Design of Bow-tie Patch Antenna with Slot to Improve the Performance at 2.5GHz

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***Abstract* - This paper presents a design of bow-tie antenna with a rectangular-shape slot on the patch for wireless application. The investigation was carried out with two different design that is a conventional bow-tie antenna and bow-tie antenna with slot on the patch. It was designed to operate with FR-4 substrate (h=1.6mm), with a dielectric constant (ε_r= 4.3) operating at frequency of 2.5GHz. The antennas were simulated using CST Microwave Studio. The antenna was fabricated and measured using Vector Network Analyser (VNA) and tested in anechoic chamber to get the radiation pattern. The results shows an increase in performance of the antenna after slot was added. From result measured, the value of return loss increased from -38.23dB to -40.46dB, the frequency shifted to 2.651GHz with bandwidth remains almost invariant after slot was added.**

Keywords- bow-tie antennas, slot antenna, Rectangular slot

I. INTRODUCTION

In recent wireless communication technologies, microstrip antennas have been widely used in research and engineering applications. This is due to the characteristics of the antenna itself which is light in weight, small size, low cost of manufacturing and ease fabrication and manufacturing. [1]

A bow-tie antenna is construct using bi-triangular shape of metal that is fabricated on a single substrate. It is a type of bi-conical antenna. A bi-conical antenna is attractive because it offer a large bandwidth, a wideband property and compact in size compared to rectangular patch.[2] Based on theory, slotted bow-tie antenna gives more bandwidth. Bow-tie antenna is used extensively in many types of applications such as ground penetrating radar and mobile application. [3]

There are many ways to increase the performance of bow-tie antenna such as EBG structure, slots on ground of the antenna and make a rounded edge at the end arm. [4] The rounded bow-tie antenna is easy to build and it is robust, but it produce lower bandwidth compared to the conventional bow-tie antenna.[5] In this design, a rectangular slot is introduced in order to increase the performance of the antenna. There is two different pattern of bow-tie antenna proposed to compare the performance after adding slot on the patch. Based on some research paper, the effects of adding a suitable slot dimension on the radiating patch includes the improvement in bandwidth.[6] The designed and analysed geometry in this paper is shown in figure below. The design without slot as a conventional structure were used as a reference antenna. Slot was added to achieve a higher performance antenna with smaller radiating patch area.[7] The parameter that is considered is the value of return loss (S_{11}) low than -10dB, VSWR low than 1.5, bandwidth, and gain of the antenna. The performance is compared before and after adding the slot on patch for both design of antenna.

II. METHODOLOGY

The major step in designing the bow-tie antenna is to determine the dimension for substrate and patch of the bow-tie. The dimension for width (W_p) and length (L_p) for patch of bow-tie is determine based on the formulations described for rectangular patch as in (1), (2), (3) and (4)

$$Width\ patch, W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$Length\ patch, L_p = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (2)$$

Where C is the speed of light in free space.

Effective dielectric constant,

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

Length extension due fringing field ,

$$\Delta L = 0.412\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad (4)$$

By using the above formulas mentioned above, design and geometry of the conventional bow-tie without slots is as shown in Figure (1). This antenna were used as a reference to compare the performance after slot were added on the patch.

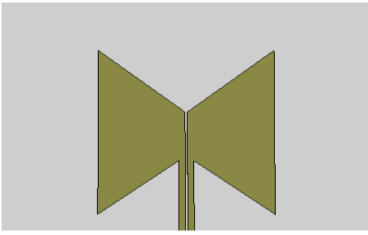

Figure 1 : Simulation design of conventional bow-tie

TABLE 1 : CALCULATED DIMENSION OF CONVENTIONAL BOW-TIE ANTENNA

Parameters	**Dimension of Bow-tie (mm)**
Length of substrate, L	45
Width of substrate, W	36
Bowtie arm length, L_p	28
Bowtie arm width, W_p	18
Length of feedline, L_s	3.137
Width of feedline, W_s	10

Table.1 show the dimension of conventional design of bow-tie antenna that based on the calculation. By using the above dimension, the resonant frequency at 2.5GHz was not obtained. Thus, the dimension of patch and substrate of the antenna was altered to shift the frequency to selected frequency. Table.2 show the different in calculated and simulated dimension of the antenna.

TABLE 2 : CALCULATED AND SIMULATED DIMENSION OF CONVENTIONAL BOW-TIE ANTENNA

Parameters	**Calculated Antenna (mm)**	**Simulated Antenna(mm)**
Length of substrate, L	45	64
Width of substrate, W	36	52
Bowtie arm length, L_p	28	15
Bowtie arm width, W_p	18	37
Length of feedline, L_s	3.137	1.1
Width of feedline, W_s	10	16

Fig.2 show the simulation design of the antenna with rectangular-shape slot and Fig.3 shows the fabricated design of bow-tie antenna after slot is added. The length of slot added is 10mm with width of 1mm. The length and width of the slot was varied to get the antenna operate at 2.5GHz. From observation, increase of length and width of slot would decrease the resonant frequency value of return loss.

