Study of Vivaldi Antenna

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Abstract— **A method to study the effect of a different size of opening width and length of the slot flare Vivaldi antenna on the VSWR and S_{11}. The six different sizes of opening width and length were used to choose the best result that fulfills the specification of Vivaldi antenna. The Vivaldi antenna is implemented by using FR4 which have dielectric constant 4.7 and thickness of 0.8mm. The antenna should be able to operate at the frequency between 8 to 9 GHz and the required value of VSWR and S_{11} are 2.0 and -10dB at frequency of 8.5 GHz.**

Keywords-component; vivaldi antenna; tapered slot antenna(TSA); ultrawideband(UWB) antenna

I. Introduction

Since more than two decades, Vivaldi antenna are widely used in many research and technological fields, ranging from commercial communication to radio astronomy[1, 2]. The Vivaldi antenna is one of the classical ultra wideband antennas with many applications. The Vivaldi antenna is a travelling-wave, leaky and end-fire antenna. Theoretically, the Vivaldi antenna has an unlimited range of operating frequencies with constant beamwidth over the entire bandwidth[3]. In UWB communications, in addition to achieving a good return loss and radiation efficiency, the ultra wideband antenna should be non-dispersive o dispersive in an acceptable range. On the other hand, for narrowband systems the traditional parameters are enough to assess the performance of the antenna but in the ultra wideband applications these parameters are inadequate for the applicability of the antenna. But practically, the operating bandwidth is limited by the transition from the feeding transmission line to the slot line of the antenna and by the finite dimensions of the antenna. The constancy of the beamwidth against frequency depends on the correct design of the antenna. The exponential tapered slot antenna was proposed by Gibson in 1979[4]. The flare radiates at different points along its length for different frequencies, determined by the flare width. The conventional flare design has theoretical unlimited bandwidth. The width at the start of the flare defines the upper frequency and the width at the mouth of the flare defines the lower frequency. From the time-domain point of view, the principle of radiation through the tapered slot is lacking any resonant parts, which results in very low distortion of radiated pulses. This aspect, together with large bandwidth of the antenna, makes Vivaldi very good UWB radiator in cases when directional antenna is desired.

A. *Objective of project*

The objective of this paper is to successfully design the Vivaldi antenna with suitable opening width and length at optimum frequency 8.5 GHz. The antenna design is able to operate between the frequency ranges 8 to 9 GHz which is suitable for radar application.

B. *Scope of study*

The scope of this project is to design, fabricate and measure a Vivaldi antenna which can be used for radar application. That requires operating frequency band ranging from 8 to 9 GHz. By varying the sizes of opening width and opening length, it is to find the best performance of the propose antenna in terms of return loss, VSWR and radiation patterns. The antenna should be small and easy to manufacture with available laboratory equipment. The return loss should be less than -10 dB and the voltage standing wave ratio should be less than 2.

C. *Basic tapered slot profile*

Many taper profiles exist for a normal tapered slot antenna (TSA). The first TSA appeared in 1979 when Prasad and Mahapatra introduced the linear tapered slot antenna (LTSA)[5]. Planar tapered slot antennas have two common features. The radiating slot act as the ground plane for the antenna and the antenna is fed by a balanced slotline. However, drawbacks for a planar TSA come in the form of using a low dielectric constant substrate and obtaining an impedance match for the slotline. The example of basic tapered profile are exponential, tangential, parabolic, linear, linear constant, step-constant and broken linear. The basic tapered profile that used in this paper is in Figure 1.

