DEVELOPMENT, OPTIMIZATION AND ANALYSIS OF SQUARE PATCH ANTENNA WITH "L" SHAPED SLOT

Ahmad Fariz Hasan[1,2], Aziean Mohd Azize[1], Amar Faiz Zainal Abidin[1], Norain Idris[1], Nurul Ashikin Rais[1] and Mohd Fikri Bin Che Husin[1,2]
[1]Universiti Teknikal Malaysia Melaka, Durian Tunggal, Melaka, Malaysia
[2]University Malaysia Perlis, Malaysia
Email: azieanazize@yahoo.com

ABSTRACT

Microstrip patch antennas have been widely used in a various useful applications, due to their low weight and low profile, compatibility, easy and cheap realization. A low profile patch antenna for WLAN application is proposed in this paper. A slot technique for microstrip antenna is proposed for better performance which is aperture slot on the design microstrip patch rectangular antenna. The study in this research is based on the performance of the aperture slot microstrip antenna, in terms of return loss, bandwidth and radiation pattern, by varying the aperture shapes. In this project, aperture shape is focused on "L" shape and is carried out from the design until simulation using Computer Simulation Tool (CST). The "L" slot aperture is designed in the middle of rectangular patch antenna. The feed line design in this project will be based on quarter wave impedance matching in order to match the 50 Ω microstrip line with load impedance. For the slot design, the length and its width will be vary to get the best response. The slotted micro strip antenna in this comparison has almost the same design parameters as the one without the slot, with the obvious difference being that slotted antenna has an "L" shaped slot in the middle. This small difference, however, yields to a much higher return loss and increase in bandwidth. Moreover, even these results can be further enhanced by optimizing the size, shape and position of the slot. The rectangular patch antenna is design such that it works in the wireless local area network (WLAN) specification. The resonated return loss for simulated rectangular aperture slot is -29.49 dB while for the antenna without slot technique gives -17.63 dB. Radiation patterns of all antennas are simulated and the performance is acceptable. They produced E-plane Half Power Beam Width (HPBW) of 80º and H-plane HPBW of 110º.

Keywords: simulation tool, wireless local area network, half power beam width, microstrip antenna, slotted antenna.

INTRODUCTION

Antennas are the basic and most important component of a wireless communication system. As the demand in mobility of communication devices increases, the need to develop small and compact electronics also increases. Eventually making, small and compact sized antennas, a great area of interest. Microstrip patch antennas offer simple configuration, compatibility, low profile, planar structure, and unidirectional radiation capabilities. These characteristics and many other make microstrip patch antennas a very good candidate for compact sized antennas. However, this antenna lags in bandwidth and radiation efficiencies due to its limited size.

A lot of work has been done to increase the various performance parameters of microstrip patch antennas according to the various applications. Common techniques include increasing patch height, decreasing substrate permittivity, using a multilayer structure consisting of several parasitic radiating elements.

In this paper we compare and study the different performance parameters, like antenna BW, return loss, gain etc., offered by microstrip antenna with and without the "L" slot.

The slotted micropstrip antenna in this comparison has almost the same design parameters as the one without the slot, with the obvious difference being that slotted antenna has an "L" shaped slot in the middle. This small difference, however, yields to a much higher return loss and increase in bandwidth. Moreover, even these results can be further enhanced by optimizing the size, shape and position of the slot.

In section II of this paper, we will discuss the design equations that we used to find our parameters of the antenna and their values that we used in the design. In section III, we display the simulation result of our designs and compare the one without slot to the one with the slot. In section IV, we will conclude our discussion.

DESIGN CONSIDERATIONS

Rectangular patch design

In the microstrip antenna, its dimension determines the operating frequency and the operability of the antenna. In this project, the antenna is designed with the following parameters:

a) Substrate - FR4
b) *Tan* δ = 0.019 (tangent loss)
c) ε_r = 4.5
d) Substrate Height (h) = 1.6 mm
e) Operating Frequency (f) = 2.4 GHz

A slot microstrip patch antenna is characterized by resonant length (L) and width (W), dielectric constant (ε_r), substrate thickness (h) and dielectric loss tangent (tan δ) which is similar to the ordinary patch antenna.

