Studies on Effect of U-Slot on Patch Radiating Element at WLAN Application

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***Abstract* – WLAN application are triggering many conducted types of research on enhancing their RF front technology. Given specific frequency at 2.4 GHz operating frequency, this technology attracting many methods introduced such as introducing a parasitic element, slotting techniques, defecting techniques and more. This paper highlights the effect of different U-slot widths on single patch antenna performances where it is focusing on return loss, VSWR, bandwidth, directivity, radiation pattern and gains at frequency 2.4GHz. U-slot inserted into the patch is used to enhance bandwidth and to increase the efficiency of the antenna. The coaxial probe is used for feeding this structure. The single patch antenna with different U-slot width was designed and simulated using CST Microwave Environment software. The slotting technique gives an increment of 1.043% for their bandwidth and a high percentage of efficiency.**

***Index Terms* – Single patch antenna, U-slot, return loss, bandwidth, VSWR, radiation pattern, CST**

I. Introduction

Microstrip antennas have become attractive candidates in a variety of commercial applications such as mobile and satellite communications. Traditionally, microstrip antennas suffer from low bandwidth characteristic. But many of communication systems required wide bandwidth which is not provided by the conventional microstrip antenna. Hence serious efforts started among the scientific community to remove its inherent drawback of narrow bandwidth. There are numerous and well known methods to increase the band width of the antennas including: the use of the substrate thickness [1], the use of low dielectric substrate [1], the use of various impedance matching and feeding techniques [2], the use of multiple resonators [3-5] and the used of slot antenna geometry [6-8]. Among these, the use of multiple resonators in stacked or coplanar antenna geometries is a very promising method to enhance impedance bandwidth [9]. However, the stacked geometry increases the thickness of the antenna on the one hand and the coplanar geometry increases its lateral size on the other hand [10]. Therefore, these geometries are not preferred for most of the modern wireless communication systems that require a single layer single patch microstrip antenna. As this design was intended to confirm the basic concept, it was decided to build the antenna using a best and successful approach.

This paper introduced U-slotting techniques in order to give bandwidth enhancement capabilities to the proposed antenna. Then, the U-slot parameter had been examined to study the effect on the behavior of the U-slotted itself at S_{11} and VSWR of proposed radiating element. The coaxial probe is used in designing this antenna and all the dimensions have been calculated, the design would then be simulated in CST Microwave Environment software to obtain the return loss, radiation pattern, and VWSR.

II. Antenna Geometry And Theoretical Formulations

The geometrical configuration of the U-slot loaded microstrip patch antenna is shown in Figure 1.

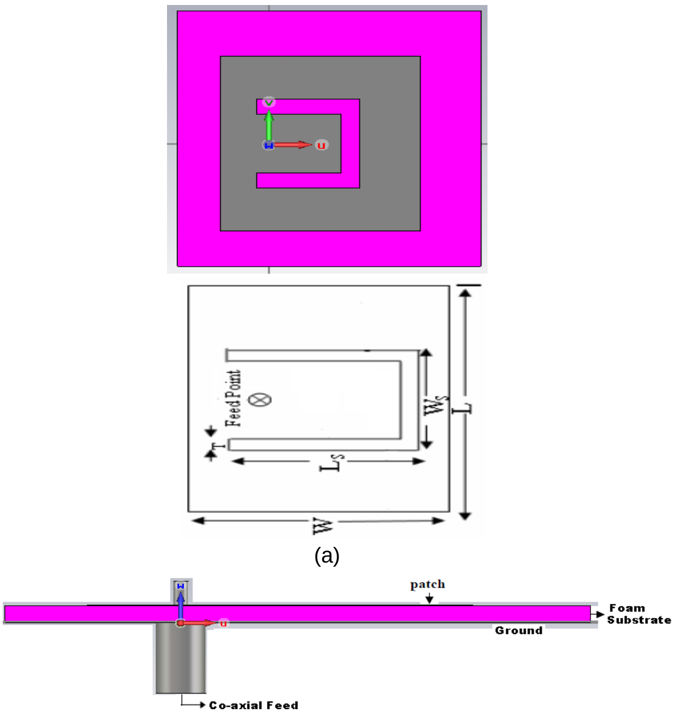


Figure 1: Antenna geometry (a) top view (b) side view

The proposed antenna consists of a conventional rectangular patch of length L = 36mm and W = 35.5mm. The rectangular patch is printed on a dielectric substrate (foam) of constant Ɛr = 4.9 and thickness h = 0.035mm. Then, an U-slot of side length Ls = 17mm, base-length Ws = 18mm and slot width T = 3mm is incorporated in the middle of the patch so that the side-arms are symmetrically positioned with respect to the feed point. The feed point (U0, V0, W0) is determined with respect to the center of the patch as (0, 0, -7). Another parameter which affects the design is the feed position. The feed location is moved from the center of the geometry to get the best possible impedance match and radiation characteristics for the antenna. The S_{11} variation with an offset from center is shown in Figure 1(b). The slots are located symmetrically inside the patch to achieve compactness. A simple microstrip patch antenna can be modeled as a simple LC-resonant circuit [11].

