Australian Journal of Basic and Applied Sciences, 8(3) Special 2014, Pages: 604-611

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

5.8 GHz Rectangular Microstrip Inset Feed Patch Antenna

M.A. Othman, M. Sinnappa, M.Z.A. Abd Aziz, W.Y. Sam, Mohd Nor Hussein, Nornikman Hassan, Hamzah Asyrani Sulaiman, Mohd Muzafar Ismail, Mohamad Harris Misran, Maizatul Alice Meor Said

Department Centre for Telecommunication Research and Innovation (CeTRI), Faculty of Electronic and Computer Engineering, UniversitiTeknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 6100 Durian Tunggal, Melaka, Malaysia.

ARTICLE INFO

Article history:
Received 20 November 2013
Received in revised form 24 January 2014
Accepted 29 January 2014
Available online 25 February 2014

Key words:
Rectangular microstrip, Inset feed patch antenna, 5.8 GHz.

ABSTRACT

This paper aim to present the design technique, parameter analysis, real prototype fabrication and measurement results compared to simulation of 5.8 GHz rectangular microstrip inset feed patch antenna. The antenna design calculation, simulation study and practical measurement results are well presented and compared. This study would be useful to realize low cost 5.8 GHz rectangular microstrip patch antenna for any appropriate system developments and investigate the parameter study. The information shared is aimed to serve the similar scientific field and improve the system features.

To Cite This Article: M.A. Othman, M. Sinnappa, M.Z.A. Abd Aziz, W.Y. Sam, Mohd Nor Hussein, Nornikman Hassan, Hamzah Asyrani Sulaiman, Mohd Muzafar Ismail, Mohamad Harris Misran, Maizatul Alice Meor Said., 5.8 GHz Rectangular Microstrip Inset Feed Patch Antenna. ***Aust. J. Basic & Appl. Sci.,*** *8(4): 604-611, 2014*

INTRODUCTION

The basis of electromagnetic theory was formulated in 1864 by James Clerk Maxwell and validated by Heinrich Hertz in his experiment during 1888. Since that, many new discovery, invention and application took place in many fields with the use of electromagnetic wave. One of deployment an electromagnetic wave is in antenna propagation. Since 1970s, microstrip antenna gets a great attention although the idea was founded in 1953 and patented in 1955.

Nowadays, the demand for microstrip patch antenna increased for applied in modern mobile, satellite and wireless communication systems, which lead the researchers to improve the performances and enhance the application potentials (Ali *et al.*, 2005). The advantage of choosing a microstrip patch antenna is not only because of light weight and cost-effect (Chen and Tao, 2010), but it's also compact, low profile and easy to integrate with Monolithic Microwave Integrated Circuits (MMICs) (Khalilpour *et al.*, 2010). There is limitation for microstrip patch antenna in term of performance like narrow bandwidth. The conventional single frequency regular shapes of microstrip antenna studied have been carried out before this. By introducing slot in the patch, the desired compactness, multiband and broadband can be achieve since the shape radiates efficient electromagnetic. The microstrip patch antenna can be design in various shapes and applications, such as pentagonal patch for Wi-Fi applications (Tecpoyotl-Torres and Vera-Dimas, 2010), circular patch for Industrial, Scientific and Medical (ISM) applications (Gohil and Bhatia, 2012), elliptical Patch for point to point communication (Priyashman *et al.*, 2012), triangular patch For Worldwide Interoperability for Microwave Access (Wi-Max) Application (Sagne *et al.*, 2012), circular patch-ring for mobile wireless communications (Al-Zoubi *et al.*, 2009), fractal shaped patch for Wireless Local Area Network (WLAN) system (Adelpour et al., 2009) and many more. There are four main feeding methods such as microstrip line, coaxial probe, aperture coupling and proximity coupling to feed microstrip antenna. There are various types of substrate in use for microstrip antenna design and usually the dielectric constant (ε_r) in range of $2.2 \leq \varepsilon_r \leq 12$. The good antenna performances are desirable with thick substrate whose dielectric constant in lower edge because, better efficiency, large bandwidth, loosely radiation into space, but an expense large element in size. The bandwidth and gain of the microstrip antenna depend on its size, and the bandwidth narrowed and the efficiency dropped as the decrease of the size (Shuairen Li *et al.*, 2009).