For an efficient radiator, practical width *(W)* that leads to good radiation efficiencies is given in following equation [1]:

$$W = \frac{1}{2f(\sqrt{\varepsilon_0 \mu_0})} \cdot \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Where,
--ε_r =relative dielectric constant
--ε_o = dielectric constant in free space
--μ_o = permeability in free space
--W = patch width

The layout design of our microstrip slot antenna can be summarize as below in Table-1.

Table-1. Design parameter for the microstrip slot antenna.

Parameter	Dimension	Unit
Patch width (W)	37.7	mm
Patch Length (L)	29.1	mm
Effective Dielectric Constant (ε_{eff})	4.177	N/A
Aperture Slot Length, L_1	4	mm
Aperture Slot Width, W_1	0.5	mm
Aperture Slot Length, L_2	0.5	mm
Aperture Slot Width, W_2	035	mm
Quarter-wave Length	18.66	mm
Quarter-wave Width	0.1044	mm
50 ohm line length	16.88	mm
50 ohm line width	2.97	mm
Substrate length	70	mm

In a microstrip patch antenna, non-homogeneous line of two dielectrics exists, typically in the substrate and air. Most of the electric field will reside in the substrate, and part of the lines exists in air. As L/h>> 1 and ε_r>> 1, the electric field lines concentrate mostly in the substrate. Fringing in this case makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ε_{eff} is introduced to account for fringing and the wave propagation in the line.

To introduce the effective dielectric constant, it is assumed that the center conductor of the microstrip line with its original dimensions and height above the ground plane is embedded into one dielectric. The effective dielectric constant is defined as the dielectric constant of the uniform dielectric material so that the line has identical characteristics. For a line with air above substrate, the effective dielectric constant has values in the range of $1 < \varepsilon_{eff} < \varepsilon_r$. For most applications where the dielectric constant is much greater than unity (ε_r>> 1), the value of ε_{eff} will be closer to the value of the actual dielectric constant (ε_r) of the substrate. The effective dielectric constant is also a function of frequency. As the frequency of operation increases, most of the electric field lines concentrate in the substrate. Therefore the microstrip line behaves more like a homogeneous line of one dielectric (only the substrate), and the effective dielectric constant approaches the value of the dielectric constant of the substrate [5].

For low frequencies, the effective dielectric constant is essentially constant. At intermediate frequencies, its value begins to monotonically increase and eventually approach the dielectric constant of the substrate. The initial values (at low frequencies) of the effective dielectric constant are referred to as static values, and are given by [4]:

$$\varepsilon_{eff} = \left\{\frac{\varepsilon_r + 1}{2}\right\} + \left[\left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + 12\frac{h}{W}\right)\right]^{-0.5} \quad (2)$$

Where,
--ε_r = relative dielectric constant
--ε_{eff} = effective dielectric constant
--h = substrate height
--W = patch width

Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical dimensions. For the principal *E*-plane (*xy*-plane) where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant ε_{eff} and the width-to-height ratio (*W/h*). A practical approximate relation for the normalized extension of the length is;

$$\Delta L = 0.412h \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

Where,
--ε_{eff} = effective dielectric constant
--h = substrate height
--W = patch width

Since the length of the patch has been extended by *L* on each side, the effective length of the patch is now:

$$L_{eff} = L + 2\Delta L \quad (4)$$

Where,
--L_{eff} =relative dielectric constant
--ΔL = patch length extension

The actual length can now be determined by solving:

$$L = \left(\frac{1}{2f\sqrt{\varepsilon_{eff}\sqrt{\varepsilon_0 \mu_0}}}\right) - 2\Delta L \quad (5)$$

VOL. 13, NO. 16, AUGUST 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Where,
--ε_r =relative dielectric constant
--μ_o = permeability in free space
--W = patch width
--ε_{eff} = effective dielectric constant

Aperture slot and feed line design

The feed line design in this project will be based on quarter wave impedance matching ($\frac{\lambda_g}{4}$) in order to match the 50 Ω microstrip line with load impedance. For the slot design, the length and its width will be vary to get the best response.

From the equation (1) till (5) above, and quarter wave impedance matching calculation (not shown here), Figure-1 describe our antenna design.