When U-slot incorporated into the patch, the resonance feature is changed as shown in Figure 2. The part of the patch enclosed by the U-slot has a current distribution like the normal patch and it resonates at a certain frequency. However, for the part of the patch beyond the U-slot, the current has to flow around the side and base arms of U-slot which causes lengthened current path. As a result, currents along the edges of U-slot introduce an additional resonance in conjunction with the main patch.

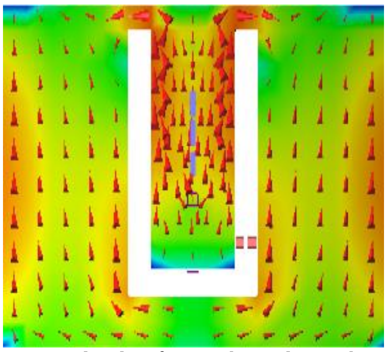


Figure 2: Simulated surface on the U-slot patch antenna

The U-slot cut in the lower patch can be considered as a combination of three narrow slots joint together in the form of U-shape. Using duality relationship of dipole and slot, the equivalent circuit of U-slot can be represented as shown in Figure 3(b) [12]. Here, RUH, XUH and RUV, XUV are radiation resistance and reactive component of the base-arm and side-arm of the U-slot. Therefore, from the equivalent circuit of U-slot show in figure 3(b), the impedance of the U-slot can be derived as Equation (1).

$$Z_U = \frac{2Z_{UV}Z_{UH}}{Z_{UV}+2Z_{UH}} \quad (1)$$

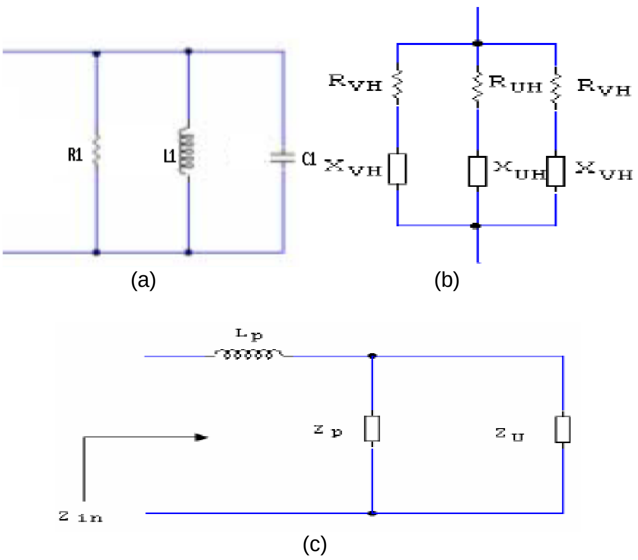


Figure 3: Equivalent circuit of (a) fed patch without U-slot, (b) U-slot and (c) U-slot loaded patch

Further, the U-slot loaded microstrip patch antenna can be considered as a parallel combination of impedances of the patch and the impedance of U-slot as shown in figure 3(c). Therefore, the impedance of the U-slot loaded microstrip patch antenna can be derived as Equation (2).

$$Z_{in} = j\omega L_p + \frac{Z_P Z_U}{Z_P + Z_U} \quad (2)$$

where Lp is the inductance due to the co-axial probe of 50 ohm. This will contribute to decrement in the size of the radiating patch. With this calculation, all initial values of proposed antenna with U-slot is used in designing proposed antenna in CST software.

III. RESULTS AND DISCUSSION

The simulation results of the single patch antenna with U-slot such as return loss, VSWR, and radiation pattern were discussed in this part.

A. Return Loss (S_{11})

Table 2 and figure 4 shows the simulated return loss graph of the single patch antenna with U-slot between different slot width at operating frequency 2.4GHz. The calculation for variation of return loss with frequency was carried out, the resulting data are shown in Figure 4. For this research, 2mm and 3mm slot width of U-slot were used to compare the return loss.

