A Study on Performance of V-slot Shapes on Rectangular Patch Antenna

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***Abstract* - In this paper, the base V - slot and sharp V-slot antennas and rectangular patch antenna have been designed. An investigation on the effect of the angles of the antennas and size of the slots on the return loss and radiation patterns had been carried out. The impedance matching network with the transmission line feeding was used in this study. Simulation results of the return loss, VSWR and input impedance were presented.**
***Keywords*— Microstrip V-slot antennas; return loss; bandwidth; Impedance matching; radiation patterns**

I. INTRODUCTION

A microstrip patch antenna is a simple antenna structure that is easy to fabricate and form into arrays for higher gain. Other advantages of patch antenna are low profile, low cost, light weight and ease of conformity. However, the main disadvantage that limits the use of patch antenna in wireless broadband communication is its narrow bandwidth, due to its inherent nature as resonant device. Microstrip patch antenna has a very high antenna quality factor (Q). Q represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. However as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. Much effort is made to develop techniques and find configurations to broaden its impedance bandwidth. Some of the techniques which have been studied are the use of thick substrates, cutting slots suitably in the metallic patch and introducing parasitic patches either on the same layer or on the top of the main patch.

Microstrip patch antenna can be fed by contacting and non contacting methods techniques. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as microstrip line. In the non contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. In this study the patch antenna with slot shape of "V" is explored. The proposed antenna is based on a U-shaped patch [1].

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II. ANTENNA CONFIGURATION

Table 1: Antenna parameters

Center Frequency, *f*	2.45 GHz
Substrate	FR-4
Dielectric Constant, ε_r	5.4
Dielectric Thickness	1.6mm
Loss Tangent	0.025
Copper Thickness	0.035mm

The square patch and microstrip line for V slot are fixed in position to monitor the performance of the V slot antenna. The V slot parameters are varied to see the effect of varying its parameters. From the parameters listed in the Table 1, certain parameters can be defined in order to calculate the dimension of the square patch microstrip antenna.
The proposed antenna structure is shown in Fig. 1. with a truncated V-slot cut on its patch. The design is similar to the U-slotted patch antenna, but the the arms of U are open to some degree, or known as 'V arms with an angle of θ". There are some relationships between the base width F and V arms lengths, G These additional parameters enable the control and optimization of the patch input impedance, to be made without moving the feed location.[2] .

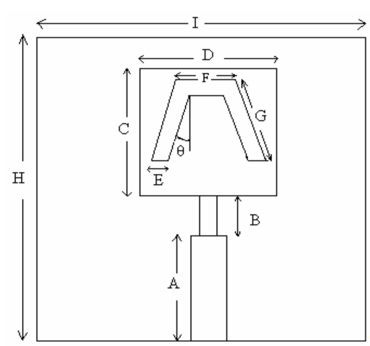


Figure. 1(a) The geometry rectangular microstrip patch with V-slot with base (V base)

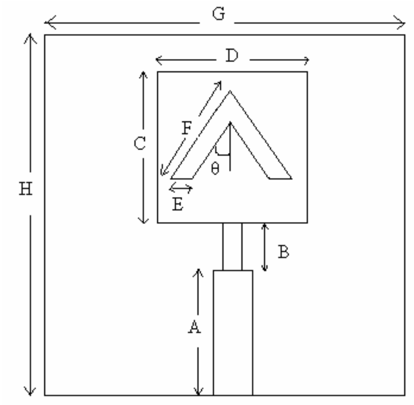


Figure. 1(b) The geometry of rectangular microstrip patch with V-slot without base. (V sharp)

On the top ground plane there is a V-type slot, and on the other side of the substrate is the microstrip feed line with a characteristic impedance of 50 Ohms. The V-slot is symmetrical.

Parameters mentioned previously are important in controlling the achievable bandwidth. The symmetrical V-shapes patch antenna has two resonant frequencies; a higher frequency and a lower frequency. For comparing purpose, some attempts have been done such as using different sizes of V arms (*G* and F), different degrees of V arm angle θ and different locations of patch toward the transmission line feeder. The V-shape without base (F) also has been used and some results are obtained.

For the rectangular patch antenna, the dimensions are as shown in Figure 2, adjustment in its length has been made in order to get the best result performed at frequency 2.45 GHz.
Throughout this study the line feeder has been maintained at the centre of length D, or close to it .This improves the symmetry of the antenna geometry and helps to eliminate the higher order mode [2].

