Designing Vivaldi Antenna using FR4 substrate

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Abstract—**Vivaldi antenna is a kind of UWB antenna with high gain at microwave frequency. This paper starts from a simple tapered slot antenna designs and analysis to a modification with a rounded corners antenna. The measurements show that the antenna has return loss lower than -10dB and VSWR less than 2. The antenna is operates at frequency between 8.5 to 9.5GHz. Vivaldi antenna is widely used for military and radar communication application.**

Keywords-component; Tapered Slot Antenna (TSA); Vector Network Analyzer (VNA); Ultra-Wideband (UWB)

I. INTRODUCTION

The usage of Ultra-Wideband (UWB) wireless communications systems get more and more extensive parallel to the development of communication technologies. That is why requirement of ultra-wideband antenna are brought forward[1]. UWB can be defined as pulse communications that use a broadcast bandwidth which operates between 3.1 and 10.6GHz[2]. If the UWB antenna was designed for mobile communication application, then it must have planar structure, light weight and omni-directional radiation pattern[3]. The first Vivaldi antenna was first introduced by P.J.Gibson in a paper entitled 'The Vivaldi Aerial' in European Microwave Conference, 1979[4]. He introduced the antenna as an amalgamation of slot and travelling wave antenna. Vivaldi antenna is a kind of slot-line UWB antenna, which is a slot with smoothly transition from narrow end to another wide end[5]. This antenna characteristics basically are high gain, simple structure, relatively wide band and easy for fabrication. Vivaldi antenna can be applied for UWB application such as satellite communication, earth-detection radar, em measurement and also military. In this paper, it will discuss about radar communication application which the frequency band is between 8 to 12GHz.

Basically, there were three types of Vivaldi antenna; (1) Tapered slot Vivaldi Antenna (2) Antipodal Vivaldi Antenna (3) Balanced Antipodal Vivaldi Antenna. Tapered slot antenna is a one-layer structure with small dimension. It has sufficient return loss and can operate for wider bandwidth. However, antipodal Vivaldi antenna is a two-layer structure. It has minimum distortion but opposite to previous type because it has larger dimension. Balanced antipodal Vivaldi antenna then is a three-layer structure which can reduce cross-polarization of antipodal structure[6]. Since tapered slot antenna (TSA) was the simplest structure, so it had been chosen for this project. It was designed and the result was analyzed. Because of its simple structure, there is a low cost for fabrication.

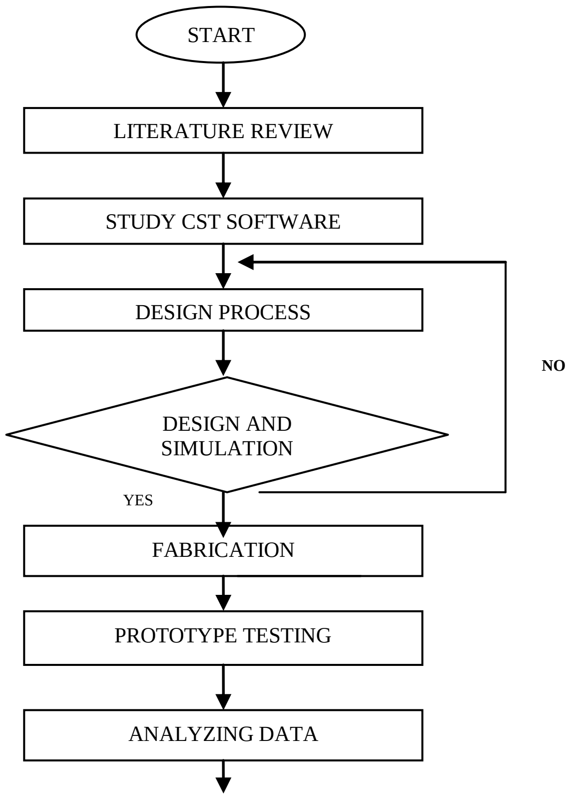
Objective

The objective of this project is to make a comparison between the simple tapered slot Vivaldi antenna with round corners Vivaldi antenna. The antenna operates at frequency between 8.5 to 9.5GHz which is the range of radar communication applications.

Scope of Study

The scope of this project is to design, fabricate and testing Vivaldi antenna which was designed for radar applications. Frequency range of radar applications was between 8 to 12GHz. The antenna was designed to have return loss less than -10dB and VSWR less than 2.

