Proximity Coupled Fed Microstrip Antenna with Different Shape of DGS

S. Rohafauzi, M.T. Ali
Antenna Research Group,
Microwave Technology Centre,
Faculty of Electrical Engineering
Universiti Teknologi Mara (UiTM)
40450 Shah Alam, Selangor, Malaysia
suzyrf_14@yahoo.com

***Abstract*- This paper presents an analysis and designing the proximity coupled fed microstrip antenna with different shape of DGS. Four slots structure were design at ground below the feed line and this simulated antenna operating at 2.4GHz resonant frequency. The software used to simulate the patch antenna is Computer Simulation Tools (CST) Microwave Environment. This antenna is fed by a 50 Ω single microstrip line feeding with width 1.15 mm. In this paper, the effects of antenna parameters like the frequency, return loss, voltage standing wave ratio (VSWR) and gain (dB) will study by using proximity coupler fed technique. The construction of the antenna consists of the microstrip feed line on a substrate proximity coupled to a single rectangular microstrip patch etched in top of surface. The dielectric constant of antenna is 4.7, the tangent loss 0.019 and thickness of the antenna is 0.8 mm. The proximity coupled antenna is measured using Vector Network Analyzer (VNA). Both the simulation and experimental results are compared and analyzed.**

***Keywords* – patch antenna, proximity coupler feed, DGS, frequency, return loss, gain**

I. INTRODUCTION

. Microstrip antenna have been one of the most innovative topics in antenna theory and design in recent years, and are increasingly finding application in a wide range of modern microwave systems [1]. The microstrip patch antennas are well known for their performance and their robust design, fabrication and their extend usage [2]. Microstrip patch antennas are widely used because of their many advantages, such as the low profile, light weight and conformity. However, patch antennas have a main disadvantage which is narrow bandwidth [3]. The basic construction of microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has aground plane on the other side [4].

Microstrip patch antennas have several well-known feeding techniques, which are coaxial probe fed (CPF), microstrip transmission line fed (TLF), proximity coupled fed (PCF) and aperture coupled fed (ACF). In proximity coupled fed microstrip patch antennas [5] technique, offer various advantages conventional edge or coaxial probe fed patches. It allow the patch to exist on a relatively thick substrate for improve bandwidth. The feed line with thinner substrate reduces the spurious radiation [1] and coupling. The disadvantage of this proximity coupled feeding technique is difficult to fabricate because it use two dielectric layers. The dielectric layers need the proper alignment and increase the overall thickness of the patch antenna. Defected ground structures (DGS) have drawn an increasing interest because of their extensive applicability in antenna microwave and circuits [6], [7]. DGS is realized by etching a specific shape in the ground plane of planar circuits and antenna [8]. The resonant frequency of this transmission zero depends on the physical dimensions of the defect [9]. The main advantages of DGS, that it is easier to model therefore to use in more complex structure [10].

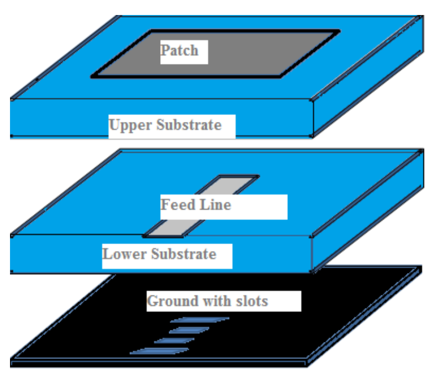


Figure 1: Geometry of single patch antenna with proximity coupled fed

In this paper, Figure 1 shows the geometric structure of a single patch antenna with proximity coupled fed. The configuration of the proposed antenna consists of two substrates, an upper substrate called the antenna substrate and a lower substrate called the feed substrate. On the top of feed substrate, the feed line is designed to have a characteristic impedance of 50 Ω. The bottom of feed substrate has a copper ground plane. The DGS loaded rightly under the microstrip transmission line. The antenna substrate has a copper patch etched on it.