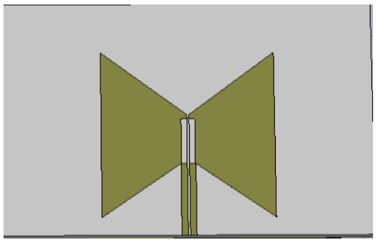

Figure 2 : Simulation design of slotted bow-tie

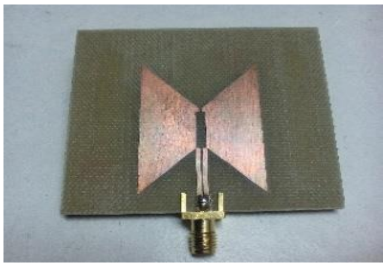

Figure 3 : Fabricated design of slotted bow-tie

To prove that with adding a slot on the patch of the bow-tie antenna would increase the performance of the antenna, a different design of bow tie antenna was designed. Fig.4 show the simulated design of bow-tie 2 without slot and Fig.5 show the simulated design of bow-tie 2 with slot. The dimension of slot added was the same as in the first antenna.

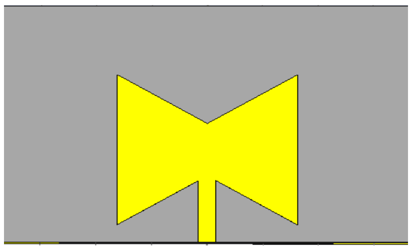

Figure 4 : Simulated Design of Bow-tie 2 without slot

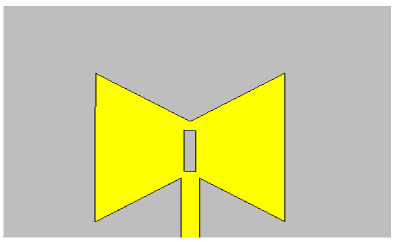

Figure 5 : Simulated Design of Bow-tie 2 with slot.

TABLE 3 : CALCULATED AND SIMULATED DIMENSION OF L BOW-TIE 2

Parameters	Calculated Antenna (mm)	Simulated Antenna(mm)
Length of substrate, L	50.5	24.34
Width of substrate, W	38.5	16.25
Bowtie arm length, L_p	27.3	56.83
Bowtie arm width, W_p	20	73.72
Length of feedline, L_s	3.137	3.137
Width of feedline, W_s	15	10

Table 3 show the calculated and simulated dimension of the second antenna design. Based on the simulated result in CST Microwave Studio, the first antenna gives better result and performance, thus it was selected to be fabricate. The fabricated antenna was then measured using Vector Network Analyser (VNA) to get the value of return loss. Lastly, to get the radiation pattern, directivity and to determine the effectiveness of the antenna, test in anechoic chamber was done.

III. RESULTS AND DISCUSSION

The proposed design is simulated using CST Microwave Studio and tested using Vector Network Analyser(VNA). To get the radiation pattern, the antenna was tested in anechoic chamber. The results from simulation and measurement of the antenna has slightly different which is might be caused by measurement error during handling the measurement process. The parameters of the antenna calculated is different from the parameters after it was optimized during simulation. This is due to the shifting frequency from the selected frequency. Thus, the parameters was adjusted in order to get the antenna to operate at the frequency selected.

A. Simulated Results

i) Return Loss

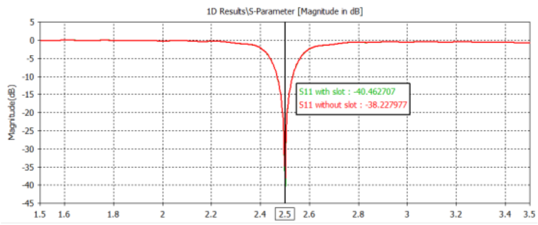

Figure 6 : Return Loss for Bow-tie 1 with and without slot

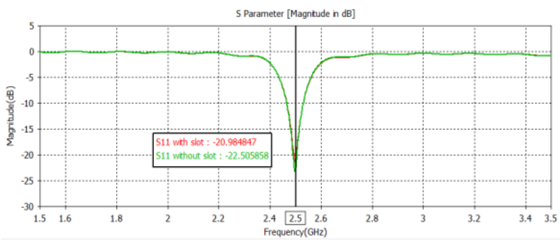

Figure 7 : Return Loss for Bow-tie 2 with and without slot

Figure 6 shows the result of return loss for Bow-tie 1 after slot was added. The value of return loss was increased from -38.227977dB to -40.462707dB. While for Bow-tie 2, the value of return loss after slot was added decreased from -22.505858dB to -20.984847dB. Even the value is decreased, in considering that it is below than -20dB, thus the signal is strong enough to be received at the receiver.