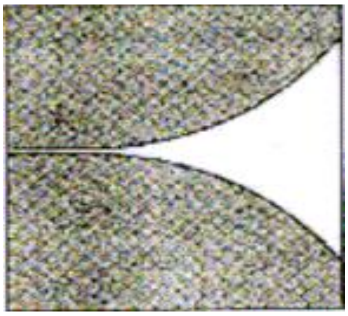
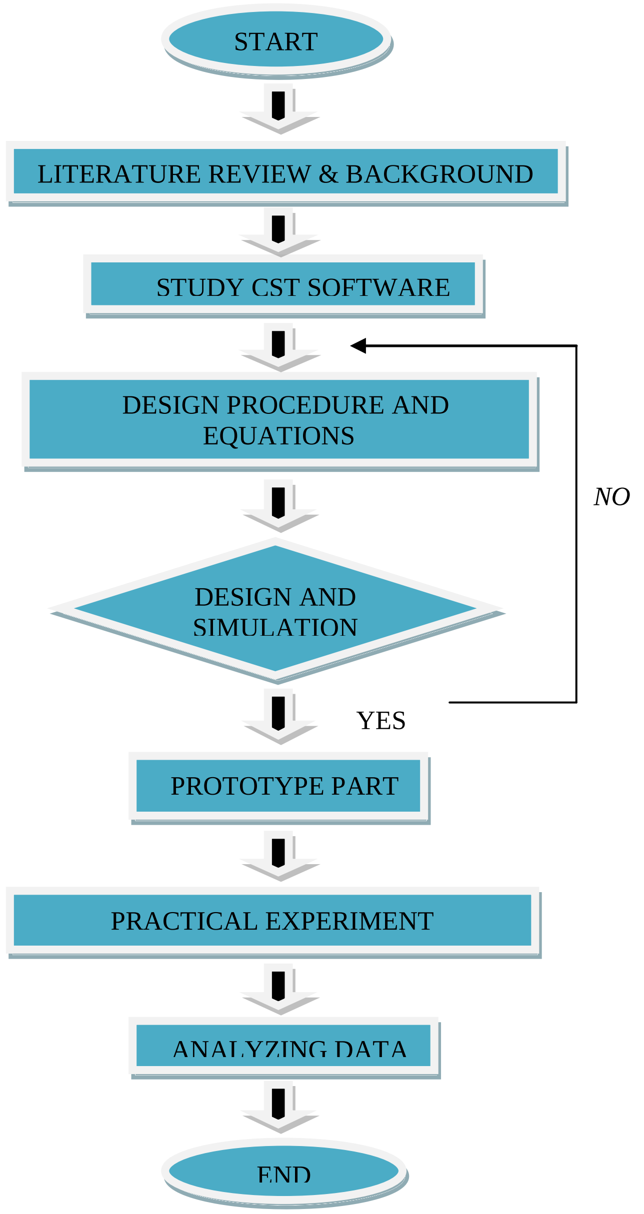


Figure 1: Exponential

II. METHODOLOGY

The objective of this project can be achieved by implementing the work flow shown below



A. *Vivaldi Exponential Flare*

The antenna indicates the exponential taper profile which is defined by opening rate, *r* and two points $P_1(x_1, y1)$ and $P_2(x_2, y2)$

$$y = C_1 e^{rx} + C_2$$

$$C_1 = \frac{x_2 - x_1}{e^{ry_2} - e^{ry_1}}$$

$$C_2 = \frac{x_1 e^{ry_2} - x_2 e^{ry_1}}{e^{ry_2} - e^{ry_1}}$$

After some calculation and simulation, the most suitable value of exponential flare, *r* was 0.08.

B. *Used substrate*

All six types of antenna were designed with regards to the substrate available for production. In this design, FR4 substrate with parameters described in the Table 1 was chosen.

Table 1

Parameter	Symbol	Value
Substrate height	H	0.8mm
Dielectric constant	ε_r	4.7
Dissipation factor	tgδ	0.025
Metallization thickness	t	35µm
Metallization conductivity	s	0.3 W/km

C. *Dimension of Vivaldi antenna*

In order to design the Vivaldi antenna, the suitable dimension considering their minimum and maximum of opening length and width were taken. Therefore for this purpose, six different sizes of opening length and width were developed.

In theory, the maximum size opening width is:

$$\lambda_g = \frac{c}{f_{min}\sqrt{\varepsilon_r}}$$

where,

c = Speed of light

f_{min} = Frequency minimum

ε_r = Dielectric constant

So,

$$W_{max} = \frac{\lambda_g}{2}$$

Then, the minimum size of opening width is:

$$W_{min} = \frac{c}{f\sqrt{\varepsilon_r}}$$

where,

f = Center frequency

From the calculation using above equation, the minimum and maximum of opening width is between 16.28 mm and 38.44 mm. The dimension for each size of antenna was described in the Table 2

Table 2

Type	Opening length	Opening width
Type 1	30	25
Type 2	35	25
Type 3	30	30
Type 4	35	30
Type 5	30	35
Type 6	35	35

D. *Prototype stage*

After the simulation is done, the fabrication for design type 6 was done to produce the prototype. The fabrication processes consist of laminator thermal transfer process, etching process and soldering. The actual antenna in Figure 2 was measured for its return loss and VSWR.