II. Antenna Design And Structure

A single patch antenna has been designed with over all dimensions width, W (mm) x Length, L (mm). The designing of proximity coupled fed patch antenna is set at resonant frequency f_r = 2.4 GHz and the dielectric substrate FR 4 (loss free) is used. The dielectric constant of the substrate is ε_r = 4.7, the tangent loss 0.019 and thickness of the substrate h = 0.8 mm. The width and length of the microstrip antenna are calculated using following equations.

$$W = \frac{1}{2f_r\sqrt{\mu_o\varepsilon_o}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{V_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where V_0 is the free-space velocity of light.

The dimensions of the patch along its length have been extended on each by a distance ΔL, which is a function of the effective dielectric constant ε_{reff} and the width-to-height ratio (W/h) and the normalized extension of the length.

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

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

The actual length, *L* of the patch can be determine as follows

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_o\varepsilon_o}} - 2\Delta L$$

The proposed geometry on Figure 2 shows the five layers for four components which are ground, feed substrate named as upper substrate; feed line, antenna substrate named as lower substrate and patch. Feed line placed in between two substrates, upper substrate and lower substrate and used copper material. The bottom line also used copper material and designed for ground. The width and length for ground same with the width and length for upper substrate and lower substrate which is (68 mm X 56 mm). In the design, a single rectangular patch is etched on the top surface of upper substrate with the width, W_1 is 41 mm and length, L_1 is 27.03mm. Both of substrates used FR 4 (loss Free) with 0.8 mm of thickness, h. Dielectric constants, ε_r for these substrates is 4.7 mm. The microstrip feed line length, L_f is 24mm and the W_f calculated in order to get the feed line impedance of 50 Ω. The dimensions of the single patch antenna with proximity coupled fed are shown in Table 1. The single patch antenna with proximity couple is simpler in construction but to get the frequency of 2.4 GHz and return loss, S_{11} smaller than -10dB, the dimension of length, L of patch need to be optimized. Designing the slots with different shape at ground under the transmission line also need to be optimize to get good return loss, gain and frequency at 2.4GHz.

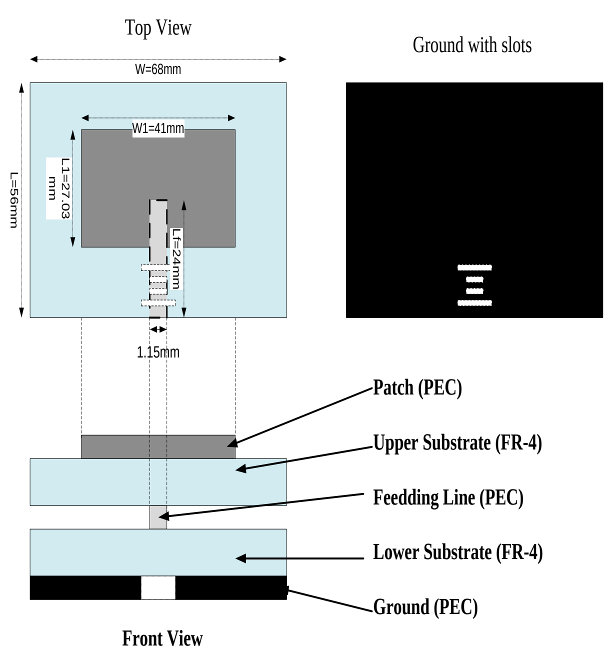


Figure 2: Geometry of proximity coupled fed microstrip antenna with slots under transmission line at ground

TABLE 1: DIMENSIONS OF THE OPTIMIZATION ANTENNA

Patch	Copper
W_1	41.0 mm
L_1	27.03 mm
Feed Line	Copper
W_f	1.15 mm
L_f	24 mm
Upper Substrate, Lower Substrate	FR 4 (loss free)
Dielectric constant, ε_r	4.7
Thickness, h	0.8 mm
Tangent Loss	0.019