In this paper, a development of the rectangular microstrip patch antenna based on antenna theory is presented. The rectangular microstrip patch antennas are designed at operating frequency of 5.8 GHz. In order

Corresponding Author: Mohd Azlishah Othman,Centre of Telecommunication Research and Innovation (CeTRI), Faculty of Electronic and Computer Engineering, UniversitiTeknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal Melaka, Malaysia.
Tel: +606-5552151, E-mail: azlishah@utem.edu.my

to improve antenna gain, the inset feed line method is applied. The advantages of this technique are the realization of microstrip patch antenna with higher gain, small in size, low cost and able to operate through garments and easy to integrate with other subsystems.

2. Design of Antenna:

By theoretically, there are few dimensions of the typical rectangular microstrip inset feed patch antenna as showed in Fig. 1 below. Instance, width (W), the length (L), extended incremental length (ΔL), inset feed point distance (y_o) and width of microstrip line (W_0).

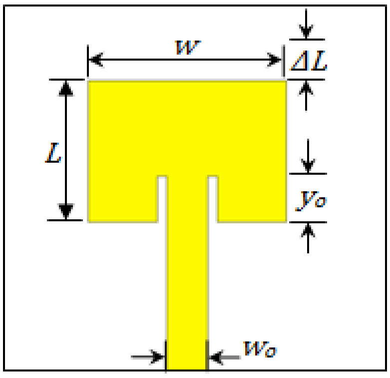


Fig. 1: Front view of rectangular microstrip inset feed patch antenna with the parameters dimensions indications.

The width (W) and the length (L) can determine by using equation below (Balanis, 2005):

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L$$

where's, c is free-space velocity, f_r is resonant frequency, and ε_r is dielectric constant of substrate, ε_{reff} is the effective dielectric constant, μ_0 is vacuum or free space permeability and ε_0 is vacuum permittivity. The ΔL is an extended incremental length of the patch which can be calculated using the equation below (Balanis, 2005):

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

where, h is the thickness of the dielectric substrate. The asymptotic value of conductance G_1 slot is identical by using equation below (Balanis, 2005):

$$G_1 = \begin{cases} \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2, W \ll \lambda_0 \\ \frac{1}{120}\left(\frac{W}{\lambda_0}\right), W \gg \lambda_0 \end{cases}$$

where in this design, the comparative value of width W is less than wavelength λ_0 of resonant frequency f_r. By that, the conductance G_1 is identified. As the total input admittance is real, the resonant input impedance R_{in} is also real and can be calculated using the equation below (Balanis, 2005):

$$R_{in} = \frac{1}{2G_1}$$

As the maximum value occurs at the edge of the slot ($y_o = 0$) where the voltage is maximum and the current is minimum, typical value are in the 150-130 ohms. The inset feed point distance y_o can be calculated using equation below (Balanis, 2005):

$$y_o = \frac{L}{\pi}cos^{-1}\left[\frac{150}{R}\right]^{1/2}$$

By using inset feed, the resonant input resistance R_{in}, can be changed, recessed by the distance y_o from slot as show in Fig. 1 above. By using CST simulation software, width of microstrip line W_0value can easily identify by selectingt the analytical line impedance option.

3. Design Flow:

In this section, the design and simulation flow will be briefly described. First, the fundamental theory and the calculation about microwave rectangular microstrip inset feed patch antenna are well understood. The resonant frequency (f_r), height (h) of substrate, dielectric constant of substrate (ε_r), wavelength (λ_0) of resonant frequency, free space permeability (μ_0) and vacuum permittivity (ε_0) value are identified. In this design that parameter all is 5.8 GHz, 1.6 mm, 3.92, 51.72 mm, 1.2566µ, and 8.8542p consequently.

Next, by those values and used of formulas mentions above, other parameters is calculated and identified. In between, there will be some assumption or decision will be made such as the mutual effect between slots existence, and which formula is right one to continue further calculation steps. After that, all parameter's value are determined such as width (W), the length (L), extended incremental length (ΔL), inset feed point distance (y_o) and width of microstrip line (W_0), before starting to design a simple rectangular patch antenna in CST simulation software. In the design process, the width of the inset feed slot just assumes as 1mm to complete the design of rectangular microstrip inset feed patch antenna. All calculated parameters are shown in Table 1 below.

