Design Proximity Coupler Fed Technique with Defected Ground Structure (DGS) effects.

Musfirah Hilmi
Faculty of Electrical Engineering
Universiti Teknologi MARA
Shah Alam, Selangor, MALAYSIA
musfirah.hilmi@yahoo.com

***Abstract*— Use of defected ground structure (DGS) to enhance performance of the antenna is presented in this paper. Initially, a single patch antenna is designed using proximity coupler fed technique. Then, the experimental investigations have been carried out on a single patch antenna that has been added with a DGS. In order to reduce size of the antenna, an arrow head shaped DGS is used in the ground plane. Analysis has been done to compare between the simulation and the measurement result for antenna with and without DGS. It was found that about 59.3% size of antenna has been reduced.**

Keywords: *Defected Ground Structure (DGS), Microstrip Antennas, Proximity Coupler fed*

I. INTRODUCTION

CURRENTLY, DGS are getting more and more popular in designing an antenna. Various slot DGS antenna have been reported such as V-shaped, dumbbell, square, and many more. Besides, many application that have been reported also for the use of DGS such as harmonic reduction [1], cross-polarization suppression [2] and mutual coupling reduction [3] in antenna arrays etc. Although the back to back geometries have been reported by the various researchers [4,5] but here a new coupling method i.e. proximity coupling with the defected ground structure is used for the consideration of getting smaller antenna size and.

The objective of this project is to design a single patch antenna with DGS to reduce the size of antenna, that operating at 2.4 GHz for wireless local area network (WLAN) applications. The proposed antenna design is simulated on Computer Simulation Technology (CST) Microwave Studio Software and fabricated on Taconic substrate. This project will cover two method used which are the proximity coupler fed and DGS.

a) Proximity coupler fed

Two substrates are need for this method. The first substrate is consist of a patch on the upper side of the substrates while on the second substrate, consist of a feed line on the upper side and a ground plane at the back of the substrate. Figure 1 illustrates the proximity coupler fed technique.

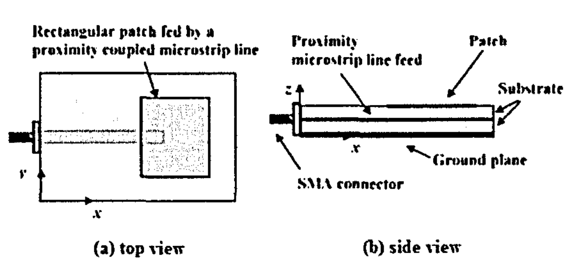

Figure 1: The geometry of proximity coupler feed antenna [6].

b) Defected Ground Structures (DGS)

Defected Ground Structure (DGS) is a technique, where the ground plane of a microstrip antenna is purposely customized by adding any shaped of slot to enhance the performance of an antenna. The basic element of DGS is a slot in the ground plane, and located exactly below a feed line. Figure 2 shows various structure of DGS slot that can be used [7].

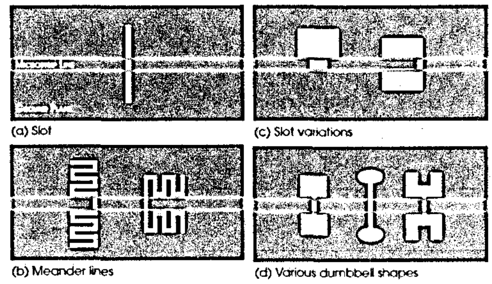

Figure 2: Some common configurations for DGS resonant structures [7].