Table 1
Return Loss of Single Patch Antenna With U-Slot At 2.4GHz

Slot Width	*2mm*	*3mm*
Return Loss (dB)	-15.7422	-25.02981

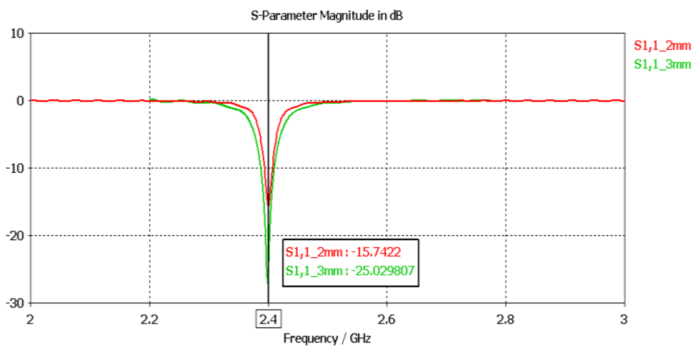
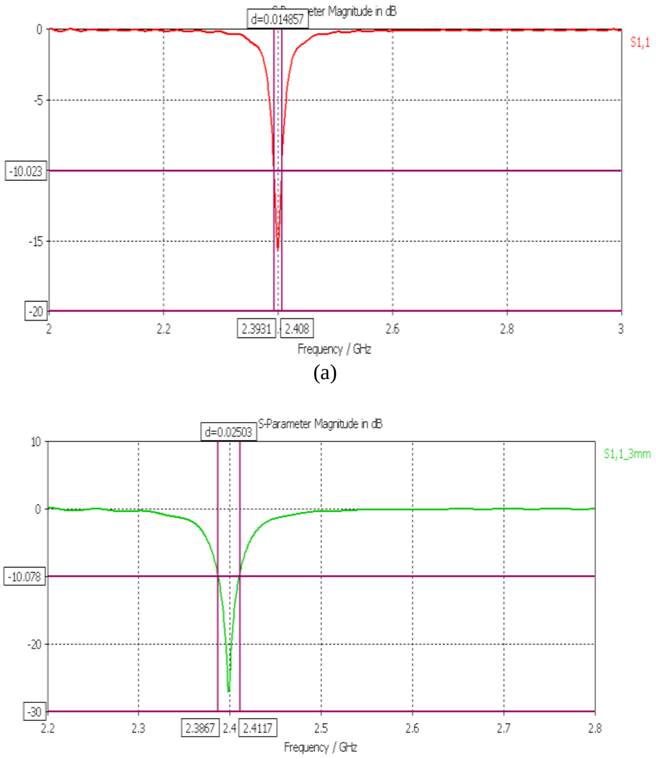


Figure 4: Return loss of simulation result with different slot width at frequency 2.4GHz

From Table 1 and Figure 4, it shows that the single patch antenna with the changes of the slot width of U-slot has a significant effect on return loss at operating frequency 2.4GHz. It can be observed that the implementation of U-slot within proposed antenna can enhance the bandwidth of microstrip antenna. For the single patch antenna with 2mm slot width the S_{11} is -15.7422dB while for 3mm slot width the S_{11} is -25.02981dB. In addition, it can be observed that the antenna has very good return loss with the changes of the U-slot width.



(a)

(b)

Figure 5: The bandwidth for the single patch antenna with (a) 2mm slot width and (b) 3mm slot width at frequency 2.4GHz

Figure 5 shows the bandwidth for the single patch antenna with 2mm and 3mm U-slot width. Refer to Figure 6, it shows that comparison of the bandwidth of single patch antenna with the different U-slot width was improved.

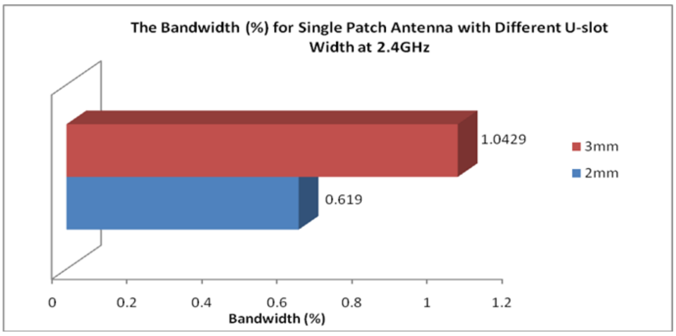


Figure 6 : The bandwidth (%) for single patch antenna between with 2mm and 3mm U-slot width.