III. RESULTS AND DISCUSSIONS

The antenna is designed using CST simulator to get the return loss less than -10dB and the slot that is designed under the transmission line at ground is needed to be optimized to get the resonant frequency at 2.4 GHz. The slots designed with four different shapes. For the first design is with H-shape and the simulation results show that the value of resonant frequency is 2.3912 GHz. The farfield radiation pattern shows that the gain is 6.625 dB. The second design is E-shape with resonant frequency is increased to 2.3944 GHz but the gain decrease to 6.620 dB. When optimized the slot with double dumbbells shape, it shows that the simulation at 2.4008 GHz and the gain also decreased to 6.596 dB. When optimized again with four rectangular slots, the resonant frequency is at 2.4008 GHz and the gain is increased to 6.627 dB. Figure 4 and 5 show the results for four resonant frequencies of return loss and VSWR respectively. The lines indicated the red line (Four rectangular slots), purple line (double dumbbells), green line (H-shape) and blue line (E-shape). These results are tabulated in Table 2.

Return loss is the property of an amount of power which is reflected back to the source from an incorrectly terminated line. It should be as large a negative number as possible. The simulated result shows that all frequencies have good return loss which is lower than -10 dB. Four rectangular slots has good return loss among the other shapes which is at -47.76 dB.

VSWR is a measure of how much power is delivered to an antenna. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0, in which case none of the power is reflected, which is the ideal case. From the VSWR result, it was observed that the VSWR operated resonant frequency at 2.4008 GHz is 1.008 and 1.239 for rectangular slots and double dumbbells respectively. The simulated results of proposed antenna indicate that the VSWR is better compared to VSWR of other designs.

At resonant frequency of 2.4008 GHz, the bandwidth for proposed antenna is estimated about 1.6 %. The bandwidth s express as a percentage of the frequency difference over the center of the bandwidth.

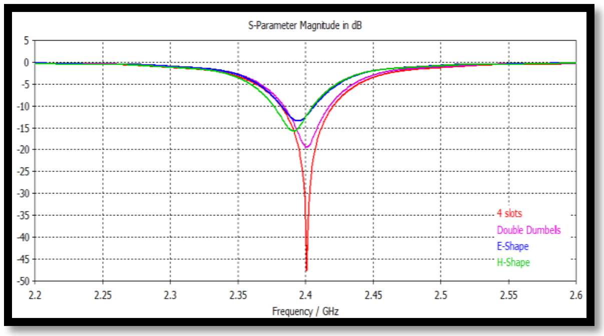


Figure 4: Simulated return loss of four different shapes at ground.

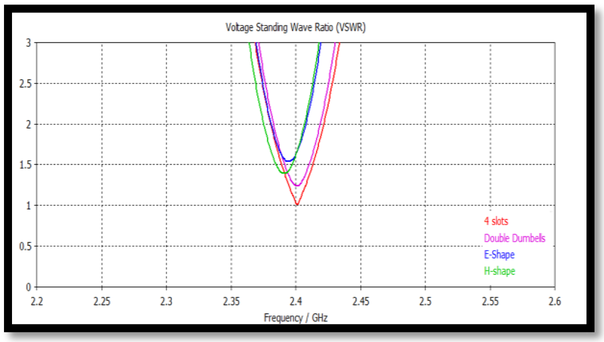


Figure 5: Simulated VSWR of four different shapes at ground.

TABLE 2: TABULATED RESULTS OF GAIN, RETURN LOSS, FREQUENCY AND VSWR

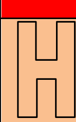
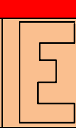
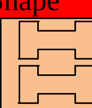
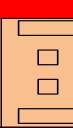
	Shape			
				
Parameters	H shape	E shape	Double Dumbell	Four rectangular slots
Gain (dB)	6.625	6.620	6.596	6.627
Return Loss, S_{11} (dB)	-17.74	-13.48	-19.48	-47.76
Frequency (GHz)	2.3912	2.3944	2.4008	2.4008
VSWR	1.39	1.537	1.239	1.008

Figure 6 shows the simulated far-field amplitude for proposed antenna which is four rectangular slots at ground. The figure shows that the maximum gain is at 6.627 dB and operating at 2.4008 GHz resonant frequency. Besides, the figure shown that this antenna has good directional radiation pattern at 2.4 GHz resonant frequency.