II. METHODOLOGY



III. ANTENNA DESIGN

The design and parameter of Vivaldi antenna are shown in Figure 1 and 2 respectively. The manufactured TSA was fabricated on FR4 substrate with relative dielectric constant of 4.7, thickness of 0.8mm, loss tangent of 0.014 and copper thickness of 0.035mm. Generally, the performance of TSA is sensitive to thickness and dielectric constant of the antenna substrate. The antenna indicates the exponential taper profile which is defined by opening rate *R* and two points $P_1\ (x_1, y_1)$ and $P_2\ (x_2, y_2)$

$$y = c_1 e^{Rx} + c_2 \qquad (1)$$

Where

$$c_1 = \frac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}}, \qquad c_2 = \frac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}} \qquad (2)$$

Both points will determine the value of constant c_1 and c_2. Coordinate of start point (x_1, y_1) is (2.5, 55) and coordinate of end point is (x_2, y_2) is (19.5, 20). In this design, the opening rate, *R* is 0.08. The antenna had been designed to match at 50Ω. Since the antenna is a directional antenna, so, the ground plane will cover up all dimensions. The antenna has the dimension of width = 52mm, length = 51.9 mm, opening width = 35mm and opening length = 35mm. The ratio of the opening width to the opening length must be between 1 and 1.5. For this design the ratio is 1.

After all the parameter of the antenna had been identified, the design was simulated in CST Microwave Studio® (CST MWS) to get good performance at the operating frequency. The best antenna design was then modified to a round corner TSA while all the other parameters were kept constant. The antenna was simulated again and both results were compared.

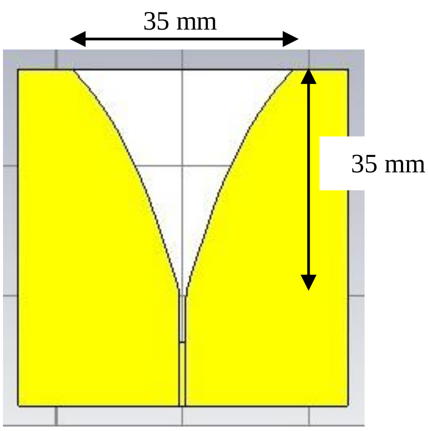


Figure 1.The design of tapered slot Vivaldi antenna

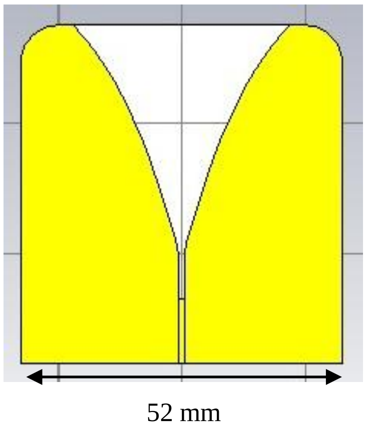


Figure 2.The design of round corners Vivaldi antenna

IV. RESULT

A. Return Loss(S_{11})

Return loss can be defined as a ratio of the power reflected back from the line to the power transmitted into the line. At first, the simple tapered slot Vivaldi antenna was simulated using CST MWS. The simulation result shows that the antenna has a good return loss which is -33.765dB at the center frequency of 9GHz. Then the result is compared with the round corners Vivaldi antenna. It shows that the value of the return loss had decreased to -24.054dB. The minimum value of the return loss also had shifted to 9.13GHz. Both simulation results are represents in Figure 3(a) and (b) respectively.