Table 1: Calculated parameters for rectangular microstrip inset feed patch antenna

Description	Calculated Value (mm)
Width (W)	16.48
Extended Incremental Length (ΔL)	0.740
Length (L)	12.44
Inset Feed Point Distance (y_o)	3.760
Microstrip Line (W_o)	3.360

The simulation of rectangular microstrip inset feed patch antenna is carried out with the setting of waveguide port, simulation frequency range, specify the boundary condition and transient solver parameter setting in the CST simulation software. In order to make sure the rectangular patch is working on 5.8 GHz, the most response varying parameter in term frequency shift is the length (L) of the patch. This length (L) is varied, until get the resonant frequency (f_r) is 5.8 GHz.

Regarding to Fig. 2 below, if the simulated output frequency is at upper then desired frequency, the patch length should be increased to shift the frequency to left side and get on desired frequency.

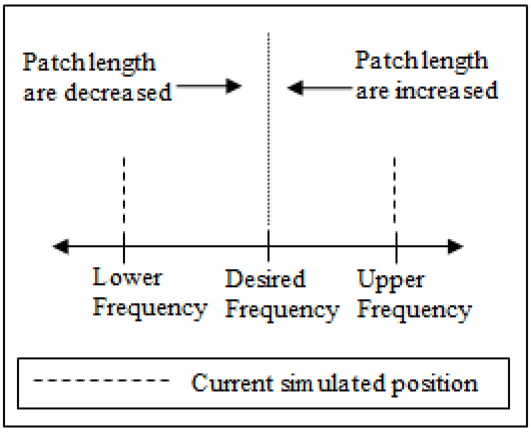


Fig. 2: Parameter study of patch length variation to frequency shift.

If the simulated output frequency is at lower than desired frequency, the patch length should be decreased to shift the frequency to right side and get on desired frequency. This consideration applied just for frequency shift and other parameter are not considered here. After that, the inset feed slot width is varied from 1mm to appropriate value which based on the best optimum results in term bandwidth, return loss and gain. The inset feed slot width is very sensitive to those mention parameters. Overall, the design should cover appropriate desired gain (dB), operation frequency (Hz), return loss (dB), bandwidth (Hz), radian efficiency (dB), and impedance matching (Ohm).

Australian Journal of Basic and Applied Sciences, 8(4) Special 2014, Pages: 604-611

RESULT AND DISCUSSION

Simulation Result:

The CST simulation design value starts at the calculated value of rectangular microstrip inset feed patch antenna in the frequency range 4 to 7 GHz. The width of the inset feed slot just assumes as 1mm for temporary. The calculated first designs of antenna are simulated in CST environments and the results are simplified in Table 2 below. Following that the varying parameter analysis and study began, in order to design 5.8 GHz rectangular microstrip inset feed patch antenna with a good response for using in appropriate system.

Table 2: Simulation results of first calculated design.

Description	Simulated Value
Frequency (GHz)	5.566
Return Loss (dB)	-21.544
Bandwidth (GHz)	0.253
Gain (dB)	-2,554
Radiation Efficency	-2.554
ZC Match (Ω)	54.442

By that, the patch antenna length (L) is varied. It is because, the first design simulation in Table 2 above, shows the operation frequency of 5.566 GHz. As discussed earlier, the best frequency shift can achieve by varying the length (L) of the rectangular patch antenna. Here, the length (L) should decrease in order to shift the frequency to 5.8 GHz.

Regarding to Table 3 below, the length (L) of patch antenna is decreased and simulated results well presented. As the length (L) decreased, the gain and frequency increased, and the return loss decreased. The length (L) equal to 5.53 mm, provide frequency operation sharp at 5.8GHz with higher return loss when compare with others. Other parameters approximately near to each other's. Next, the inset feed slot width is varied.

Table 3: Simulation results of varied length patch.

Description	Varied Length (mm)		
	5.54	5.53	5.52
Frequency (GHz)	5.797	5.800	5.803
Return Loss (dB)	-25.246	-24.904	-24.571
Bandwidth (GHz)	0.258	0.257	0.257
Gain (dB)	4.778	4.818	4.819
Radiation Efficency	-2.554	-2.507	-2.506
ZC Match (Ω)	54.442	47.491	47.520

Regarding to Table 4 below, the inset feed slot width is varied from 1mm previous design, where the length (L) is 5.53 mm. The simulation results in Table 4 shows, as the inset feed slot width are decreased, the bandwidths are increased and the return loss is decreased. By that, the narrow bandwidth with high return loss and good gain can achieve by appropriate slot width.

