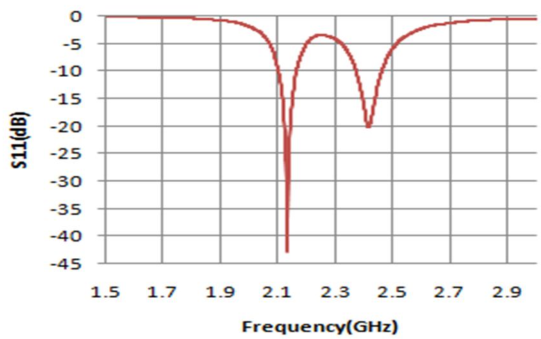

Fig.2. Simulated S11 parameter of proposed antenna

The graph of S11 clearly shows that the proposed design resonates at two frequencies which are at 2.13GHz and 2.41 GHz with a value less than -10 dB. The band of 62.7 MHz at 2.13 GHz frequency is appropriate for 4G/LTE application and the band of 89 MHz at 2.41 GHz frequency is good for Wi-Fi application. Wi-Fi has evolved for mobile computing devices like laptops, but nowadays it is used in mobile phones, TVs, DVD players, and digital cameras.

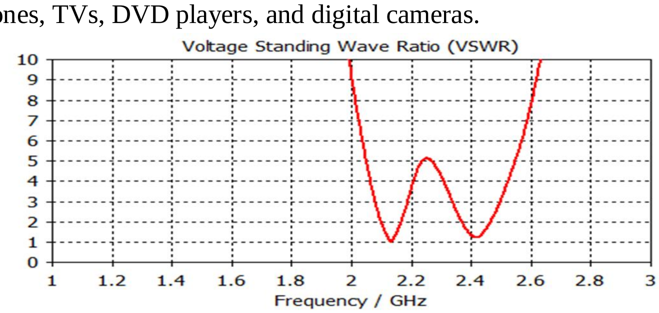

Fig.3. Simulated VSWR with frequency

From Fig.3, it can be observed that the value of VSWR is quite good at desired frequencies while at other frequencies, the VSWR value becomes greater than 2.

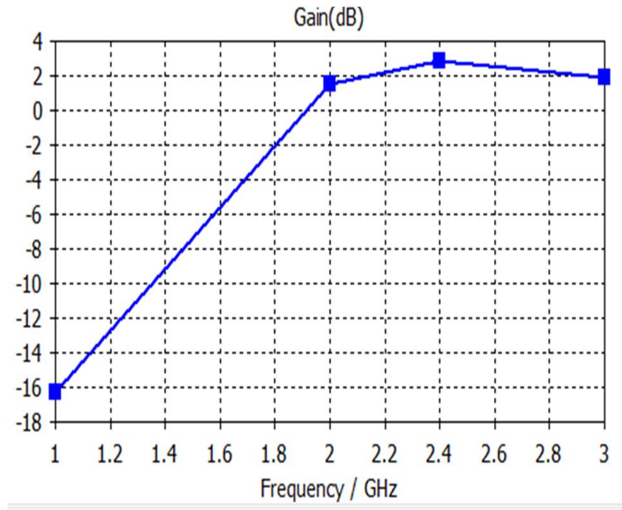

Fig.4. Variation of Gain with frequency

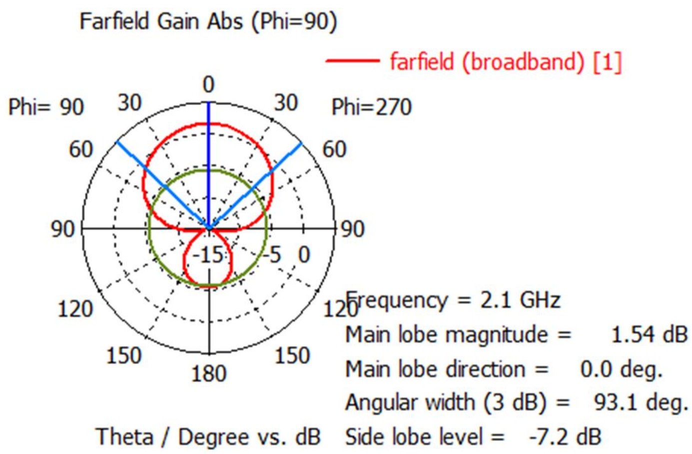

Fig.5.Simulated Polar plot of Gain (dB) at 2.1 GHz.