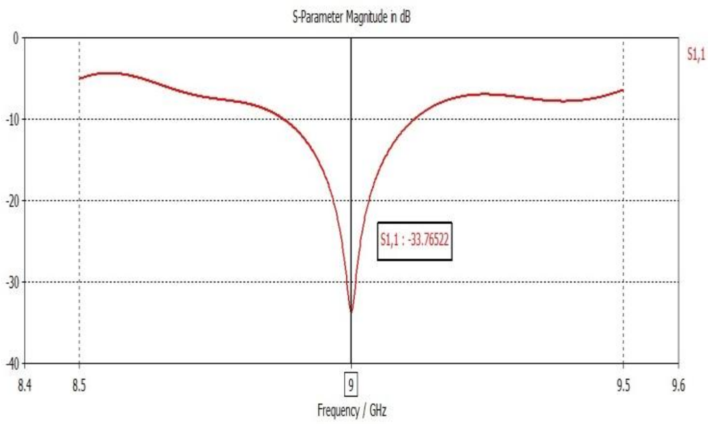


Figure 3(a).Simulation result of simple tapered slot Vivaldi antenna

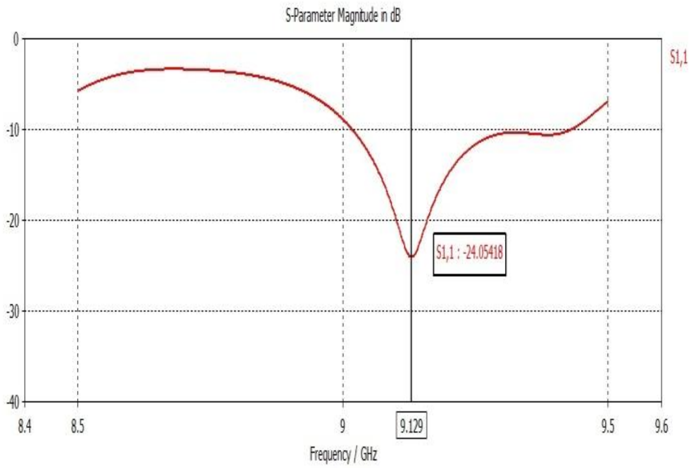


Figure 3(b).Simulation result of round corners Vivaldi antenna

Based on the result of return loss above, we could see that the simple Vivaldi antenna perform better compared to the round corners Vivaldi antenna. This is because simple Vivaldi antenna has a more negative value of the return loss and could lie exactly at 9 GHz.

For the round corners Vivaldi antenna, it could be seen that more losses had occurred at the higher frequency of operation. That is why the value of the return loss had been decreased.

B. Voltage Standing Wave Ratio (VSWR)

In a transmission line, voltage standing wave ratio (VSWR) can be defined as the ratio of maximum voltage to the minimum voltage. For simple Vivaldi antenna, value of VSWR is 1.042. However, for round corners Vivaldi antenna, value of VSWR had increased to 1.134. Both result are represents in Figure 4(a) and (b) respectively.

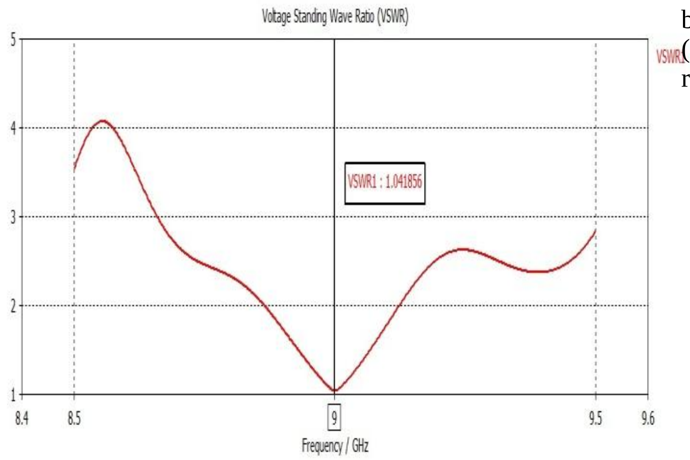


Figure 4(a).Simulation of VSWR of tapered slot Vivaldi antenna

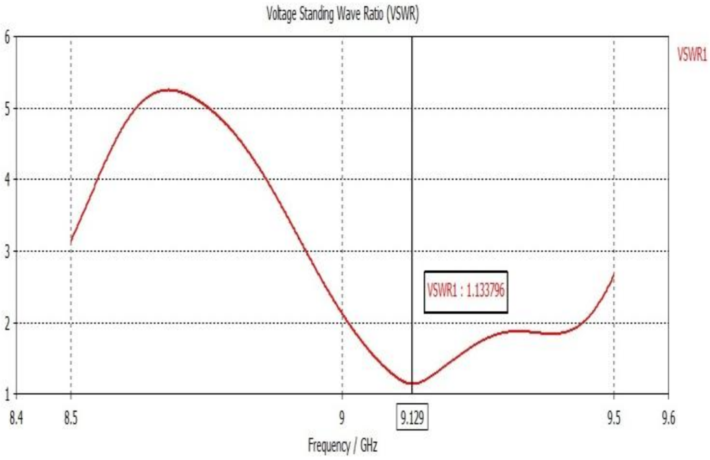


Figure 4(b).Simulation of VSWR of round corners Vivaldi antenna

Based on the result obtained, it could be seen that again simple Vivaldi antenna perform better compared to the round corners. This is because simple Vivaldi antenna has a lower value of VSWR. Basically, the value of VSWR is used as an indication on how good the impedance match is. So, the lower value is better since the impedance is perfectly matching. However, it is rarely to see the perfectly match of impedance which the value of VSWR equal to 1. In more cases, the range of 1.2 is considered perfect.