II. ANALYTICAL ANALYSIS OF THE ANTENNA

A. Calculation

The value of width (W) and length (L) for this patch is determined by using Equation 1 and Equation 2 respectively.

$$W = \frac{1}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1)$$

$$L = \frac{v_0}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2)$$

Where ε_{eff} and ΔL can be calculate by,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \qquad (3)$$

$$\Delta L = 0.412h\frac{\left(\varepsilon_{eff} + 0.3\right)\left({}^{w}/_{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left({}^{w}/_{h} + 0.813\right)} \qquad (4)$$

The microstrip feed line is determined by using Equation 5 and Equation 6.

$$\frac{w}{h} = \frac{8e^{A}}{e^{2A} - 2} \qquad for\ {}^{w}/_{h} < 2 \qquad (5)$$

$$l = \frac{{}^{90}/_{360} \times 2\pi}{k\sqrt{\varepsilon_{eff}}} \qquad (6)$$

Where A can be calculated by,

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \qquad (7)$$

B. Antenna design.

The proposed printed single patch antenna is shown in Figure 3. The patch is printed on the side upper of the first substrate while the microstrip feed line is on the upper side of the second substrate, the ground plane is on the back side of the second substrate. The antenna is designed on a Taconic RF-30 substrate with a relative dielectric constant εr=3 and thickness h=0.76mm. The characteristic impedance of the microstrip line is 50Ω. The length (L) and width (W) of the patch are 33.88mm and 37.19mm respectively, which are optimized to operate at 2.4 GHz frequency.

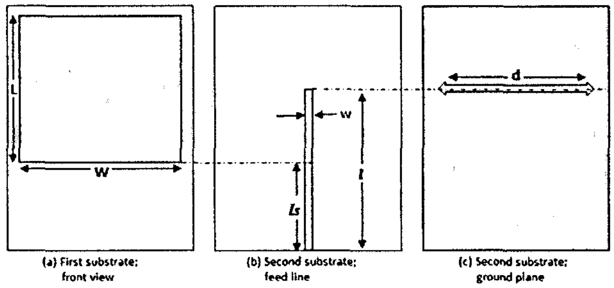

Figure 3: Antenna geometry.

Then the ground plane of the antenna is then purposely modified by aading a slot to observe the antenna performance. The arrow head slot shaped DGS with dimensions d = 10mm, s = 31mm x = 2mm and h = 1mm was added in the ground plane of the antenna. The geometry of shapes of DGS slot is shown in Figure 4. Detailed dimensions are shown in Table 1.

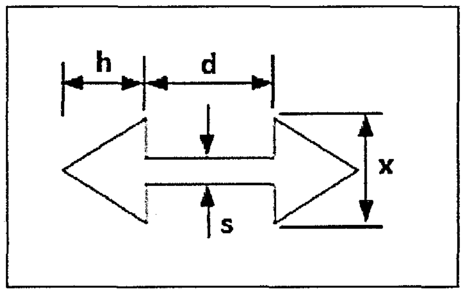

Figure 4: Geometry of shapes of DGS slot.

Parameter (mm)	Without DGS	With DGS
Length, L	33.78	21.6
Width, W	37.19	21.8
w	1.91	1.91
l	37.04	20
l_s	20.1	8.06
d	-	21.91
s	-	1
h	-	1
x	-	2

Table 1: Dimension for both antennas.

III. CST SOFTWARE SIMULATION

A. Single patch antenna with Proximity-fed

The antenna was designed and simulated using CST software to verify the antenna operation of the proposed configuration. Before reaching to the final stage of designing the antenna, a parametric study was investigated by altering

L and W of the patch. As shown in Figure 5, with the decrease in the value of L, the resonant frequency of the antenna is increasing. As for width, by decreasing size W, the return loss is decreasing as well as shown in Figure 6.

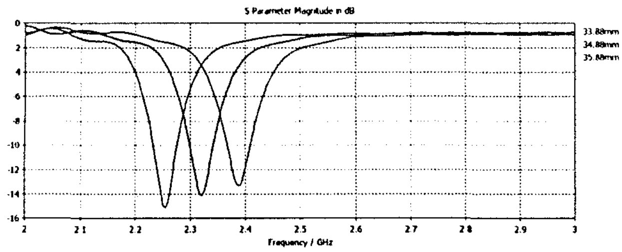

Figure 5: Alteration of the length, L

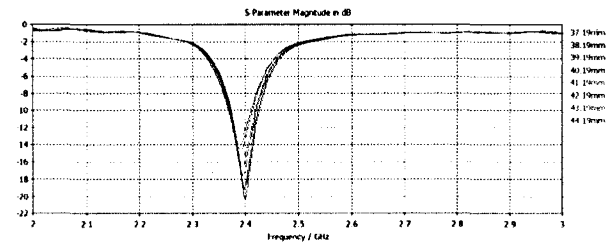

Figure 6: Alteration of the width, W

The simulated return loss is shown in Figure 7. The operating frequency is centred at 2.4GHz with -18.553dB.