Table 4: Simulation results of varied patch inset feed slot width.

Description	Varied Slot (mm)		
	0.9	0.8	0.7
Frequency (GHz)	5.809	5.821	5.830
Return Loss (dB)	-33.612	-36.610	-24.660
Bandwidth (GHz)	0.268	0.279	0.283
Gain (dB)	4.824	4.808	4.853
Radiation Efficency	-2.498	-2.517	-2.481
ZC Match (Ω)	48.862	49.772	51.792

However, went varied the slot for better parameters response, the frequency is shift a bit. So, the rectangular patch length (L) and insert feed slot width has to change consequently until get better performance results that desired in designing rectangular microstrip inset feed patch antenna design in simulation. By that, the final design dimension and simulation results in CST software are detailed in Fig. 3 and Table 5 below consequently. Regarding to Fig. 3 and Table 5, the final design and results in CST software are presented. The yellow colour in Fig. 3 (a), (b) and (c) above, indicate the material of copper (annealed) and the type is lossy metal.

Australian Journal of Basic and Applied Sciences, 8(4) Special 2014, Pages: 604-611

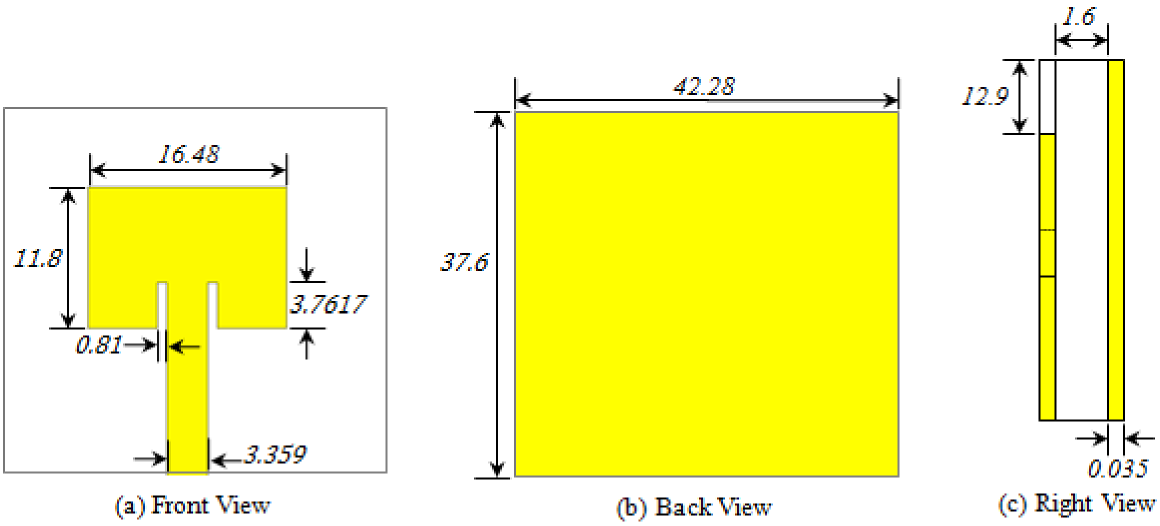


Fig. 3: Final CST software simulated design dimension (mm) of rectangular microstrip inset feed patch antenna: (a) Front View, (b) Back View and (c) Right View.

Table 5: CST software simulation results for final identified patch design.

Description	Simulated Value
Frequency (GHz)	5.800
Return Loss (dB)	-31.700
Bandwidth (GHz)	0.273
Gain (dB)	4.863
Radiation Efficency	-2.469
ZC Match (Ω)	50.518

The 1.6 mm thickness in Fig. 3 (c), indicate the material FR-4 (lossy) with the dielectric constant 3.92 of substrate (ε_r) for rectangular microstrip inset feed patch antenna. The rectangular microstrip inset feed patch antenna in full size is as width, length and thickness is 42.28, 37.6 and 1.67 mm consequently.