Meanwhile, for the bandwidth of single patch antenna with U-slot, the percentage for 2mm slot width is 0.619% while for 3mm slot width the percentage increases to 1.0429%. This shows that microstrip antenna has shortcomings in terms of narrow bandwidth but, it can be concluded that to increase the U-slot width can give increment in the percentage of the bandwidth. Thus, the good characteristic of the return loss and the bandwidth is obtained when U-slot width is 3mm and it can be effectively applied to the single patch antenna with U-slot.

B. Voltage Standing Wave Ratio (VSWR)

The results in Figure 7 and Table 2 show that the simulation results of voltage standing wave ratio (VSWR). All points in the required bandwidth at 2.4GHz have successfully met the design specification of an antenna is (VSWR < 2dB).

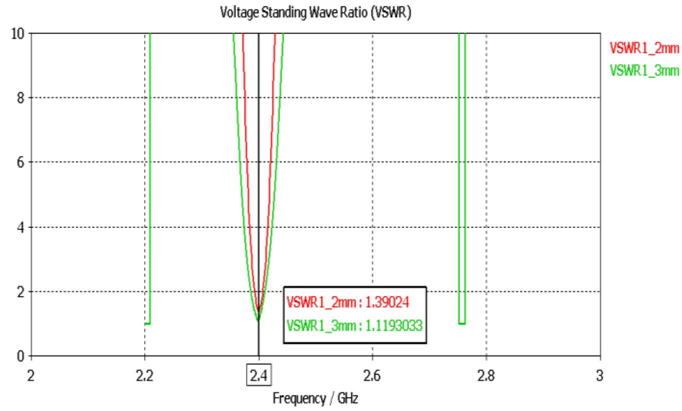


Figure 7: VSWR for single patch antenna between with 2mm and 3mm slot width at frequency 2.4GHz

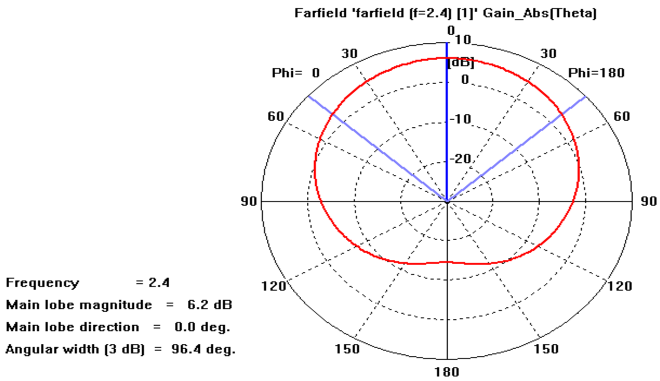
Table 2
VSWR of Single Patch Antenna with U-Slot at 2.4GHz

Slot Width	*2mm*	*3mm*
VSWR	1.39024	1.1193

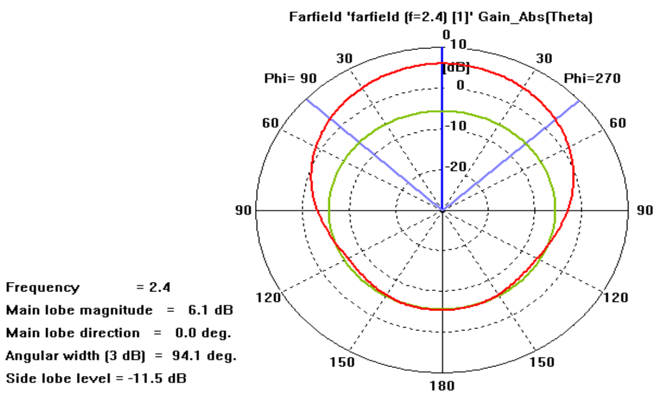
From the Table 2, at centre frequency 2.4GHz, the VSWR value for 2mm slot width is 1.39024 while for 3mm slot width the VSWR is 1.1193. It shows that the antenna is properly tuned and in good working order with low VSWR because the VSWR for 2mm and 3mm slot width is less than 1/2 of 1% of output power.

C. Radiation Pattern

From the radiation pattern as shown in Figure 8, the normalized value of the radiation pattern which 50Ω input impedance will give half power beam width value. Half power beam width (HPBW) is a measurement of angular spread of the radiated energy. It shows that the values radiation pattern at 3dB for 2mm and 3mm U-slot widths are 96.4°and 94.1° respectively. From figure 8(a), the main lobe magnitude for 2mm U-slot width at 2.4GHz is 6.2dB. While from Figure 8(b) show that the main lobe magnitude the side lobe level for 3mm U-slot width at frequency 2.4GHz are 6.1dB and -11.5dB.