Figure 2

III. RESULT AND DISCUSSION

A. *Simulation result*

Return loss

Return loss S_{11} refers to the ratio of power reflected back from the transmission line to the power transmitted to the transmission line. The value of the return loss described the reduction in amplitude for the reversed energy as compared to forward energy.

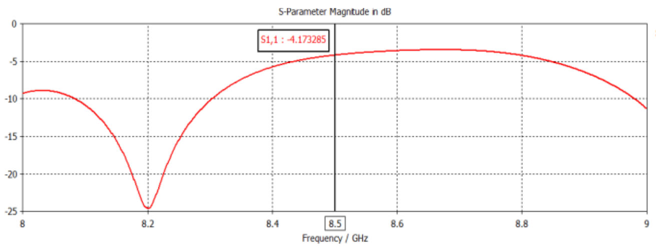


Figure 3: Simulation result for type 1

Figure 3 shows the simulation result of return loss for type 1. The value of return loss at frequency 8.5 GHz is -4.173 dB.

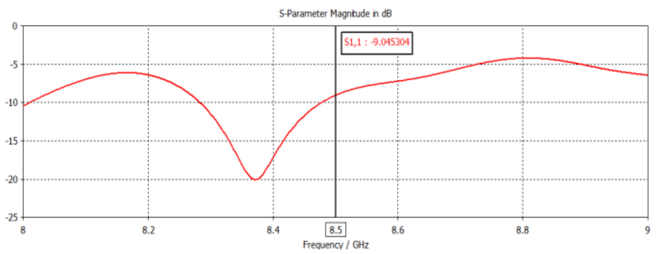


Figure 4: Simulation result for type 2

Figure 4.1B shows the simulation result of return loss for type 2. The value of return loss at frequency 8.5 GHz is -9.045 dB.

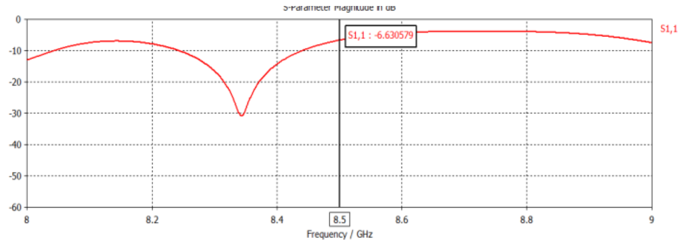


Figure 5: Simulation result for type 3

Figure 4.1C shows the simulation result of return loss for type 3. The value of return loss at frequency 8.5 GHz is -6.631 dB.

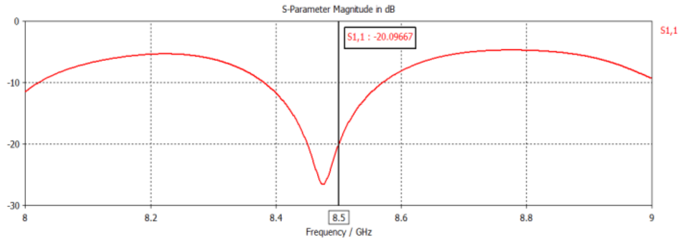


Figure 6: Simulation result for type 4

Figure 4.1D shows the simulation result of return loss for type 4. The value of return loss at frequency 8.5 GHz is -20.097 dB.

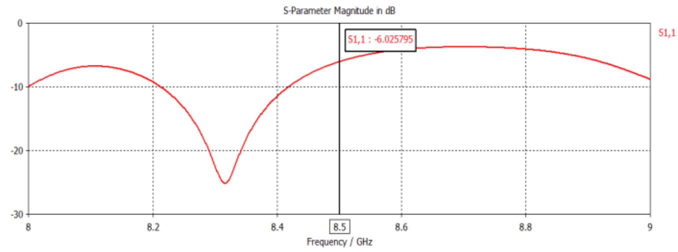


Figure 7: Simulation result for type 5

Figure 4.1E shows the simulation result of return loss for type 5. The value of return loss at frequency 8.5 GHz is -6.026 dB.