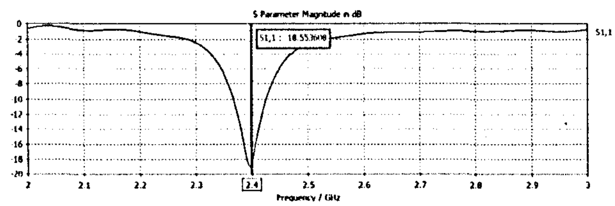

Figure 7: Antenna return loss

Figure 8 shows the radiation pattern that show the directivity and the gain in 3D of the antenna.

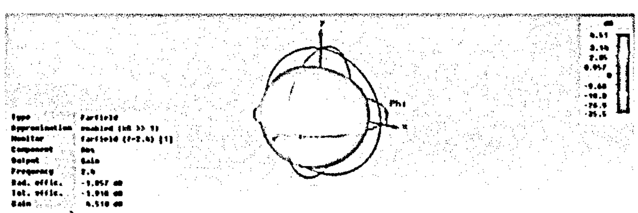
Figure 8: Antenna radiation pattern

B. Single patch antenna with DGS effects

The antenna is then been modified at the ground plane to enhance performance. The arrow head slot shaped DGS was created at the ground plane of the antenna. A parametric study was done by varying s, d, h and x of the slot. The simulated return loss is shown in Figure 9. The operating frequency is centered at 2.4GHz with -34.56dB.

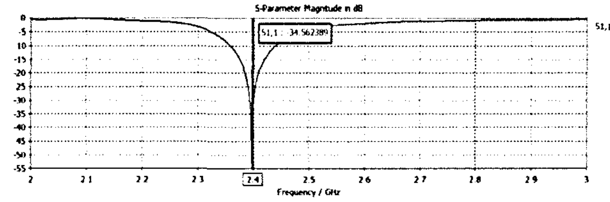

Figure 9: Antenna return loss

Figure 10 shows the radiation pattern that shows the directivity and the gain in 3D of the antenna.

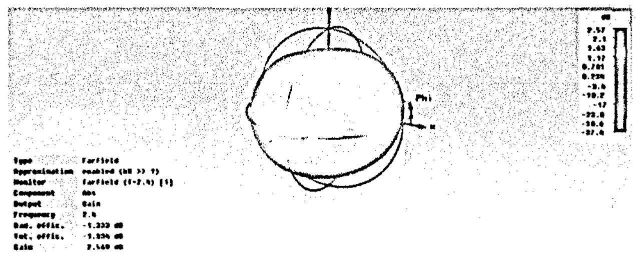
Figure 10: Antenna radiation pattern

C. Comparison

It has been shown that the size of the antenna can be reduced by adding a Defected Ground Structure (DGS). The result of both design are shown in Table 1.

Antenna Parameter	Without DGS	With DGS
Bandwidth	55.73 MHz	81.48 MHz
Return Loss	-18.53 dB	-34.56 dB
Gain	4.5 dB	2.6 dB
VSWR	1.26	1.03
Antenna size	2408mm^2	980mm^2

Table 1: Antenna parameters

The simulated return loss for both designs is shown in Figure 11. It shows that the return loss is reduced after adding a DGS.