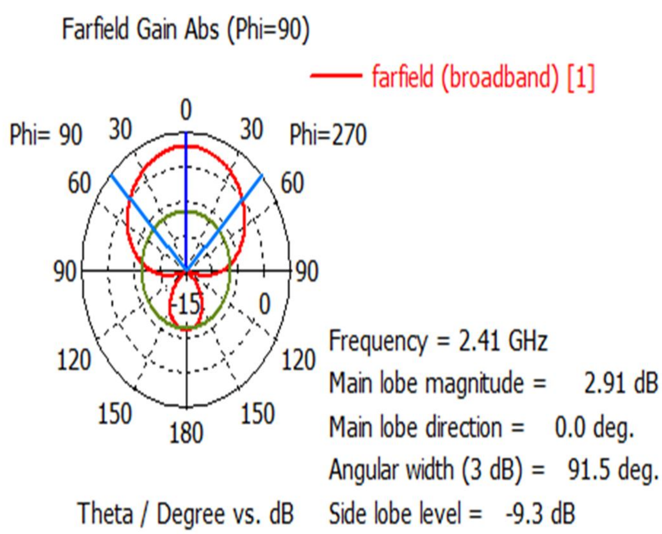

Fig.6. Polar plot of Gain (dB) at 2.41GHz

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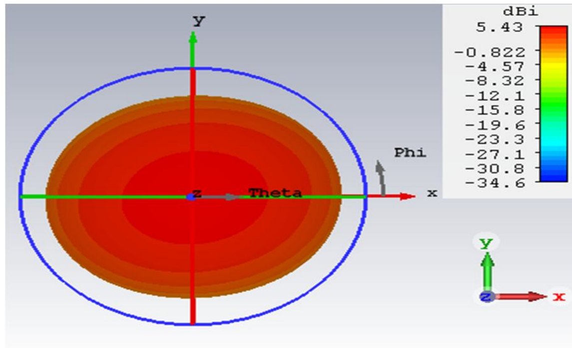
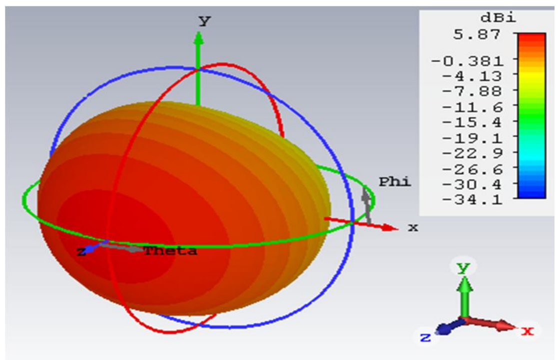


(a) 2.13 GHz



(b) 2.41GHz

Fig.7. 3D pattern of Far-field directivity at (a) 2.13GHz (b) 2.41GHz

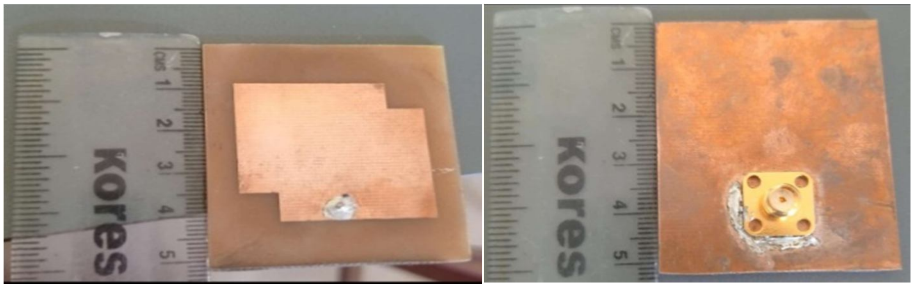
B. *Comparision With Conventional Antenna*

The Comparison of antenna characteristics of conventional [6] and proposed antenna are arranged in Table.1.The objective of this research is to improve the return loss, bandwidth and percentage bandwidth at an operating frequency of 2100MHz and 2400MHz.