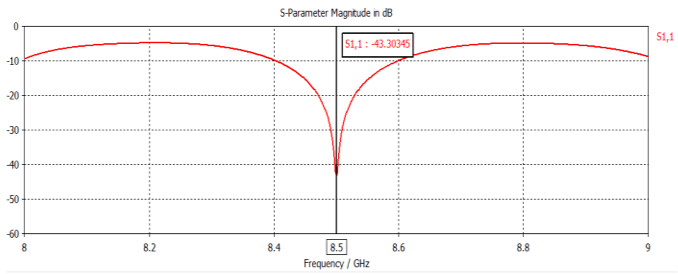


Figure 8: Simulation result for type 6

Figure 4.1F shows the simulation result of return loss for type 6. The value of return loss at frequency 8.5 GHz is -43.303 dB. From all the six types of opening width and length, this simulation result which is type 6 give the highest reduction in amplitude for the reversed energy and also the lowest ratio of power reflected back from the transmission line to the power transmitted to the transmission line.

VSWR

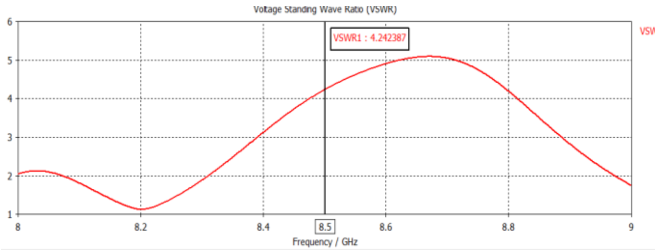


Figure 9: Simulation result for type 1

Figure 4.2A shows the simulation result of VSWR for type 1. The value of VSWR at frequency 8.5 GHz is 4.242.

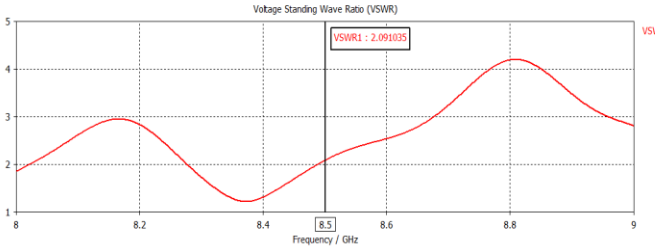


Figure 10: Simulation result for type 2

Figure 4.2B shows the simulation result of VSWR for type 2. The value of VSWR at frequency 8.5 GHz is 2.091.

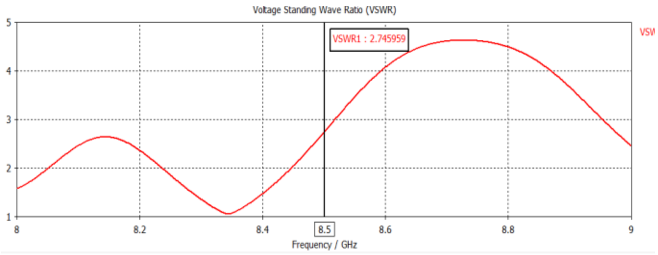


Figure 11: Simulation result for type 3

Figure 4.2C shows the simulation result of VSWR for type 3. The value of VSWR at frequency 8.5 GHz is 2.746.

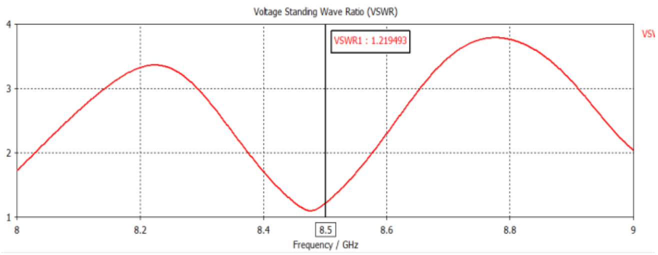


Figure 12: Simulation result for type 4

Figure 4.2D shows the simulation result of VSWR for type 4. The value of VSWR at frequency 8.5 GHz is 1.219.