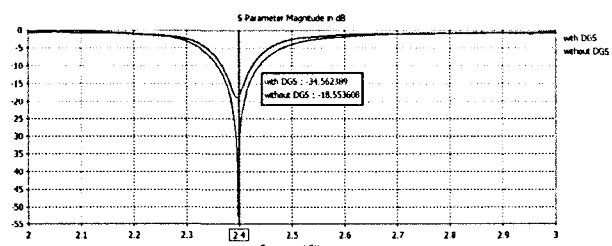

Figure 11: Simulated return loss

IV. RESULT AND DISCUSSION

Initially, the antenna without the DGS in the common ground was simulated and was found to resonate at 2.4 GHz with -18.553 dB return loss. Then the antenna was simulated with the arrow head shaped DGS. Before accomplish to the final size of the DGS, a parametric study was done by varying each parameter of the slot.

Based on Figure 12, by increasing the size of d, the resonant frequency of the antenna is decreasing. The length of the patch is reduced to optimize the resonant frequency to be operated at 2.4 GHz. In addition, by changing the position of the DGS along the feed line, the resonant frequency is remain same but has higher return loss.

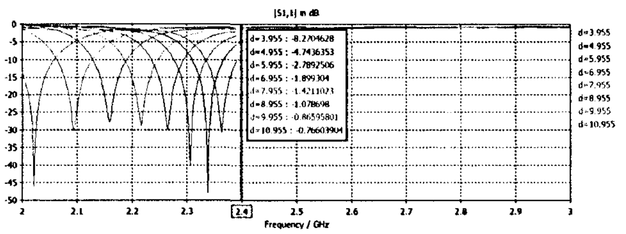

Figure 12: Return loss by varying DGS length, d.

Figure 13 show the implemented prototype of the proposed antenna. It shows that the size of the antenna has been reduced by adding a DGS in the ground plane.

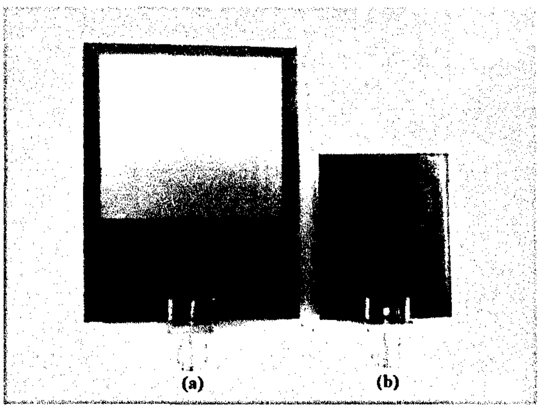

Figure 13: Fabricated Antennas; (a) without DGS, (b) with DGS.

The simulated and measured return loss plot of the structure with and without DGS is shown in Figure 14 and Figure 15 respectively. Both graph shows that the return loss is shifted. This may due to the material used and the glue used to bond the first and second substrate. The glue is not taken into consideration during the simulation process.

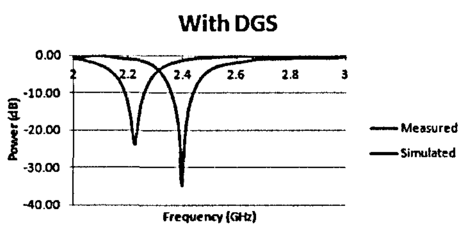

Figure 14: Return loss for antenna with DGS

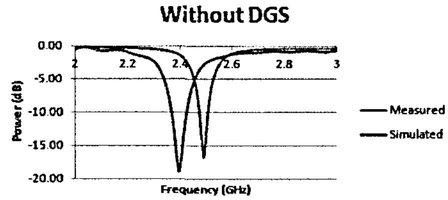

Figure 15: Return loss for antenna without DGS

The measured radiation patterns for both antennas are shown in Figure 16. It can be observed that the H- plane radiation pattern is quite similar. Measurements errors are mainly because the antenna measurements did not carried out inside an anechoic chamber.