Result Comparison Study:

In this section, a comparison study is carried out by comparing the CST simulation results with practical measurement of rectangular microstrip inset feed patch antenna. To achieve that objective, the CST software simulation design must transform to the physical fabricated antenna. In order to obtain a fabricated antenna, the CST design structure element must export into DXF files. By using CoralDRAW 12 software, the design structure elements are printed out from Canon LBP3300 Laser Shot printer on transparency film using black. After that, the printed designs on transparency film are used for ultraviolet (UV) exposure on the positive FR-4 board double side with dielectric constant (ε_r) of substrate is 3.92. After that, the image of the antenna design is developed throw etching. Lastly, the boards is dried and cut according to design, before solder the RS-SubMiniature version A (SMA) female Connectors with impedance 50 Ω. The fabricated rectangular microstrip inset feed patch antenna is shown in Fig. 4 below. Finally, the antenna is tested with the Vector Network Analyzer (VNA) from Agilent Technologies N5242A (PNA-X Network Analyzer). The simulated and measured return loss is compared as shown in the Fig. 5 below.

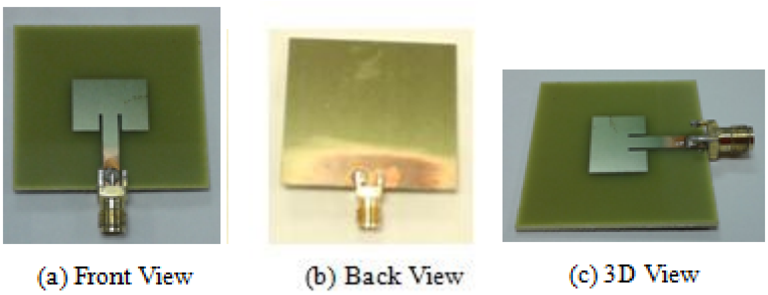


Fig. 4: Fabricated 5.8GHz rectangular microstrip inset feed patch antenna: (a) Front View, (b) Back View and (c) 3D View.

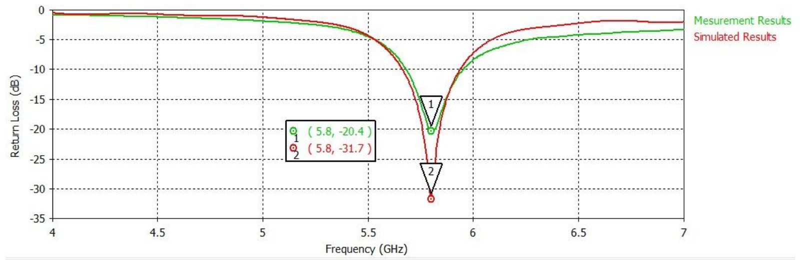
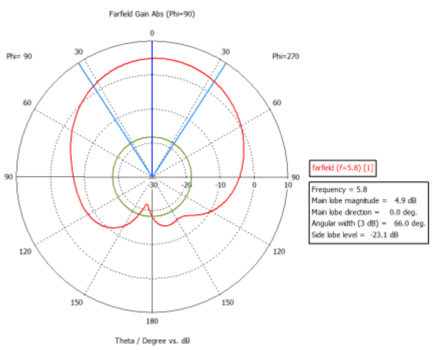


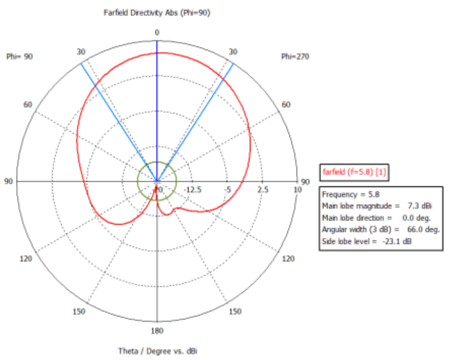
Fig. 5: Comparison of return loss (dB) versus frequency (GHz) of simulated and measurement of 5.8 GHz rectangular microstrip inset feed patch antenna.

Regarding to Fig. 5 above, the operation frequency for both simulation and fabricates measured works for rectangular microstrip inset feed patch antenna lies on 5.8 GHz sharply. The simulated and measured return loss is -31.7 and -20.4 dB consequently. Identically it meets the minimum return loss below -10 dB. The difference between fabricated measurement and simulation return loss is 11.3 dB. The bandwidth of fabricated and simulated patch design is 0.273 and 0.271 GHz accordingly. The differences bandwidth between simulated and fabricated patch in value is 2 MHz. The impedance matching results for simulation and fabrication rectangular microstrip inset feed patch antenna at operation frequency 5.8GHz is 50.518 and 47.884 Ohm consequently. Both results are from the frequency range from 4 to 7 GHz. In comparing simulation and fabrication result, there is 2.634 Ohm different in impedance matching value.

