Parametric Variations of Rectangular Microstrip Patch Antenna Designed for WLAN Application

Archana Tiwari¹ and Dipika Sagne²

¹Assistant Professor, Electronics Engineering Department, Shri Ramdeobaba College of Engineering & Management, Nagpur, India

²Reserch Scholar, Indian Institute of Information Technology, Nagpur

ABSTRACT

Antennas are the key parameter for wireless communication and microstrip patch are the simplest form of planar antennas. Rectangular patch has attracted many applications like Wi-Fi, Wi-max, WLAN etc. The proposed work is concentrated on design, implementation and designing procedure of rectangular microstrip patch antenna with inset feed for Industrial-Scientific-and Medical (ISM) band applications. The paper shows the parametric variation to achieve good return loss at a targeted frequency. The best results in the variation were selected for fabrication. The paper shows the rectangular patch of dimension 28.3×37.5 mm² with a finite ground plane 39x 47.5 mm². The patch is designed with the substrate FR4 with thickness 1.6 mm, and antenna is fed with inset feeding technique with feed length 3.14 mm. The paper presented with a considerable match between simulated and fabricated antenna results. The antenna is simulated using a CST tool and gain and return loss were obtained as 1.977dBi and -19.25dB respectively. The paper is targeted for Wireless Local Area Network (WLAN) application.

KEY WORDS: MICROSTRIP, PATCH, ANTENNA, INSET FEED, WLAN.

INTRODUCTION

Microstrip antennas are increasing their popularity in wireless communication due to low manufacturing cost, easy to integrate, good accuracy and light weight. In that Rectangular patch antenna are more popular because it is easy to design but it has disadvantage such as narrow impedance bandwidth (typically a few percent). Nowadays Industrial-Scientific-and Medical (ISM) band which is an unlicensed frequency band attracted different applications in wireless communication such as Wireless Local Area Network (WLAN: 2.4–2.484, 5.15–5.25, 5.25–

5.35, 5.47–5.725 and 5.725–5.850 GHz) and Worldwide Interoperability for Microwave Access (WiMAX: 2.5–2.69, 3.40–3.69 and 5.25–5.85 GHz). One of the frequency bands of the ISM band is 2.40GHz-2.48GHz where the proposed antenna design is presented. The antenna can be fed with different feeding techniques like edge feed, aperture feed, coaxial feed etc.

P. K. Sarkar, I. Rahaman, M. N. Rahman, and Md. F. Hasan, discussed the investigation of compact antenna structure. Ramadan Ali, Al-Husseini Mohammed, Tawky Youssef, KabalanKarim Y., El-ajj Ali presented a frequency and Pattern-reconfigurable Microstrip Antenna for WLAN Applications is presented targeting the 2.4 GHz frequency band. A Compact patch antenna for WLAN application were presented by Natarajamani S, S K Behera& S K Patra. A triangular microstrip patch antenna is proposed by Keon-Myung Lee, Young-Je Sung for multi-band applications, and designed using a chip capacitor and T-shaped slit.

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*Corresponding Author: tiwariar@rknec.edu

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In the presented design the square patch is fed with the inset line-feed feeding technique, in which the microstrip feed line i.e. conducting strip is connected to the patch antenna, it is slightly inserted inside the microstrip patch. The dimension and the location of microstrip feed line is depends upon matching of impedance and dimensions of feed line is very narrow width as compared to patch antenna.

Figure 1. Rectangular patch antenna Design 5

Table 1. Formulae And Calculation Of Rectangular Patch Antenna.