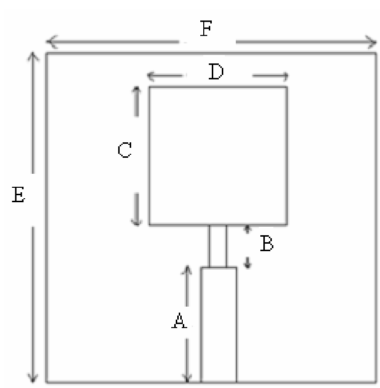


Figure. 2 . The geometry of rectangular microstrip patch

III SIMULATION RESULTS

The software used to model and simulate is CST Microwave Studio Suite for V-slot and square patch antennas.

TABLE 2

Comparison of angle, θ parameter to Return Loss of
(a) Base V-slot antenna. (b) sharp V-slot antenna

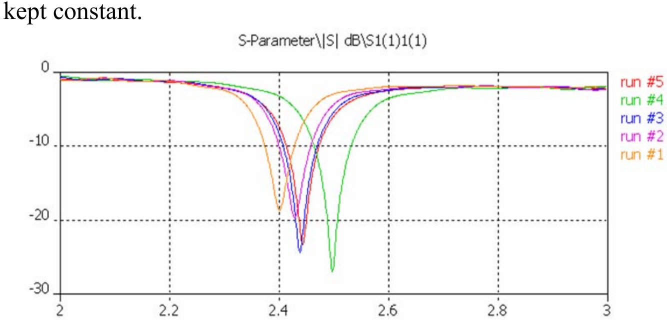
Run ID	Angle of θ (°)	Frequency (GHz)	Return Loss (RL) (dB)
run #1	15.0	2.401	-18.59
run #2	20.0	2.429	-19.60
run #5	22.6	2.444	-23.19
run #3	25.0	2.439	-24.30
run #4	30.0	2.498	-26.90

(a)

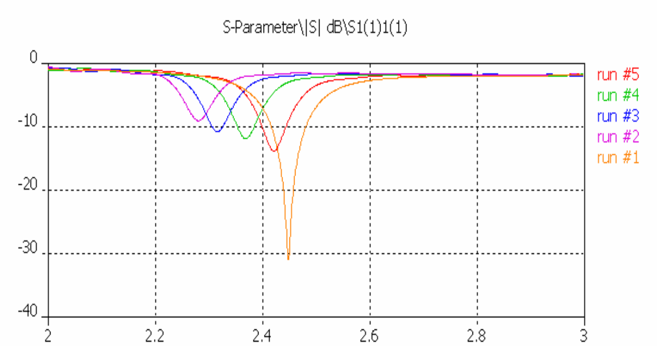
Run ID	Angle of θ (°)	Frequency (GHz)	Return Loss (RL) (dB)
run #1	41.4	2.448	-30.83
run #5	40	2.421	-13.76
run #4	35	2.369	-11.80
run #3	30	2.316	-10.66
run #2	25	2.281	-8.939

(b)

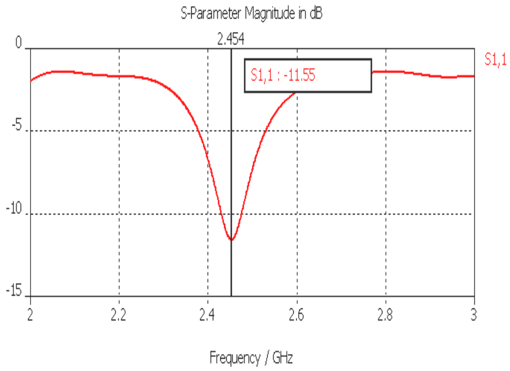
Figure 3 shows the return loss plot for V-slot square patch antenna with different angle of V slot's arm. The θ parameter is increased and decreased by 5° each for four parameters. Angles for desired frequency are also observed and compared for each type of V-slot antennas. The other parameters are kept constant.



(a)



(b)



(c)

Figure 3. (a) Return Loss for several θ of base V-slot antenna.
(b) Return Loss for several θ of sharp V-slot antenna.
(c) Return Loss for rectangular patch antenna.

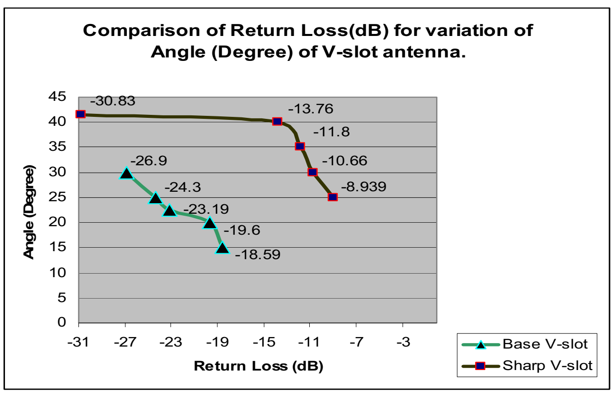


Figure. 4. Comparison of Return Loss at the range of 2.2 Ghz to 2.5 Ghz

Figure 4 shows the comparison of angle variation versus return loss between base V-slot and sharp V- slot antenna. The θ parameter is increased and decreased by 5° each. From Figure 4, it is noted that the angles that achieved desired frequency are at 41.4º and 30º for sharp V- slot and base V-slot antenna respectively. The return loss for each shape is -30.83 dB and -26.9 dB.

