Design Of Bow-Tie Antenna With Slot On Ground Plane At 2.5 GHz.

Siti Norlihaina Binti Mohd Razali
Faculty of Electrical Engineering
Universiti Teknologi Mara (UiTM)
Shah Alam, Selangor
noliehaina12345@gmail.com

***Abstract*— This paper focus on the design of the bow-tie antenna with u-slot on ground plane. The designed was carried out at two different structures. First, designed the bow-tie antenna without slot and second, with slot on ground plane. The microstrip patch antennas were designed using 1.6mm FR-4 substrate with dielectric constant of 4.3 and loss tangent 0.025. The design were simulated by using CST Microwave Studio and measured by using Vector Network Analyzer(VNA) for return loss and using Anechoic Chamber for the radiation pattern. The value for the return loss is increased from -24.659 to -25.537 dB for bow-tie patch antenna without slot on ground plane while the bow-tie antenna with slot on ground plane, the return loss is reduced from -31.833 dB to -30.478 dB but the resonant frequency is shifted from 2.5 GHz in simulation to 2.65 GHz and 2.64GHz in measurement.**

Keywords: Bow-tie, Microstrip, U-slots, FR4

I. INTRODUCTION

Microstrip patch antenna is become increasingly useful nowadays, because this antenna can be printed directly onto a circuit. Therefore, microstrip patch antenna is a metal conductor on a substrate. It is an antenna that has a light mass, easy to fabricate, suitable to be placed on almost any type of surface and small size. Patch antenna has some disadvantages such as narrow bandwidth, small gain and directivity, and low efficiency.

In [1], the bow-tie antenna patch is actually the combination of a two triangular patches which are fabricated in single substrate. There are different methods that can be applied to increase the performance of the antenna such as using slots, EBG, DGS and others. EBG can produce the back lobe reduction in [2] that is from -10.24 dB to -17.67 dB. By incorporating DSG onto the antenna, return loss were also improved from -26.089 dB to -41.28 dB [3]. In [4], the effects of the slots in patch and ground plane of the Rectangular Microstrip Patch Antenna were demonstrated as the slots length and width increases, the frequency shifted toward lower side. Moreover, the effect of slots on ground of the antenna produced the worse performance of the antenna compared to slots on patch. The bandwidth of the antenna can be increased by applying the slots to the antenna geometry [5]. Slots based on their location and geometry has different effects on the antenna bandwidth.

In this paper, the bow-tie patch antennas with U-slot on ground plane and without slot were designed and the performance of the antennas were analysed.

II. METHODOLOGY

In this section, the bow-tie patch antenna and U-slots on ground plane explained in completed flow chart below.

A. Flow chart design process of antenna.

The flow chart of this project is illustrated in **Figure 1**.

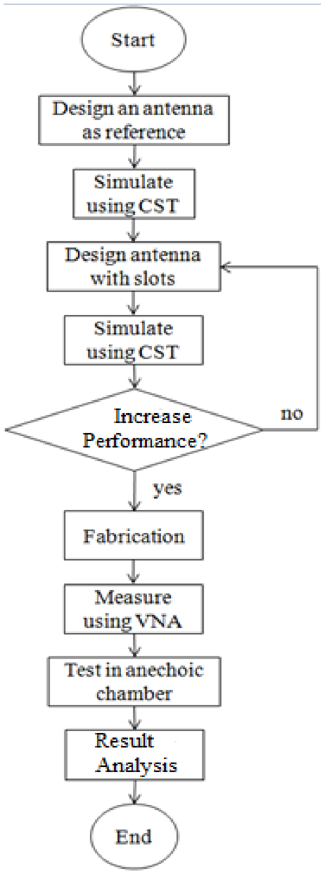


Figure 1. Flow Chart of the Project

The design started with design of the bow-tie patch antenna without slot on ground plane at the 2.5GHz as resonant frequency. The designed then simulated by using Computer and Simulation Tools (CST) Microwave Studio. The patch antenna with slot on ground plane was designed. Analysed either the performance of antenna with slots on ground plane can increase the performance of the antenna or not. The antenna was fabricated, and then measured the return loss using Vector Network Analyzer (VNA) and test in anechoic chamber for the radiation pattern and directivity of the antenna.