Sr. No.	Antenna Parameters	Formula	Calculated values
1.	Width of the patch	$w = \frac{c}{2fr} \sqrt{\frac{2}{\epsilon_r + 1}}$	$w = 37.26\text{mm}$
2.	Effective dielectric constant of an antenna	$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{h}{1 + 12 \frac{h}{w}} \right]^{-1}$	$\epsilon_{eff} = 4.082\text{mm}$
3.	Length of the patch	$L = \frac{c}{2fr \sqrt{\epsilon_{eff}}} - 2\Delta L$	$L = 29.72\text{mm}$
4.	The effective length	$L_{eff} = L + 2\Delta L$	$L_{eff} = 30.3\text{mm}$
5.	The extended length of an antenna	$\Delta L = h \cdot 0.412 \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.8) \left(\frac{W}{h} + 0.8 \right)}$	$\Delta L = 0.29\text{mm}$

Where, c = velocity of light which is $3 \times 10^8\text{m/s}$
 ϵ_r =dielectric constant of the substrate material

Design Consideration and its Flow: The rectangular patch design is considered with inset feed technique. The antenna design flow is as follows:

A. Selection of Frequency: The square patch antenna is designed to target ISM BAND frequency as its freely available band and there are many applications that work on it i.e. Wi-Fi, Wi-MAX, RF-ID etc. The proposed design is targeted to frequency 2.4GHz i.e. 2.40 to 2.48GHz band.

Table 2. Antenna Parameters With Different Variation

Parameter (Unit in mm)	Calculated Parameters (Design 1)	Parameter Variations			
		Design 2	Design 3	Design 4	Design 5
Height of substrate (Hs)	1.6	1.59	1.59	1.6	1.6
Width of substrate (Ws)	60	58	56.9	40	45
Length of substrate (Ls)	60	58	56.9	39	39
Length of Patch (Lp)	29.72	28.45	37.26	28.45	28.3
Width of Patch (Wp)	37.26	28.45	28.45	35	37.5
Width of Feed (Wf)	3.03	3.03	3	3.14	3.14
Length of Feed (Lf)	16.62	16.62	16.62	16.62	10
Simulation Results					
Impedance(ohm)	30.56	37.02	39	40	49.02
Return loss (dB)	-21.23	-21.98	-6.27	-11.53	-19.25
Directivity (dB)	6.557	6.307	6.536	6.269	5.897
Gain(dB)	-1.997	1.693	1.623	1.529	1.977

B. Selection of Substrate Material: The most economic substrate used for designing purpose is FR-4 epoxy. Hence in the proposed design FR4 (lossy) dielectric is selected, with dielectric constant (ϵ_r) = 4.4, loss tangent ($\tan \delta$) = 0.01 and substrate thickness of (h) = 1.6mm.

C. Calculation of Dimensions of Rectangular Patch Antenna: For 2.4 GHz frequency, the patch antenna parameters like width and length can be calculated using theoretical considerations. The formulas are as follows in table 1.

D. Parametric Variation: While considering above parameters of antenna for designing, the results obtained in terms of resonant frequency, return loss and impedance matching were not satisfactory. Hence to improve results, different parameters of micro-strip patch antenna were modified. In order to match the impedance, changes were made in the width of the feed-line. By decreasing the width of the feed-line, it was observed that the input impedance of the patch antenna is getting matched. Table 2 shows the various parametric variations of microstrip patch antenna and shown its effect on simulated results

in terms of return loss and resonating frequency and figure 1 shows the antenna design 5.

E. Simulation Software: There was many software available like IE3D, CST, HFSS, ADS and CADFEKO etc. For proposed design the simulation results were presented using CST tool. CST is a tool which is specialized for the 3D Electromagnetic high frequency simulation. CST

performance in terms of speed and accuracy makes this software more popular amongst technology leading R&D departments. CST are used to analyze the behavior of high frequency devices such as antennas, filters, couplers etc. CST gives users a great flexibility in tackling a wide application range through the variety of available solver technologies. CST uses time Domain solver and the Frequency Domain solver models and it also facilitate to extract spice parameters.