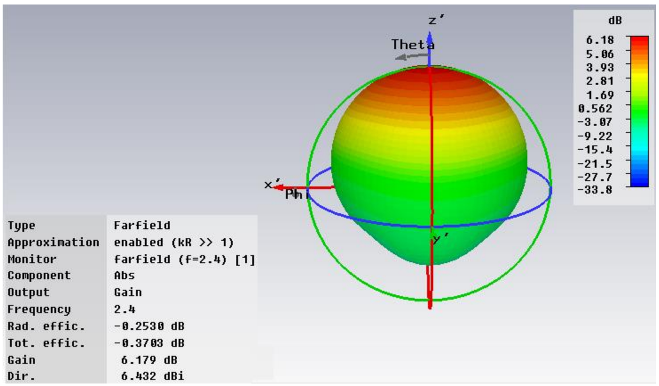
(a)



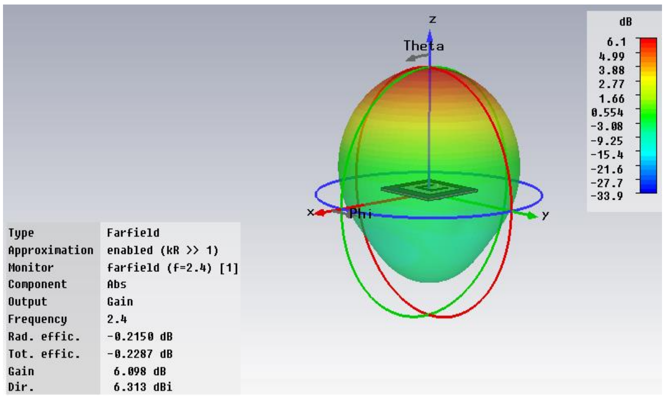
(b)

Figure 8 : The radian pattern (polar) of a single patch antenna with (a) 2mm U-slot width and (b) 3mm U-slot width at frequency 2.4GHz

Figure 9(a) is the simulated radiation pattern of a single patch antenna with 2mm U-slot width. The directivity is 6.432 dBi and gain is 6.179dB. Figure 9(b) is the simulated radiation pattern of a single patch antenna with 3mm U-slot width. The directivity and gain are 6.313dBi and 6.098dB respectively.



(a)



(b)

Figure 9: The radian patterns (3D) of a single patch antenna with (a) 2mm U-slot width and (b) 3mm U-slot width at frequency 2.4GHz

Table 3
The Characteristic of Radian Patterns of Single Patch Antenna with U-Slot at 2.4GHz

Slot Width	*2mm*	*3mm*
Gain, G (dB)	6.179	6.098
Directivity, D (dBi)	6.432	6.313
Efficiency (%)	96.07	96.59

From the Table 3 shows that the percentages of efficiency for single patch antenna with 2mm and 3mm U-slot width. The percentage of efficiency for 2mm U-slot width is 96.07% while for 3mm U-slot width is 96.59%. As both radiation patterns compared, it can be concluded that the single patch antenna with 3mm U-slot width design generates more intensity or focus at the center of the radiation. Thus, to increase of U-slot width having high efficiency for the single patch antenna.

IV. Conclusion

Based on the result, it can be concluded that a single patch antenna with U-slot is capable of improving the bandwidth of single patch antenna [8]. The single patch antenna with 3mm U-slot width improves 1.0429% bandwidth. Variation of U-slot width does show the effect on return loss and VSWR at the centre frequency of 2.4GHz. The return loss for 2mm U-slot width is -15.72dB while return loss for 3mm U-slot width increase -25.03dB. The VSWR for 2mm U-slot width is 1.39 while return loss for 3mm U-slot width decrease 1.12. The percentages of efficiency for a single patch antenna with 2mm U-slot width is 96.07% while for a single patch antenna with 3mm U-slot width improve 96.59% efficiency. This proved that the higher value of U-slot width is the best technique to improve bandwidth on a single patch antenna [8-14]. Besides that, the higher value of U-slot width having high efficiency for the single patch antenna. The performances of the single patch antenna strongly depend on several factors such as the type of substrate, the thickness and dielectric constant of the substrate respectively [1]. The single patch antenna with U-slot is more effective, less costly and easier to design.

For future development, one of the ways of increasing the performances of the antenna is by doing an array configuration instead of using a single element of the antenna. The way antenna has been fed is also important where the matching technique contribute to a massive impact on the performances of the antenna.

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