B. Antenna design

The bow-tie antenna was printed on FR4 Substrate with size $73 \times 56 \times 1.6\, mm^3$ with the thickness 1.6 mm is include and dielectric constant of 4.3. The dimension of patch geometry is given by [6].

1. Calculations of patch dimensions

i) The patch dimensions,W

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

Where the ϵ_r, dielectric constant of material is 4.3 and c, speed light in free space is 3×10^8 m/s.

ii) Effective dielectric constant

$$e_{reff} = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon_r-1)}{2}[1+12\frac{h}{W}]^{-1/2} \qquad (2)$$

Where thickness of substrate=1.6mm.

iii) Length extension due fringing field, ΔL

$$\Delta L = 0.412h\frac{(e_{reff}+0.3)(\frac{W}{h}+0.264)}{(e_{reff}-0.258)(\frac{W}{h}+0.8)} \qquad (3)$$

iv) The actual length of the antenna

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad (4)$$

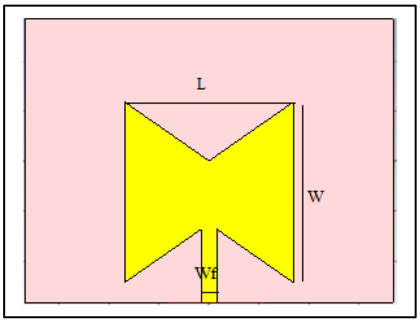
v) Width of the substrate

$$Wg = W + 6h \qquad (5)$$

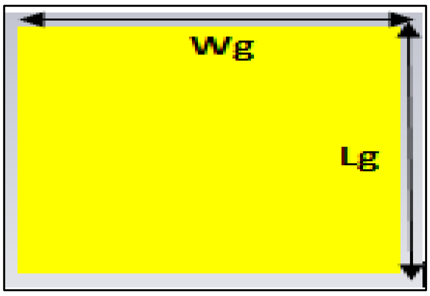
vi) Length of the substrate

$$Lg = L + 6h \qquad (6)$$

The geometry design of bow-tie patch antenna was shown in the **Figure 2** respectively and the design of the U-slot on the ground plane of the antenna.



(a)



(b)

Figure 2. Conventional Bow-tie patch antenna. (a) is front view of antenna while (b) is back view of antenna.

2. Calculation of U-slot dimensions using equation below [7] and the dimensions of U-slot shows in **Figure 3**.

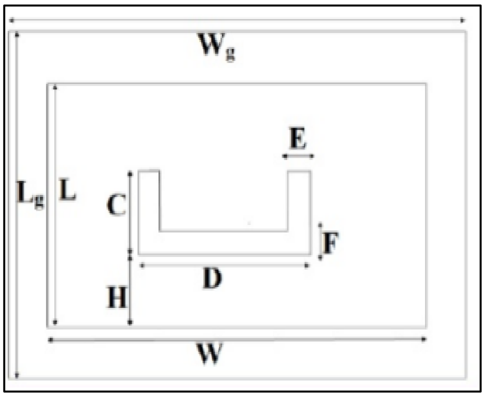


Figure 3. Dimensions of the U-slot

i) Slot thickness, E=F

$$E = F = wavelength\ of\ light/60 \quad (7)$$

ii) Slot width, D

$$D = \frac{c}{2f(e_{reff})^{1/2}} - 2(L + \Delta L - E) \quad (8)$$

iii) Slot height, C.

$$C = D \times 0.75 \quad (9)$$

iv) Height of slot from base, H.

$$H = \frac{L-E+2\Delta_{L-E-H}-1}{(e_{reff})^{\frac{1}{2}}(\frac{c}{f}-(2C+D)} \quad (10)$$

v) Where $2\Delta_{L-E-H}$ is

$$2\Delta_{L-E-H} = 0.824h\left[(e_{reff} + 0.3)\left(\frac{(D-2F)}{(h+0.262)}\right)\right] / [(e_{reff} - 0.258)\left(\frac{(D-2F)}{(h+0.813)}\right) \quad (11)$$

Figure 4 below shows the U-slot designed on the ground plane of the conventional bow-tie patch antenna.