C. Radiation pattern

Radiation pattern can be defined as a graphical description of the relative field strength transmitted or received by the antenna.

CST Microwave Studio software has an advantage which the radiation pattern can be view both in 2D and 3D. 2D basically easier to understand compared to 3D view. Figure 5 (a) and (b) represent the 3D radiation pattern of both antennas respectively.

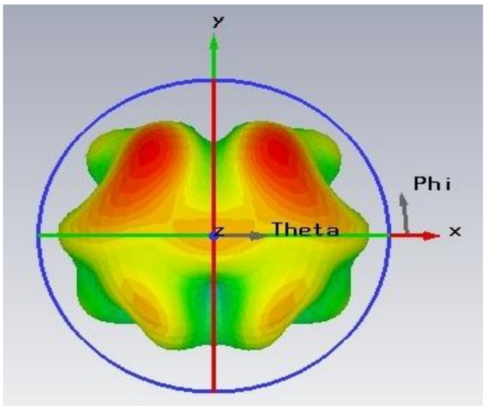


Figure 5(a). 3D radiation pattern of simple Vivaldi antenna

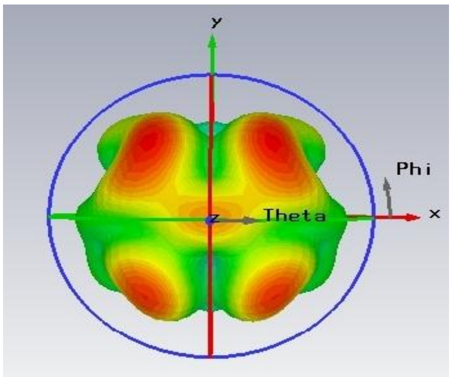


Figure 5(b).3D radiation pattern of round corners Vivaldi antenna

3D radiation pattern can be used to determine directivity of the antenna. The color contour is used to determine the signal strength that radiated from the antenna. Red color represents the strongest directivity direction of the signal. For simple Vivaldi antenna, directivity is 6.117dBi while for round corners Vivaldi antenna, directivity is 6.37 dBi. Comparison between both of them shows that round corners has a better directivity.

From all the results above, we could see that the design of simple Vivaldi antenna is better than the round corners of Vivaldi antenna. This is because, regarding to the specifications it shows that simple Vivaldi antenna can fulfill them. Simple Vivaldi antenna has a better return loss and VSWR. Although the directivity of round corners Vivaldi antenna is better, but it is not a focus in this project.

Basically, rounding the taper corners is a way of maintaining smooth taper profile[7]. Round corners allow the signal to travel to the outer edges of the antenna more easily[7]. However, for such improvement, the antenna dimension had been increased and the fabrication process will be more complicated.

V. CONCLUSION

UWB antenna plays an important aspect of the research of UWB. However, there is not much research about the round corners of Vivaldi antenna. In this paper, it shows the comparison between the simple tapered slot Vivaldi antenna and round corners Vivaldi antenna. From the result that had been obtained, it can be concluded that simple Vivaldi antenna is better than round corners Vivaldi antenna. This is because the simulation results of simple Vivaldi antenna shows that the antennas could fulfill the specifications needed.

Future work includes the design of round corners Vivaldi antenna with different substrate such as RT/Duroid5880. This is because RT/Duroid has a lower value of relative dielectric constant which is 2.2. Lower relative dielectric constant could provide better efficiency, wider bandwidth and has lower electrical loss.

The performance of single element of the antenna can be enhanced with the array arrangement. The more numbers of array used, the lower losses will occur.

Lastly, there is other software that can be used to simulate the designed antenna. They are Ansoft HFSS and Sonnet Software. The simulation result then could be compared in order to decide which software is more efficient.

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