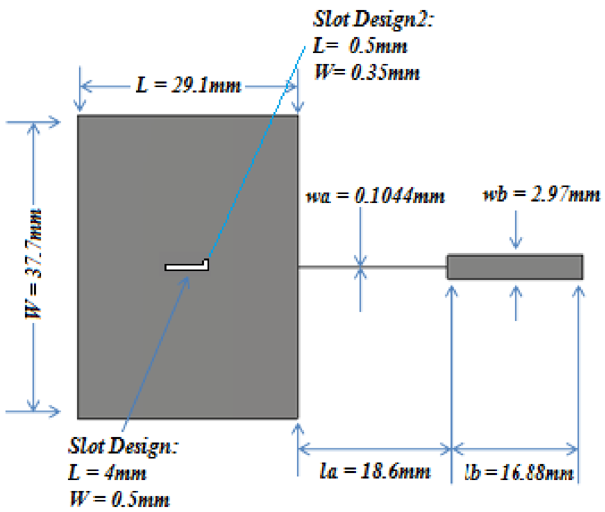

Figure-1. Propose of microstrip patch design with aperture slot.

RESULTS

This section shows the results of the proposed L shaped antenna. The 3D view of the one slot antenna is shown in Figure-2.

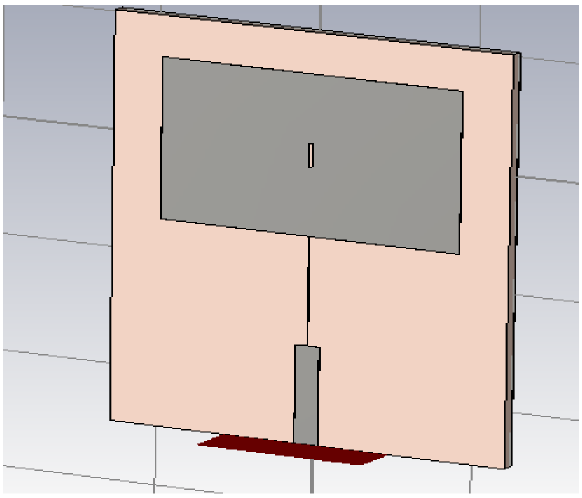

Figure-2. 3D view of microstrip antenna with one slot.

The resonated return loss simulated for the antenna without slot technique gives -17.63 dB as shown in Figure-3 while rectangular aperture slot is -29.49 dB as depicted in Figure-4. Table-5 shows the S11 comparison between both microstrip with and without slot. Radiation patterns of all antennas are simulated and the performance is acceptable. Figures 6 and 7 show the radiation pattern of the microstrip antenna without and with L slot respectively. They produced E-plane half power beam width (HPBW) of 80º and H-plane HPBW of 110º.

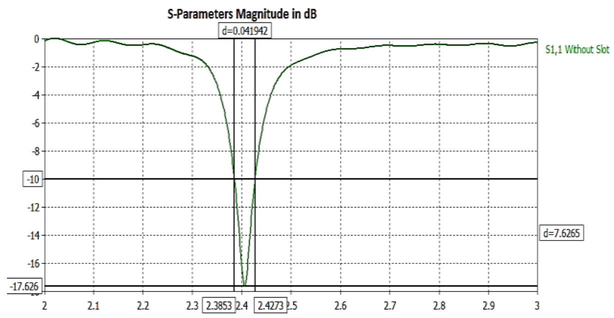

Figure-3. Return loss result for microstrip patch without L slot.

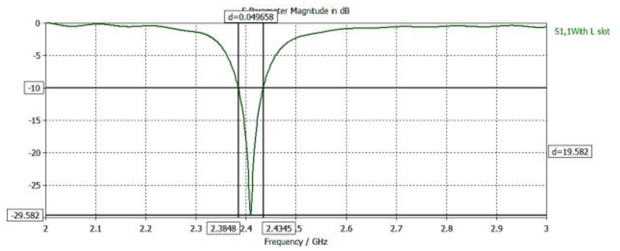

Figure-4. Return loss result for microstrip patch with l slot.