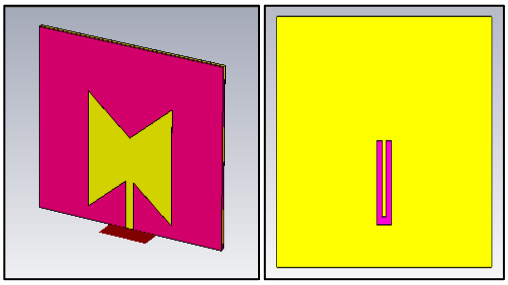


Figure 4. Bow-tie patch Antenna with U-slot on the ground plane.

Thus, Antenna with slots on ground plane was fabricated as shown in **Figure 5** below.

Figure 5: Fabricated bow-tie patch antenna without and with u-slot on ground plane at 2.5GHz

The calculation parameters of the antenna and the U-slot were optimized in CST Microwave Studio and will discuss in the results and discussion section.

III. Results and Discussion

In this section, the results that obtained from the Computer Simulation Software (CST) Microwave Studio for the conventional bow-tie patch antenna with U-slot on ground plane were analysed and discussed. The simulation results were comparing to analysis both antenna performances. The measurement result after fabricated was obtained from Vector Network Analyzer (VNA) and Anechoic Chamber.

A. Simulated Results

Table I and **Table II** shows the parameters of the Bow-tie patch antennas that were designed using CST design software.

TABLE I. Conventional Microstrip Patch Antenna Parameter

Parameter	Calculated	Optimized
Resonant Frequency, f_r	2.5 GHz	2.5 GHz
Dielectric Constant, ε_r	4.3	4.3
Substrate Thickness, h	1.6 mm	1.6 mm
Copper Thickness, t	0.035 mm	0.035 mm
Width of Patch, W	36.83 mm	36.10 mm
Length of Patch, L	29.22 mm	33.70 mm
Width of Substrate, W_g	73.72mm	70.72mm
Length of Substrate, L_S	56.824mm	56.654 mm
Width of Feed, W_f	3.137 mm	3.137 mm
Width of the gap, W_{gap}	4 mm	12.58mm
Length of Inset Feed, L_i	28.4 mm	25.5mm

TABLE II. PARAMETER OF BOW-TIE PATCH ANTENNA WITH SLOTS ON THE GROUND PLANE

Parameters	Calculated	Optimized
Slot thickness ,E=F	2mm	1.8mm
Slot width, D	19.09mm	5.1mm
Slot height, C	14.3175	19.155
Height from the base, H	1.757mm	7.8mm

From the table of parameters the antennas, it was observed that the dimensions of the bow-tie patch antennas were changed after being optimized. Optimization process took placed because the resonant frequency was shifted to the other frequency, the return loss is higher than 10 dB and the main lobe direction was not at 0 degree. For the frequency shifted, the length of the bow tie patch antenna as the main role can optimized to shift at resonant frequency. Therefore, the width gap between the triangular also optimized to increase the return loss value. The angle of the bow-tie antenna will increase due to the length of the arm of bow-tie antenna.

Figure 6 shows the simulated return loss at 2.5 GHz. These results are for Bow-tie patch Antenna with slot ground plane and without slot on ground plane represented by red and blue colour.

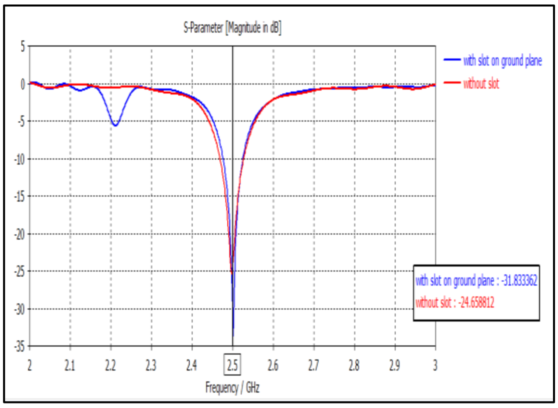


Figure 6. Return Loss (S11) for bow-tie patch antenna without slot and without slot on ground plane at 2.5GHz.