Table.1. Comparison table of proposed work versus published numerically simulated data

Parameter	**Conventional Antenna** [6]		**Proposed Antenna (**Fig.1)	
Structure	Single band (two structure)		Dual band (one structure)	
f_0(GHz)	2.1	2.3	2.13	2.41
Return Loss(dB)	-34.68	-36.39	-42.64	-20.13
Bandwidth (MHz)	50 (2.112-2.062)	56 (2.32-2.264)	62.7 (2.1642-2.1015)	89 (2.461-2.372)
Percentage Bandwidth	2.38 %	2.43%	2.94 %	3.69%
Application	4G		4G and Wi-Fi	

From the Table, it can be seen that the proposed antenna has a better performance than the conventional antenna. Return loss, Bandwidth, and Percentage Bandwidth of the optimized design (Fig.1) are better than the reference design [6]. The antenna prototype has been manufactured and is shown in Fig.8, while the simulated and experimental result of S11 is compared and presented in fig.9.



(a) Top view (b) Bottom view

Fig.8.The manufactured design of the proposed antenna (a) Top view (b) Bottom view

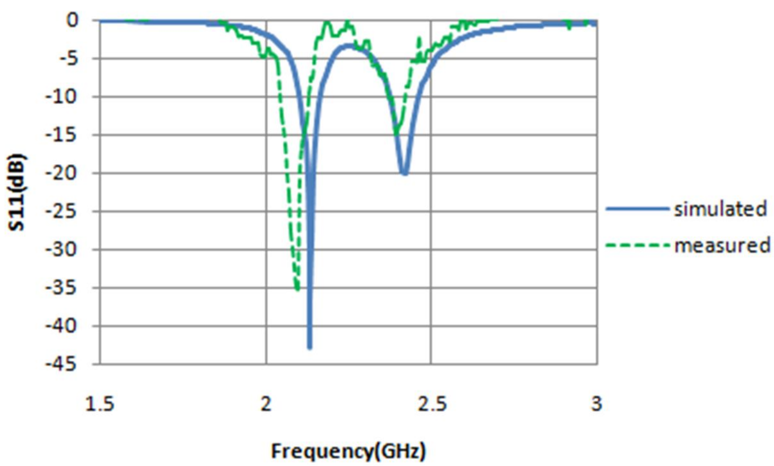


Fig.9. Simulated and measured results of S11 parameter

Fig.9. illustrates that a slight variance of the S11 parameter of the simulated and measured results. The measured result of S11 is moderately switched towards the left side of the simulated results with a slight decrease in the value of S11 because of various reasons. One of the reason is the value of the dielectric constant could not be estimated correctly in the fabrication procedure while in the simulation procedure the value of dielectric constant ($\varepsilon_r = 4.3$)is used. The other reasons are may be because of measurement considerations, fabrication material purity, connector soldering, and testing environment. The results of return loss and bandwidth are compared and arranged in Table.2.

Table.2. Simulated result versus experimentally measured result of proposed antenna

Results	Simulated		Measured	
Resonant frequency (GHz)	2.13	2.41	2.094	2.388
Return Loss(dB)	-42.64	-20.13	-35.18	-15
Bandwidth (Hz)	62.7	89	62	88.23

FromTable.2, it is clearly shown that the measured results obtained after testing are quite comparable to the simulated results. So, the designed antenna is appropriate for the application of 4G/LTE and Wi-Fi.

IV. CONCLUSION

In this manuscript, a compact dual-band Single feed diagonally corner cut square shaped patch antenna is designed and the simulation is done using CST for 4G/LTE and Wi-Fi applications. The proposed antenna resonates at 2.13GHz and 2.41GHz with optimized antenna parameters such as return loss of -42.64 dB for 2.13GHz and -20.13 dB for 2.41GHz and their corresponding frequency band is 62.7 MHz and 89MHz respectively. The percentage bandwidth is 2.94% for 2.13 GHz and 3.69% for 2.41 GHz which is appropriate for wireless applications. The simulated and experimental results of return loss are closely related to one another. In a nutshell, the designed antenna has better characteristics to be utilized for 4G/LTE and Wi-Fi applications.

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