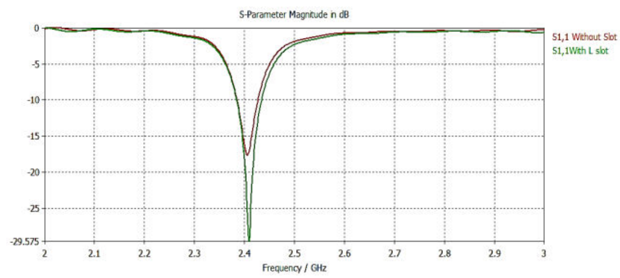

Figure-5. S11 comparison between microstrip patch without slot and with slot.

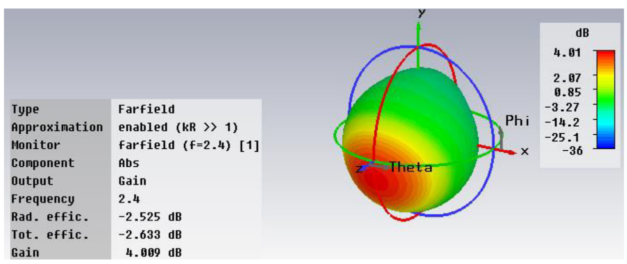

Figure-6. Radiation pattern of the microstrip antenna without L slot.

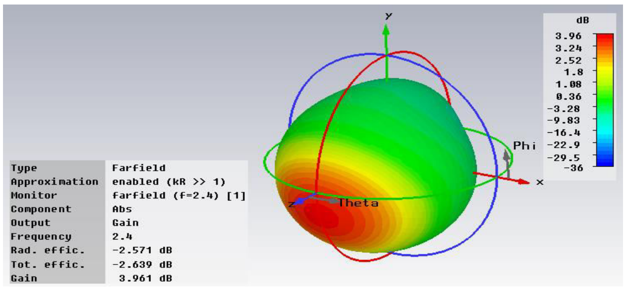

Figure-7. Radiation pattern of the microstrip antenna with L slot.

CONCLUSIONS

This paper focused on designing and comparing microstrip antennas with and without the "L" shaped slot. It can be reported that by loading an "L" shaped slot in the microstrip antenna working in the WLAN band of 2.4 GHz, we notice a substantial increase in the return loss, while a minimal, but not negligible, enhancement in the bandwidth. However, negligible decrease in gain and directivity is observed. We also note that these performance parameters of microstrip antennas, when compared with other antenna types, are not that efficient; especially they lag in bandwidth and gain.

ACKNOWLEDGEMENTS

The authors would like to thank Centre for Telecommunication Research and Innovation (CeTRI), Universiti Teknikal Malaysia Melaka (UTeM), CRIM-UTeMfor sponsoring this work under PJP grant.

REFERENCES

[1] T.A. Denidni, M. Hotton. 1999. Design of Aperture-Coupled Microstrip Antenna for Applications in Wireless Communications. SBMODEEE M'IT-S IMOC'99 Proceedings. IEEE, 654-657.

[2] D.M Pozar. 1996. A Review of Aperture Coupled Microstrip Antennas: History, Operation, Development, and Applications. Amherst: University of Massachusetts at Amherst.

[3] V. Rathi, G. Kumar, K.P. Ray. 1996. Improved Coupling for Aperture Coupled Microstrip Antenna. IEEE Transaction on Antennas and Propagation, Vol. 44, August: IEEE, 1196 - 1198.

[4] Balanis C.A. 1997. Antenna Theory: Analysis and Design. 2nd Ed. New York: John Wiley and Sons.

[5] R.A Sainati. 1996. CAD for Microstrip Antennas for Wireless Application. Boston: Artech House

[6] R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon. 2001. Microstrip Antenna Design Handbook. London: Artech House.

[7] D.M Pozar. 1998. Microwave Engineering. 2nd Ed. New York: John Wiley and Sons.

[8] P.L. Sullivan, D.H. Schaubert. 1986. Analysis of an Aperture Coupled Microstrip Antenna. IEEE Transaction on Antennas and Propagation, Vol. AP-34, No. 8. August. IEEE: 977 - 984.

[9] Applied Wave Research. 1999. Microwave Office 2000 Quick Start Guide. Applied Wave Research.

[10] D.M. Pozar. 1992. Microstrip Antenna. Proceedings of the IEEE, Vol. 80, No 1. January, IEEE: 79-91.