Figure 7 shows the simulated radiation pattern at 2.5 GHz. The results were for Bow-tie Patch antenna without slot and the antenna with slot on ground plane that represented by blue and red colour respectively.

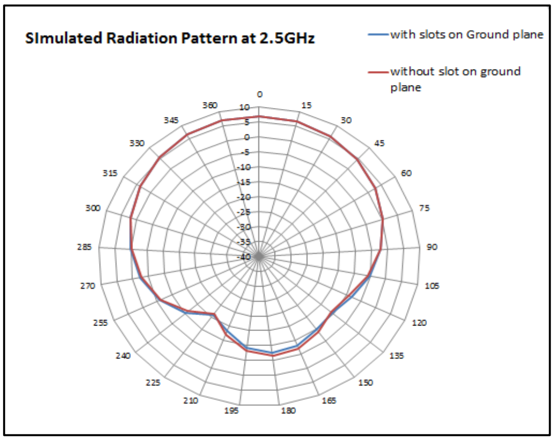


Figure 7. Simulated Radiation Pattern at 2.5GHz

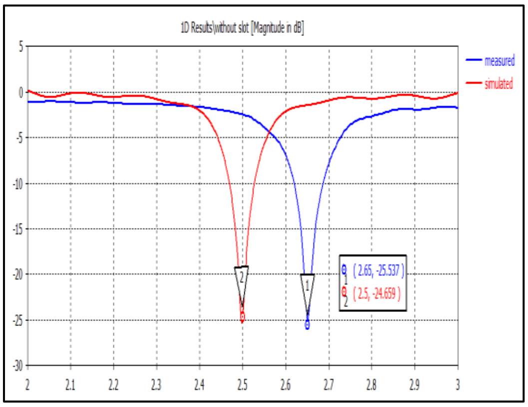
The **Table III** shows the simulated results between the bow-tie antenna with and without slot on ground plane.

TABLE III. SIMULATED RESULTS.

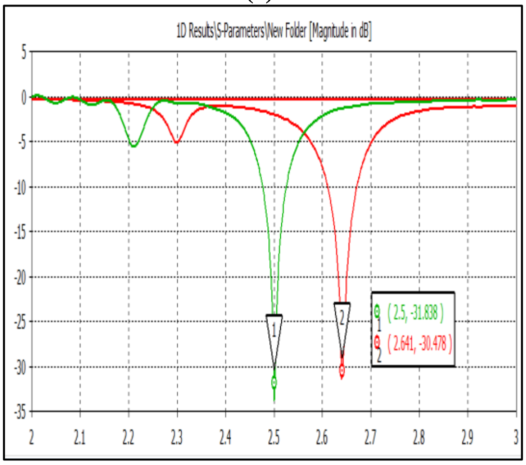
Antenna	Resonant Freq. (GHz)	Return Loss (dB)	Directivity (dBi)	Radiation Efficiency (%)
Bow-tie Patch Antenna without slot on ground plane	2.5	-24.659	6.94	53.74
Bow-tie Patch Antenna with slot on ground plane	2.5	-31.833	6.89	54.4

B. Measured Results

Both fabricated antennas were measured using VNA and tested in the anechoic chamber. **Figure 8** shows the graph of return loss against frequency for simulated and measured results of patch antenna. **Figure 9** shows the simulated and measured radiation pattern for Patch Antenna. **Table IV** and **Table V** show the comparisons between simulated and measured bow-tie patch antenna without and with U-slots on ground plane.