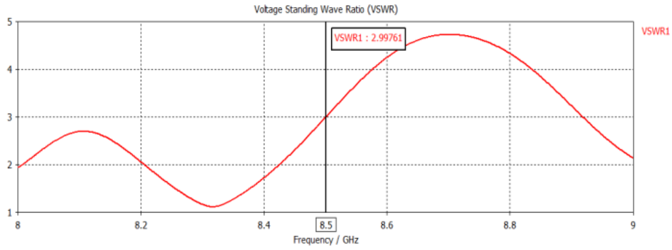


Figure 13: Simulation result for type 5

Figure 4.2E shows the simulation result of VSWR for type 5. The value of VSWR at frequency 8.5 GHz is 2.998.

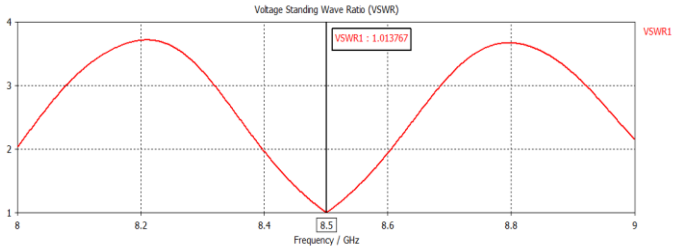


Figure 14: Simulation result for type 6

Figure 4.2F shows the simulation result of VSWR for type 6. The value of VSWR at frequency 8.5 GHz is 1.014. The result of VSWR for type 6 also gives the best result compared to the other sizes of opening width and length.

B. Measurement result

Return loss and VSWR of fabricated type 6 antenna.

Return loss

Figure 15: Return loss of type 6

VSWR

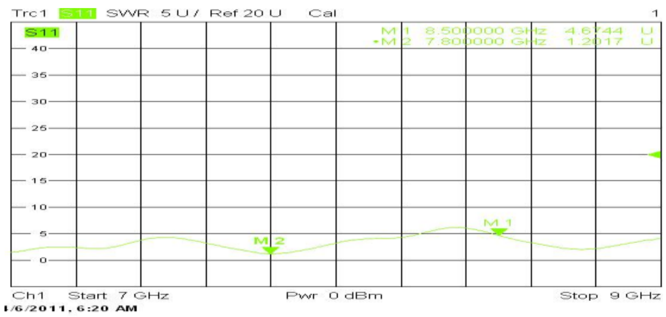


Figure 16: VSWR of type 6

C. Discussion

From the observation of the simulation result, the best output comes from type 6 which have opening length of 35 mm and opening width of 35 mm. Type 6 gives the value of S_{11} of -43.3 dB and VSWR of 1.01 at frequency 8.5 GHz. This result is the best compared to the other types of dimension. So, only type 6 was fabricated due to its best result. But from the measurement result of type 6, the values of S_{11} and VSWR at frequency 8.5 GHz are not as expected. From Figure 15, the value of S_{11} is only -3.8 dB at 8.5 GHz which is too far from the value of simulation result. But the value of S_{11} at frequency 7.8 GHz is -21.159 dB. Refer to the Figure 16, the value of VSWR at frequency 8.5 GHz is 4.6744 which is not below than 2. But at frequency 7.8 GHz, the value of VSWR is 1.2017. It shows that all the values that were taken are shifted from 8.5 GHz to 7.8 GHz. This could be happen because of error in fabrication. The dimension of fabricated antenna is slightly different compared to dimension of antenna in simulation. Furthermore, the substrate itself may not really suitable for application of higher than 10 GHz. The FR4 is not really stable and could suffer more losses at higher frequency. So, as the frequency increases to 10 GHz, the signal become unstable and could shift to the lower frequency.

IV. CONCLUSION

From this paper, it shows that the design of the opening length and width affects the characteristic of antenna. The different type of opening length and width give the different result for S_{11} and VSWR. It shows that a lot of research about the dimension of antenna should be done in order to design a good Vivaldi antenna. From the six types of antenna design, type 6 antenna gives the better result compared to the other types and it follows the antenna specification.

Recommendation

There are a lot of improvements could be done to the so that better S_{11} and VSWR could be obtained.

- The feed mechanism should be analyzed more thoroughly. Particularly, by fabricating and testing the transition, it could be found out as to why the single transition behaves worse than the double transition.
- The better substrate use in designing the antenna. The choice of dielectric constant plays an important role in the design and simulation because it can provide better efficiency and a wider bandwidth.
- The array configuration can avoid too much reflection from the antenna and the antenna from becomes unstable.
- Some development could be done in fabrication process because some human errors could cause the bad impact to measured result.

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