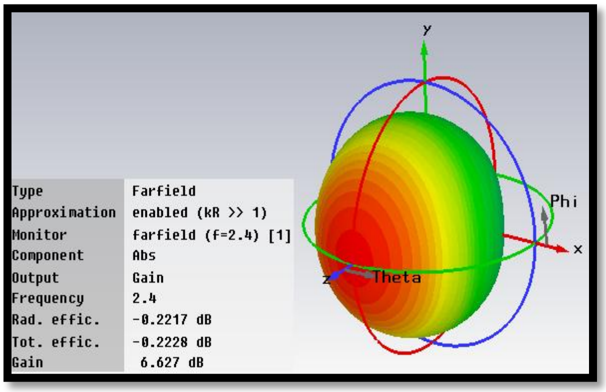


Figure 6: Simulated far-field amplitude for proposed antenna.

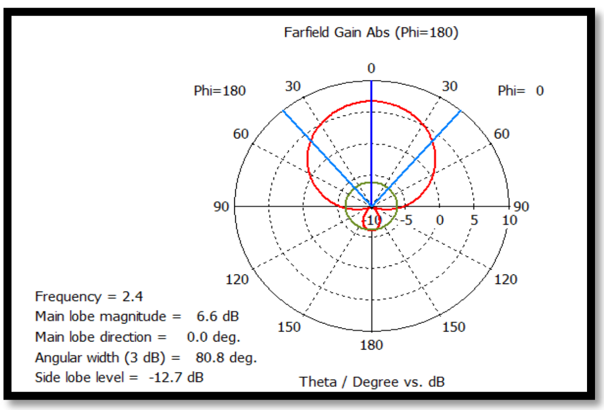


Figure 7: Simulated radiation pattern for proposed antenna

Figure 7 shows the simulated radiation pattern at 2.4GHz. Half power beam width (HPBW) is the angle between the two directions in which the radiation intensity is one-half value of the beam in a plane containing the direction of the maximum of a beam. On the other words, the HPBW (-3 dB) is a measure of the directivity of the antenna. The HPBW for the proposed antenna is 80.8 degree. A side lobe is a radiation lobe in any direction other than the intended lobe. The side lobe of far field radiation pattern at 2.4 GHz can be observed in Figure 7. The radial distance from the center represents signal strength. The signal strength for the side lobes is -12.7 dB.

The measured result of return losses of the proposed proximity coupled fed antenna compared with the simulation is shown in Figure 8. The simulation result indicated that the proposed antenna has operation frequency at 2.4008 GHz and return loss of -47.76 dB. It can be seen that the measured frequency response of -6.751 dB return loss is shifted to 2.5025 GHz. It is showed that the result of measured and simulation antenna is inaccurate. These inaccuracies may be caused by antenna fabrication process such as during soldering and losses occurred while doing the measuring process due to environment errors. The measured result also shows that the return loss is greater than -10 dB which is smaller than the simulated return loss.

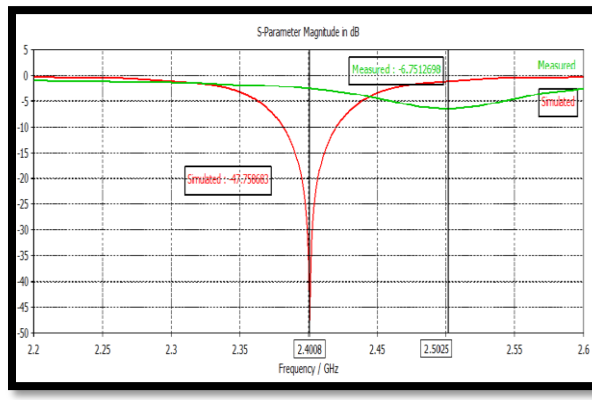


Figure 8: Simulated result of VSWR for proposed antenna.

The measured result for VSWR is depicted in Figure 9. It can be observed that the simulated VSWR of 1.008 is approximate to minimum which is better than the measured VSWR. The measured result for VSWR s about 2.65 which is greater than 2.