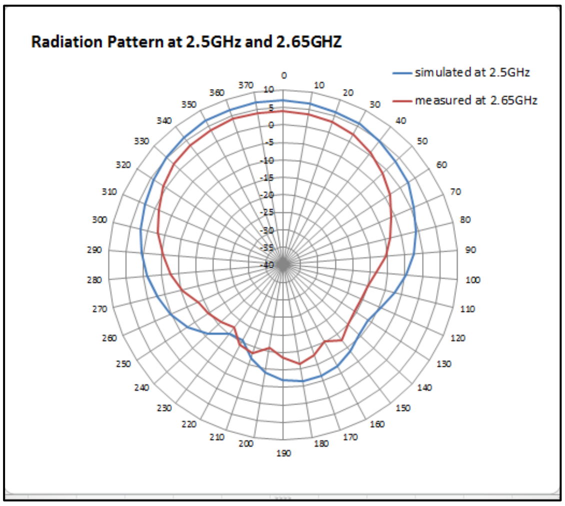
(a)



(b)

Figure 8. Simulated and Measured Return Loss of (a)Bow-tie Patch antenna without slots on ground plane while (b) Bow-tie Patch antenna with u-slot on ground plane.

The return loss for Antenna without slots on ground plane is increased from -24.659 dB to -25.537 dB while for the bow-tie patch antenna with U-slots on ground plane is reduced from -31.833 dB to -30.678dB but the resonant frequency was shifted from 2.5 GHz to 2.65 GHz and 2.64GHz.



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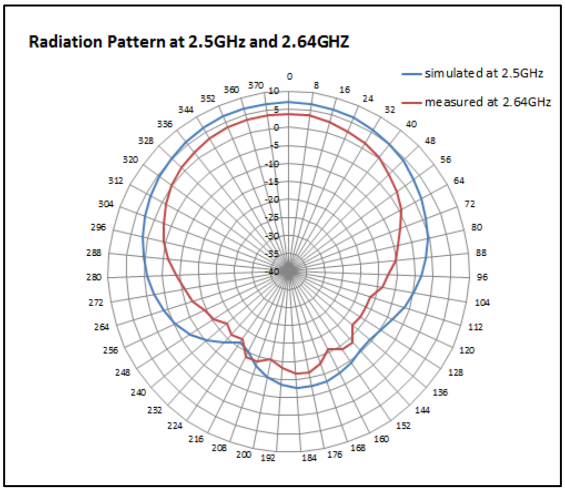

(b)

Figure 9. Simulated and measured radiation pattern at 2.5GHz ,2.65GHz and 2.64GHz(90Degree Phi) for (a)bow-tie patch antenna without U- slot on ground plane while (b) bow-tie patch antenna with U- slot on ground plane.

TABLE IV. COMPARISON BETWEEN MEASUREMENT AND SIMULATED RESULTS ANTENNA WITHOUT U- SLOT ON GROUND PLANE.

Antenna	Resonant freq. (GHz)	Return Loss (dB)	Directivity (dBi)	Radiation Efficiency (%)
Simulated	2.5	-24.659	6.94	53.74
Measured	2.65	-25.537	7.49	44.87

TABLE V. COMPARISON BETWEEN MEASUREMENT AND SIMULATED RESULTS ANTENNA WITH SLOT ON GROUND PLANE.

Antenna	Resonant freq. (GHz)	Return Loss (dB)	Directivity (dBi)	Radiation Efficiency (%)
Simulated	2.5	-31.833	6.89	54.8
Measured	2.64	-30.478	7.67	39.63

IV. CONCLUSION

In conclusion, the return loss of the bow-tie antenna with slots on ground plane is reduced but the frequency is shifted to the other frequency. Therefore, the directivity of the antenna also decreased due the slots on ground plane compared without the slot. Radiation efficiency of the antenna with slot on ground plane was increased compared to the antenna without the slots in simulated but for the measurement the radiation efficiency for the bow-tie patch antenna with U-slot on ground plane is decreased. This shows that the performance of the patch antenna becomes worse when the slots were on the ground plane. For the measurement results shows that the return loss of the antenna slightly decreased from the simulated and the radiation efficiency decreased due to the fabrication process. Something needs to do with the fabrication and the material that used for fabricate the antenna.

V. ACKNOWLEDGMENT

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