Both designed antennas showed a good S_{11} value of less than -10 dB, however the sharp V-slot antenna had better return loss as compared to base V-slot antenna and rectangular patch antenna.

Figure.5 show the comparison of length variation versus return loss of F and G of V- base antenna. The return loss is increased when the length of G is decreased while the return loss is increased as the length of F is increased. For the desired frequency both G and F are in the range of 15mm to 16mm.

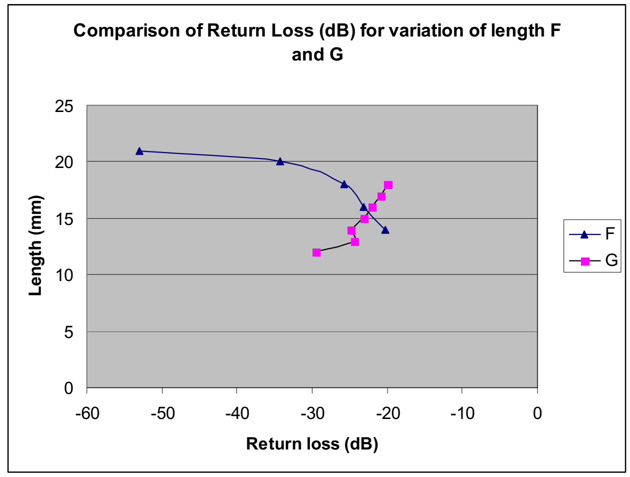


Figure.5 Comparison of length of G and F to Return Loss for base V-slot antenna. at the range of 2.2 Ghz to 2.5 Ghz

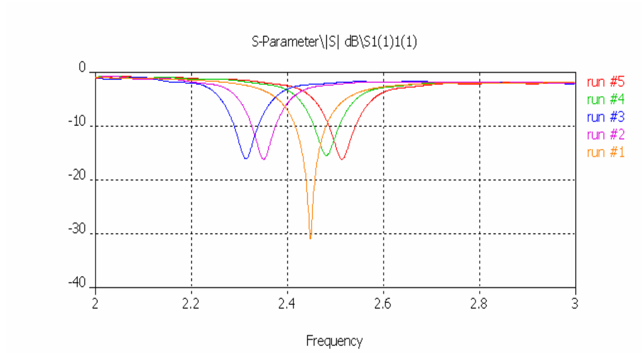


Figure.6 Return Loss for variation of length F of sharp V-slot antenna.

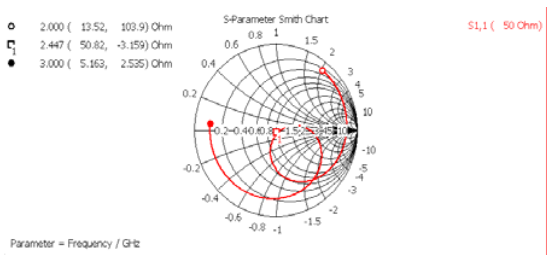
Table 3 and Figure 6 show that the return loss is maintained near -15dB to -16dB although the length of F parameter is changed except at length of 18mm which has return loss of -30.83dB. This shows that to achieve higher return loss, the length of F must be between ranges of 17mm to 19mm.

TABLE 3

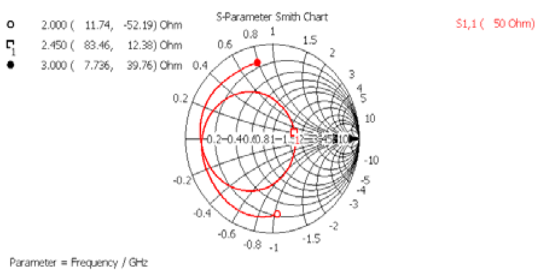
Comparison of F parameter to Return Loss for sharp V-slot antenna.

Run ID	Length of F (mm)	Frequency (GHz)	Return Loss (RL) (dB)
run #3	20	2.314	-15.99
run #2	19	2.351	-16.07
run #1	18	2.448	-30.83
run #4	17	2.482	-15.36
run #5	16	2.514	-16.03

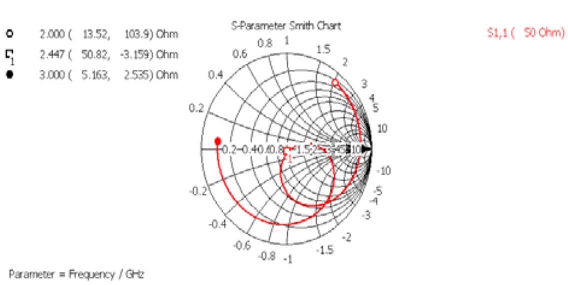
Input Impedance



(a) Base V-slot : 53.19 – j7.65 Ω.