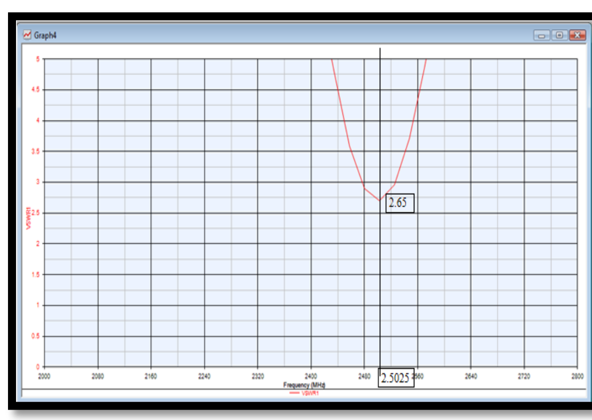


Figure 9: Measured result of VSWR for proposed antenna.

IV. CONCLUSION

The single patch antenna with proximity coupled fed with slots at ground is presented in this paper at 2.4GHz resonant frequency. By only adjusting and designing the different shapes of slots at ground, it can obtain the desired result at the resonant frequency and satisfactory performances. From the simulation results, it can be conclude that the proposed antenna with four slots at ground operate at resonant frequency 2.4 GHz with good return loss, VSWR and gain compared to the other shapes.

ACKNOWLEDGEMENT

The author would like to thank to her supervisor, Dr. Mohd Tarmizi Ali for his support and advise. Special thanks also to friends and members in Microwave Technology Centre (MTC), Universiti Teknologi MARA (UiTM) for their helps in completing this project.

.

REFERENCES

[1] David M. Pozar, *"Microstrip Antennas"* Proceedings of the IEEE, Vol 80, No.1 January 1992.

[2] Indrasen Singh, Dr. V. S Tripathi *"Microstrip Patch Antenna and its Application: a Survey"* Int. J. Cmp. Tech. Appl., Vol 2 (5), 1595-1599.

[3] Fan Yang, Xue Xia Zhang, Xiaoning Ye,Yahya Rahmat –Samii "*Wide-Band E-Shaped Patch Antennas for Wireless Communications" IEEE Transaction on Antenna and propagation*, Vol. 49, No.7, July 2001.

[4] A. Beno, Dr. D. S. Emmanuel, T. Sidhuj, K. Packia Lakshmi, " *Modified Compact High gain Multiple Patch Slotted Microstrip Antenna for Multiband wireless communication"* International Journal of Scientific & Engineering Research Vol. 2, Issue 7, July 2011.

[5] D.M.Pozzar and B. Kaufman, *"Increasing the bandwidth of microstrip antenna byproximity coupling",* Electronics Letters, vol. 23, no 8, pp. 368-369, April 1987.

[6] A. K. Arya, M. V. Kartikeyan, A. Patnaik, *"Defected ground structure in the perspective of microstrip antenna: A review*", Frequenz Int. Journal of RF Engineering and Telecommunications, vol. 64, pp. 79-84, 2010.

[7] K. Hing Chiang and Kam Weng Tam, *"Microstrip monopole antenna with enhanced bandwidth using defected ground structure"*, IEEE Antennas and Wireless propagation Letters, vol. 7, pp. 532-535, 2008.

[8] Pravin R. Prajapati, M. V. Kartikeyan, *"Proximity Coupled Stacked Circular Disc Mcrostrip Antenna with Reduced Size and Enhanced Bandwidth Using DGS for WLAN/WiMAX Applications",* IEEE Students' Conference, pp. 1-4, 2012.

[9] Zied Harouni, Lotif Osman, Ali Gharsallah, *"Efficient 2.45 GHz proximity coupled microstrip patch antenna design including harmonic rejecting device for microwave energy transfer"*, International Renewable Energy Congress, pp. 73-75, November 2010.

[10] J. I. Park, C. S. Kim, J. Kim, J. S. Park, Y. Qian, D. Ahn and T. Itoh, " *Modeling of photonic bandgap and its application for the low pass filter design*", Proceeding of Asia Pasific Microw. Conf. (APMC), pp. 331-334, 1999