ii) Directivity

TABLE 4: DIRECTIVITY OF ANTENNA WITH AND WITHOUT SLOT

Antenna	Directivity(dBi)	
	Without Slot	With Slot
Bowtie 1	7.150	7.219
Bowtie 2	6.950	6.960

Based on the Table 4, the directivity of both antenna increased when slot was added on the patch. Thus, the performance to transmit signal of the antenna will also increase.

iii) Radiation Pattern

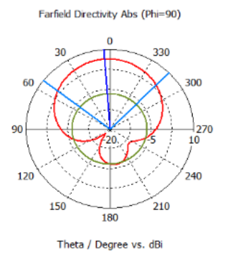

Figure 8 : Simulated Radiation Pattern of Bow-tie 1

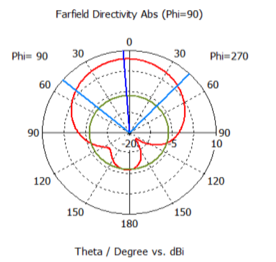

Figure 9 : Simulated Radiation Pattern of Bow-tie 2

Figure 8 and Figure 9 show the simulated radiation pattern for both antenna. The radiation efficiency of Bow-tie 1 increased from 50.29% to 50.42% when slot was added while for Bow-tie 2 the radiation efficiency was invariant when slot was added that is 49.12%.

B) Measured Results

i) Return Loss

The return loss was measured using Vector Network Analyser (VNA). Based on Fig.10 and Fig.11, the frequency that was simulated at 2.5GHz was shifted to higher frequency that is 2.651GHz. The value return loss decreased to -26.746dB from -40.292 dB.

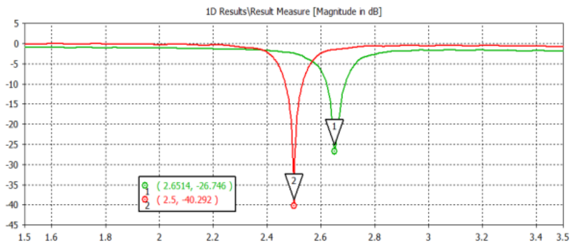

Figure 10 : Return Loss of simulated and measured for slotted Bow-tie 1

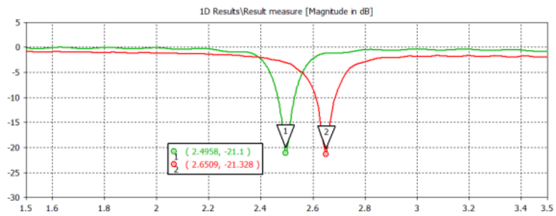

Figure 11 : Return Loss of simulated and measured for slotted Bow-tie 2

ii) Directivity

Bow-tie 1 was tested in anechoic chamber to check the radiation directivity and radiation pattern after slot was added.

TABLE 5 : COMPARISON DIRECTIVITY OF SIMULATED SLOTTED BOW TIE AND MEASURED

Directivity(dBi)	
Simulated	**Measured**
7.219	6.415

Table 5 show the measured directivity in anechoic chamber was a bit lower compared to simulate. Directivity of the antenna with and without slot was compared in simulation process, the directivity after slot was added is higher than conventional bow-tie.

TABLE 6 : COMPARISON BETWEEN SIMULATED AND MEASURED RESULTS

Antenna	Return Loss (dB)	Directivity (dBi)	Radiation Efficiency(%)
Simulated	-40.46	7.219	50
Measured	-26.75	6.415	42.66

Table 6 summarized the comparison of simulated and measured results of the antenna after slot was added. The efficiency of the antenna decreased to 42.66% after tested in anechoic chamber compared to the efficiency simulated that is 50%.

iii) Radiation Pattern

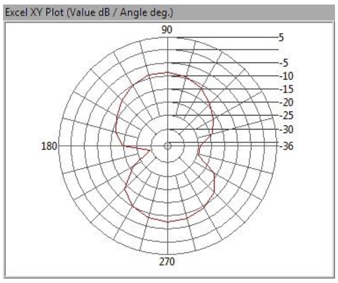

Figure 10 : Measured radiation pattern at 2.651GHz

Radiation pattern was measured in anechoic chamber at phi=90°. The radiation pattern was measured at 2.651GHz because the antenna resonated at the frequency when tested using VNA. The pattern measured was likely the same as pattern simulated in CST.

IV. CONCLUSION

In conclusion, by adding slots on the patch of the bow-tie antenna have increased the performance of the antenna. For both antenna design, the performance of antenna was increased. The bandwidth of both antenna remain invariant. The value of return loss, directivity, VSWR, and gain was increased. Thus, in overall the efficiency of the antenna to operate at the frequency selected was also increased. The measured results was slightly lower from the simulated results, this is due to several reason such as the material of the substrate, loss during fabrication and error in handling the measurement.

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