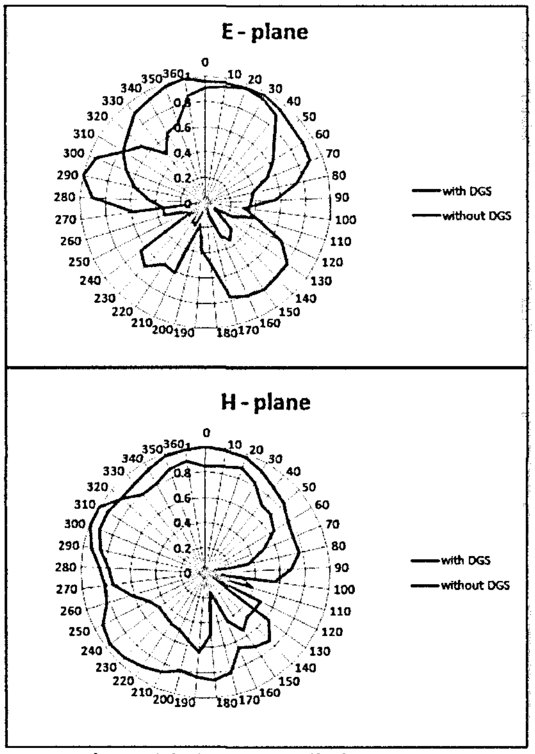

Figure 16: Antenna radiation pattern.

V. CONCLUSION

The antenna design and analysis for DGS effects were carried out in this report. A single patch antenna with proximity coupler fed technique has been designed. The optimization has been made to get a good performance of the antenna. Results have shown that the size of the antenna can be reduced by adding a DGS. It was found that about 59.3% size of antenna has been reduced.

VI. RECOMMENDATION

Based on the research work carried out in the present investigations, future work recommendations can be carried by using different shape of the DGS slot.

VII. REFERENCES

[1] H. Liu, X. Sun and J. Mao, "Harmonic Suppression with Photonic Bandgap and Defected Ground Structure for a Microstrip Patch Antenna," IEEE Microwave and Wire-less Component Letters, Vol. 15, No. 2, February 2005, pp. 55-56.

[2] D. Guha, M. Biswas and Y. M. M. Antar, "Microstrip Patch Antenna with Defected Ground Structure for Cross Polarization Suppression," IEEE Antenna and Wireless Propagation Letter, Vol. 4, No. 1, 2005, pp. 455-458.

[3] M. Salehi, A. Motevasselian, A. Tavakoli and T. Heidari, "Mutual Coupling Reduction of Microstrip Antenna using Defected Ground Structure," IEEE Singapore Interna-tional Conference on Communication System, Singapore, 2006, pp. 1-5.

[4] J. Guterman, Y. R. Samii, A. A. Moreira and C. Peixeiro, "Quasi-Omni Directional Dual-band Back-to-Back E- shaped Patch Antenna for Laptop Applications," Elec-tronics Letters, Vol. 42, No. 15, 2006, pp. 845-847.

[5] H. Iwasaki, "A Back-to-Back Rectangular-Patch Antenna Fed by a CPW," IEEE Transactions on Antenna Propa-gation, Vol. 46, No. 10, October 1998, pp. 1527-1530.

[6] K. F. Lee and K. M. Luk. *Microstrip Patch Antenna*, Singapore: Imperial College Press. 14-17; 2011.

[7] B. Gary. An Introduction to Defected Ground Structures in Microstrip Circuits. *Summit Technical Media, LLC.* 2008

[8] C. A. Balanis. *Antenna Theory Analysis and Design.* 3rd edition. Canada: John Wiley & Sons Inc. 1-2; 2005.

[9] M. Esa, U. Jamaluddin and M. S. Awang. Antenna with DGS for Improved Performance. *Proceedings of 2010 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE 2010).*

[10] A. K. Arya, M. V. Kartikeyan and A. Patnaik. Efficiency Enhancement of Microstrip Patch Antenna with Defected Ground Structure. *Proceeding of International Conference on Microwave (2008).*

[11] H.K. Gupta, P. K. Sharma, K. R. Rajriya and A. Duvey. Microstrip Patch Antenna with Defect Ground Structure in Efficient Rectenna Design for Wireless Power Transmission.