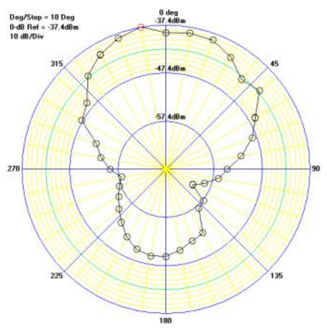
Based on the Fig. 6 (a) below, the simulated farfield gain for 5.8GHz rectangular microstrip inset feed patch antenna are presented. The main lobe magnitude is 4.9 dB. Refer to farfield directivity simulation results in Fig. 6 (b), the main lobe magnitude is 7.3 dBi. For both simulated gain and directivity results as in Fig. 6 (a) and (b), the angular width at 3 dB is 66.0º and side lobe level is -23.1 dB. Based on Fig. 6 (c), the measured radiation patterns are shown where it consist 36 points with step size of 10º . At 0 dBm reference point, maximum value measured in radiation pattern of 5.8 GHz rectangular microstrip inset feed patch antenna is -37.4 dBm. On the other hand, the minimum value of measured radiation patterns is -61.02 dBm.



(a) Simulated Farfield Gain



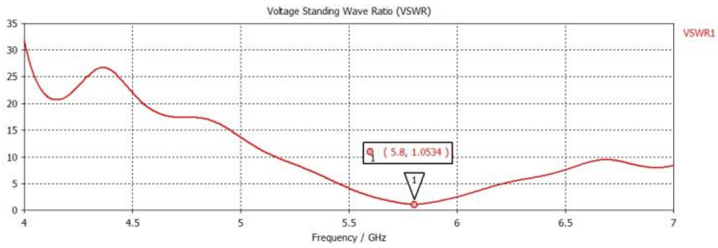
(b) Simulated Farfield Directivity



(c) Measured Radiation Pattern

Fig. 6: 5.8GHz rectangular microstrip inset feed patch antenna : (a) Simulated Farfield Gain, (b) Simulated Farfield Directivity and (c) Measured Radiation Pattern.

Regarding to Fig. 7, the simulated and measured Voltage Standing Wave Ratio (VSWR) at 5.8 GHz operating frequency is 1.0534 and 1.2124. By that, the 5.8GHz rectangular microstrip inset feed patch antenna is matched to the transmission line and minimum power is reflected from antenna went compared to ideal VSWR. The difference between simulated and measured VSWR is 0.159.



(a) Simulated VSWR

(b) Measured VSWR

Fig. 7: VSWR for 5.8 GHz Rectangular Microstrip Inset Feed Patch Antenna: (a) Simulated VSWR and (b) Measured VSWR.

By referring Fig. 8 below, the simulated surface current of H-Field for 5.8 GHz rectangular microstrip inset feed patch antenna are obtained.

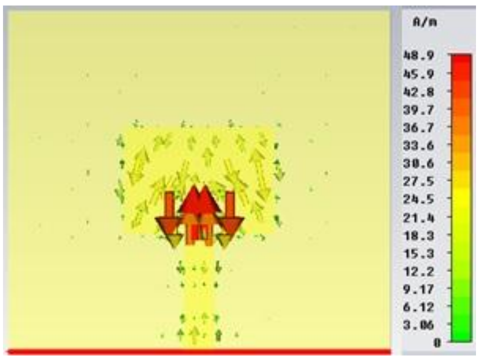


Fig. 8: Simulated surface current density (A/m) for 5.8 GHz rectangular microstrip inset feed patch antenna.

The surface current of the H-field is 48.9213 A/m. It clearly shows that the inset feed method will enhance the surface current particular at the inset feed slot area. The Table 6 below shows the CST software simulation and practical fabricated measurement results for 5.8 GHz rectangular microstrip inset feed patch antenna in terms return loss, bandwidth and impedance matching (Z_C).

Table 6: Comparison between CST software simulation and fabricated results of rectangular microstrip inset feed patch antenna.