(b) Square patch : 83.46 + j12.38 Ω.

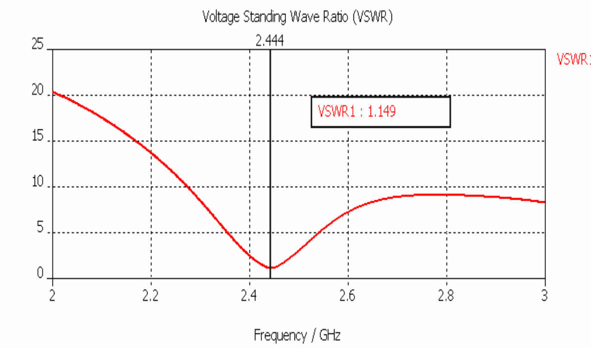


(c) Sharp V-slot 50.82 –j3.159 Ω.

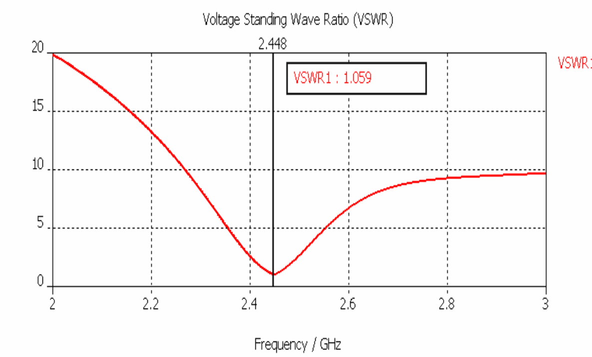
Figure.7 Comparison of Input Impedance

Figure.7 (a), (b) and (c) show the value of input impedance for base V-slot antenna, sharp V-slot antenna and square patch microstrip antenna respectively. The input impedance for sharp V-slot is 50.82Ω which is neared to 50 Ω of impedance matching for the 2.45GHz. Input impedance for base V-slot which is 53.19 Ω can be considered near 50Ω impedance. However, square patch has the worst input impedance matching which is 83.46Ω. This may cause the power transfer efficiency to square patch antenna to decrease or interrupted because of the mismatch of the input impedance. This shows that sharp V-slot has better power efficiency than others.

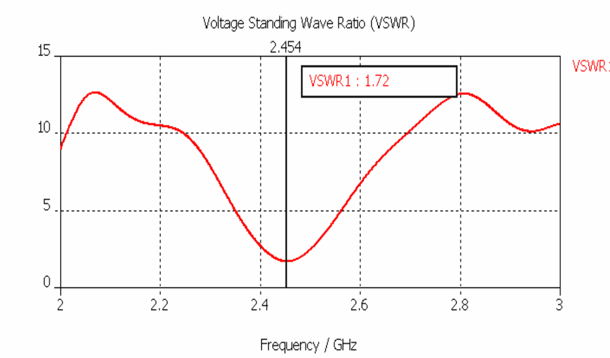
Voltage Standing Wave Ratio VSWR



(a) Base V-slot antenna has 1:149 of VSWR.



(b) Sharp V-slot antenna has 1:1.059 of VSWR.



(c) Square patch antenna has 1:1.72 of VSWR

Figure.8 Comparison of VSWR

Base V-slot antenna shows the VSWR in Figure 8 (a) with the ratio of 1:149 at frequency 2.45 GHz. If two decimal points are taken the ratio for the circular patch can be written as 1.15 which is approximate to perfect impedance match. This means that base V-slot antenna is matched to the characteristic impedance of the transmission line.

As shown in Figure 8 (b), the sharp V-slot antenna's VSWR is 1.059 at frequency 2.45 GHz. For this shape of design, the ratio is about 1.06. Meanwhile from Figure (c), square patch's VSWR is 1.72. Square patch has higher VSWR than others but it is still in the range of 1 to 2. This shows that sharp V-slot square patch antenna is most to match the characteristic impedance.

II. CONCLUSIONS

The design of a rectangular microstrip patch antenna with 2 types of V-shape slot has been implemented and studied. It was shown that modifying the angles and sizes of V-arms produce better effect on the return loss, bandwidth and impedance matching improvement. The base V-slotted patches provide a smaller bandwidth as compared to sharp V-slotted bandwidth. However, the sharp V-slotted patches antenna showed high return loss even though the bandwidth was smaller.

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