Table 3. Comparison Of Proposed Design With The Existing Designs

Parameters of Comparison	2020	2016	2015	2010	Proposed Design
Size of antenna	40x40	50x50	75x48	25x25	28.3x37.5
Thickness of substrate	1 mm	Not Mentioned	1.6 mm	0.8 mm	1.6 mm
Frequency of operation	4.8337–8.1714	2– 5.6 GHz	890– 2.4 GHz	2.14–2.85, 3.29–4.08, and 5.02–6.09 GHz	2.445 GHz
Substrate	FR4	FR4	FR4	FR4	FR4
Gain of Antenna	3.87dBi	4.4, 3.5 and 2.8 dBi	2–3.5 dBi	1.77 to 2.15 dBi	1.97 dBi
Design structure	CPW Structure	Asymmetrical V slits with circular slot	A compact U-shape radiating patch	CPW-fed planar monopole	Simple Rectangular Patch with inset Feed
Design Complexity	Complex	Complex	Simple	Complex	Simple

Figure 2: Simulated Return loss (S11 parameter) Plot for Design 5

Figure 3: Simulated Impedance plot of design 5 on Smith chart

Figure 4: Simulated Radiation pattern of Design 5

Figure 5 a, b: Top view and Bottom view of Fabricated Rectangular Patch

F. Simulation Results: After parametric variation of rectangular patch antenna, the best results were obtained in terms of return loss, impedance and resonating

frequency is for design 5. Figure 2 shows bandwidth and return loss (S11 parameter) of rectangular patch antenna design 5 with central frequency 2.445 and figure 3 and 4 shows the impedance plot on smith chart and radiation pattern of design 5 respectively. The comparison with the existing designs is shown in table 3.

G. Fabricated Antenna Design: Rectangular patch antenna is fabricated on FR4 substrate, taking into consideration of dimensions of design 5. As the simulated results of design 5 were better results in terms of impedance, return loss and resonant frequency. Figure 5a and 5b shows the top layer and bottom layer of fabricated rectangular patch antenna respectively. SMA connector is connected to the feed line having 50 Ohm impedance to connect the measuring instrument like VNA for characterizing the antenna parameter of fabricated patch antenna.

Figure 6: Measurement setup of antenna with VNA

Figure 7: Frequency Vs return loss (S11 parameter) plot

H. Characterization of Fabricated Antenna: The antenna parameters like return loss (S11 parameter), bandwidth and impedance plot of fabricated patch antenna was measured using Vector Network Analyser (VNA). VNA usually performs two types of measurements i.e. transmission and reflection. Transmission measurements pass the VNA stimulus signal through the device under test (DUT), which is then measured by the VNA receivers on the other side [7]. Figure 6 shows the measurement setup of antenna with VNA.

I. Fabrication Results: Figure 7 and 8 shows the frequency VS return loss (S11 parameter) plot and impedance plot

Figure 8: Smith Chart of fabricated Antenna

Table 3. Comparison Results Between Simulated And Fabricated Patch Antenna

Parameter of Comparison	Simulated Results of Rectangular Patch	Fabricated Results of Rectangular Patch
Resonant Frequency	2.45 GHz	2.49 GHz
Measured Impedance	49.60 ohm 50.9 ohm	
Return loss	-19.25 dB -18.98 dB	

(smith chart) respectively of the fabricated antenna.

J. Comparison of the Simulated and Fabrication Results:

It was observed that the fabricated results have shown considerable matching with the simulated results. Table 3 shows the comparison of both the Antennas i.e. simulated and fabricated rectangular Patch.

CONCLUSION

The design of rectangular patch of dimension 28.3×37.5 mm² with ground plane 39× 47.5 mm² was simulated and fabricated. The patch is designed and fabricated on FR4 substrate taking into consideration of thickness 1.6 mm. The patch antenna is having 3.14 mm long inset feed. The patch antenna is simulated using a CST and then after parametric variations of patch the best simulation results obtained was for design 5 as resonant frequency ~2.45 GHz, impedance as 49.6 ohm and return loss of -19.25 dB. Hence design 5 was fabricated and characterized. The results after fabrication were found as resonant frequency 2.49 GHz, impedance as 50.9 ohm and return loss of -18.98 dB. The proposed design for WLAN application has shown considerable match between simulated and implemented results. The disadvantages of this antenna are its low bandwidth, it can be improved by the technique insertion of slit and slot. Also, antenna gain can be also improved with the array formation.

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