Description	Simulated	Fabricated
Frequency (GHz)	5.800	5.800
Return Loss (dB)	-31.7	-20.4
Bandwidth (GHz)	0.273	0.271
ZC Match (Ω)	50.518	47.884
VSWR	1.0534	1.2124

Conclusions:

In conclusion, a 5.8 GHz rectangular microstrip inset feed patch antenna is well designed and simulated by using the CST software tool. The parametric study of rectangular microstrip inset feed patch antenna was carried out. The designed antennas are fabricated using FR-4 (lossy) with the dielectric constant 3.92. The fabricated 5.8 GHz rectangular microstrip inset feed patch antenna is tested after connecting with RS-SubMiniature version A (SMA) female Connectors with impedance 50 Ω. The fabricated antennas are tested by using the Vector Network Analyzer (VNA) from Agilent Technologies N5242A (PNA-X Network Analyzer). The simulated and fabricated antenna designs are compared. The return loss, bandwidth, impedance match and VSWR for the simulated antenna design is -31.7 dB, 0.273 GHz, 50.518 Ω and 1.0534 consequently. On the other hand, the measured return loss, bandwidth, impedance match and VSWR of fabricating antenna is -20.4 dB, 0.271 GHz, 47.884 Ω and 1.2124 accordingly. The microstrip patch antenna can deploy in many systems, where its low profile, simple and low-cost to manufacture, light weight and easy installation. The thick substrate range with low dielectric constant provides better antenna performance and greater efficiency. It is also desirable in a multiband, large bandwidth and high gain with array methods.

ACKNOWLEDGEMENT

The author would like to thank Universiti Teknikal Malaysia Melaka, Malaysia (UTeM) for their financial assistance under project grant PJP/2012/KEKK (43C) S1047 and cooperative support. Furthermore, the authors also would like to thank the project coordinating supervises, lectures, student and, those involved direct and indirect for theirs continues moral supports, contribution and cooperation in completing this paper.

REFERENCES

Adelpour, Z., F. Mohajeri, M. Sadeghi, 2010. Dual-frequency microstrip patch antenna with modified Koch fractal geometry based on genetic algorithm. Loughborough Antennas and Propagation Conference (LAPC), pp: 401-404.

Ali, M.T., N. Ramli, M.K.M. Salleh, M.N. Md. Tan, 2011. A design of reconfigurable rectangular microstrip slot patch antennas. In International Conference on System Engineering and Technology (ICSET), pp: 111-115.

Al-Zoubi A., Fan Yang, A. Kishk, 2009. A Broadband Center-Fed Circular Patch-Ring Antenna With a Monopole Like Radiation Pattern. In IEEE Transactions on Antennas and Propagation, 57(3): 789-792.

Balanis, C.A., 2005. Antenna Theory: Analysis and Design. New Jersey. John Wiley & Sons.

Chen, H., Y. Tao, 2010. Antenna gain and bandwidth enhancement using frequency selective surface with double rectangular ring elements. In 9th International Symposium on Antennas Propagation and EM Theory (ISAPE), pp: 271-274.

Gohil, J.V., D. Bhatia, 2012. Design of 2×1 circularly polarized microstrip patch antenna array for 5.8 GHz ISM band applications. In Nirma University International Conference on Engineering (NUiCONE), pp: 1-4.

Khalilpour, R., J. Nourinia, C. Ghobadi, 2010. An Optimized Monopole Microstrip Patch Antenna with Gradual Steps for Ultrawideband Applications. In PIERS Proceedings of Electromagnetics Research Symposium, pp: 1072-1076.

Priyashman, V., M.F. Jamlos, H. Lago, M. Jusoh, Z.A. Ahmad, M.A. Romli, M.N. Salimi, 2012. Elliptical shape microstrip patch antenna without dots. In Symposium on Wireless Technology and Applications (ISWTA), pp: 95-97.

Sagne, D.S., N.K. Choudhary, P.L. Zade, 2012. Broadband Equilatral Triangular Microstrip Antenna for Wi-Max Application. In International Conference on Communication Systems and Network Technologies (CSNT), pp: 1-4.

Shuairen, Li, Xiaoming Zhou, Xiaobin Zhang, Jiaguo Wu, 2011. The study on microstrip antenna with miniaturization and broadband. In 4th International Conference on Biomedical Engineering and Informatics (BMEI), 4: 2179-2182.

Tecpoyotl-Torres, M., J.G. Vera-Dimas, 2010. Dual Band Pentagonal Microstrip Antenna for Wi-Fi Applications. In Electronics, Robotics and Automotive Mechanics Conference (CERMA), pp: 255-258.