An Analysis of Antipodal Vivaldi Antenna (APVA) Using Different Material Substrates at 60 GHz

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***Abstract*—The 60GHz short-range wireless communication system has gained a lot attention because it is believed to have a high rate data communications with free licensed frequency band. Thus, development of the 60 GHz antenna is a crucial issue in the system. This paper is focused on the design of antipodal vivaldi antenna (APVA) at 60GHZ for wireless communications. The antenna is designed by comparing the performance using three different types of material substrates which are Silicon, Ferro A6s and Duroid 5880. The parameters to be observed in this paper include radiation pattern, bandwidth and gain of the antenna. The performance of the antenna is simulated by using CST Microwave Studio with the ranges frequency between 50GHz to 70GHz. The changes in the performance between three different types of material substrate are discussed further in this paper. From the simulation results, the value of return loss is as the desired results, where it needs to be less than -10dB for the three different types of substrate used. Out of the three substrates, Ferro has a better antenna performance radiation pattern and wider bandwidth, which makes it suitable to be used as a 60GHz antenna for wireless communication.**

***Index Terms*—Vivaldi; Antipodal; Silicon; Ferro A6s; Duroid 5880.**

I. INTRODUCTION

Antenna is mandatory equipment for transferring the information and data in wireless communications. For modern wireless communications, it is required to be in small in size, low weight, directivity pattern and the most important is wide bandwidth [1]. Nowadays, 2.4GHz and 5GHz, also known as Wi-Fi, is rapidly starting to run out of spectrum because of the traffic or the number of users who connected to it. The congestion issue occurred because mostly a single person will have one or more devices that are connected to the internet. Even, IEEE expected that by the year of 2018, there will be more than 10 Exabytes of traffic, which means it almost exceeds the bandwidth of the current antenna for wireless communications [2]. Furthermore, there is also the mutual interference problem in the ultra-wide band where the 2.4 GHz frequency is overlaid with the 5GHz frequency [3]. Thus, people nowadays are demanding for better and higher data rate for wireless communications.

Thus, the implementation of a 60GHz antenna for better wireless communication is required because the 60GHz antenna can work better where it has a higher data rates. It can deliver unprecedented data rates from 7Gbps up to 28Gbps. With higher data rates, it allows uncompressed HD media transfer and allows the instantaneous access to massive libraries of information. Significantly, it is expected to replace books, paper media and also computer hard drive. Furthermore, with the very small size of the antenna, it is easy to use it as an on-chip solution especially in the smartphones and other small electronic appliances [4][5].

The purpose of this project is to design an Antipodal Vivaldi antenna for wireless communication at 60GHz. The designs are focusing on the directional antenna. The result of the antenna will focus on the simulation of the radiation pattern, bandwidth and gain of the antenna. The project design is simulated and tested by using CST Studio Suite software.

The substrate is the base layer or other surface upon which something is deposited, etched, attached or fabricated. A substrate provides physical support and insulation such as the base film of magnetic tape or the plastic base of a compact disc. The right substrate materials are very important in giving the best antenna performance in simulation as well as in the fabrication. There are some factors that need to be considering when choosing the substrate such as the dielectric constant, the loss tangent of the dielectric, Resistivity, coefficient, cost and manufacturability. Thus, the tangent loss should be considered to cope as well. Usually, a low dielectric constant substrate is chosen as it offers greater efficiency and huge bandwidth of the radiator. In this paper, the first step in designing the antenna is selecting the best dielectric and tangent loss of substrate material. After considering a few factors, three suitable substrates for the designed antenna are chosen. This paper also analyzes the performance of antenna when using different types of substrate which are Silicon, Duroid 5880 and Ferro A6s.

II. ANTIPODAL VIVALDI ANTENNA DESIGN

The first step in designing the antenna is choosing the best dielectric and tangent loss of the substrate material. After considering a few factors, the most suitable substrate for the designed antenna is Silicon, Ferro A6s and Duroid 5880.

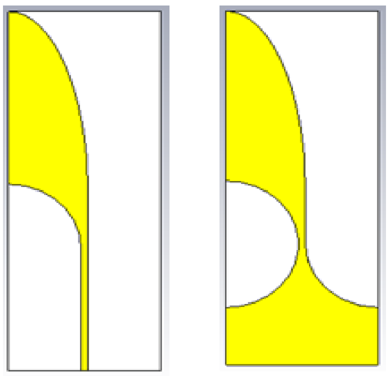
The design specification of an APVA is based on a number of specifications and materials used in order for the antenna to maintain the performance. First and foremost, with references to other various technical papers, all the design specifications and the parameter of the antenna has been determined.

Table 1
Specifications of Antipodal Vivaldi Antenna

Antenna Parameter	Value
Frequency	60GHz
Radiation pattern	Directional pattern
Gain	More than 2dB

The dimensions of the antenna are calculated according to some equations referred to some technical paper. The length of the antenna should be over the length of free space wavelength which ranges from 2λ to 12λ. The length of APVA will give effect on the return loss, gain and directivity of the designed antenna [6]. Antenna width refers to the overall width of the antenna which dependent on the aperture width of the antenna. Gibson suggests that the conductor separation should be equal or over half of free space wavelength of the lowest frequency interest for the radiation to occur [7]. Antenna slope curve referred to the curvature of the APVA which is dependent on the dimension of the antenna itself. The design of the slope is the main point to obtain the better radiation of the signal to the surrounding [8]. In the APVA designed, parallel stripline to microstrip is chosen. However, some alteration is added to the structure of the antenna since the antenna's radiating element is connected to a parallel stripline. The conversion from the parallel stripline to the microstrip is calculated based on the research paper. The top layer where the parallel stripline is located is linked using tapered transmission line to the microstrip line. Then, the width of the parallel stripline at the bottom layer is steadily increased to form the ground plane required for the microstrip feeder [9].

CST 2011 Studio Suite software is used to determine the features of the designed antenna as the project is fully 100% on simulation. Different designs are being proposed in the antenna by improving the dimensions of the APVA and the Archimedean spiral antenna. All the change made in the dimensions will be simulated and tabulated in the results. From the results obtained, the performance of the antenna will be analyze based on the radiation pattern and gain. The comparison in the results can determine the best antenna design that may be required for other applications.



(a) (b)

Figure 1: Dimension of APVA (a) Front (b) back

The initial design parameters of the APVA is shown in Table 2. There are three parameters variation in the parametric study in order to get the optimized value in the design. After doing a parametric study and various designs of APVA, the final design of APVA with the expected design specifications is achieved. From the final designed, the parameter will be analyzed and observed.

Table 2
Initial Design of Antipodal Vivaldi Antenna

Name	Value (mm)	Description
W	3	Width of substrate
L	6	Length of substrate
rc	1.4325	Radius of circle
ws	0.135	Width of stripline
re	1.5675	Radius of eclipse
tc	0.038	Thickness of copper
ts	0.8	Thickness of substrate
lbr	2.727	Length of rectangle
wbr	3	Width of rectangle

III. Result And Discussion

A. Gain

Antenna gain defined how much power transmitted in the direction of peak direction to an isotropic source. The better antenna gain is 3dB where it means the power received far from the antenna will be 3dB higher compared to the received value from the lossless of an isotropic antenna. Realized gain is measured by considering the total efficiency of the antenna along with the directivity. Realized gain usually lowered than the IEEE gain due to mismatched loss and efficiency loss. The optimized design of APVA is simulated, the results shown in Figure 2.

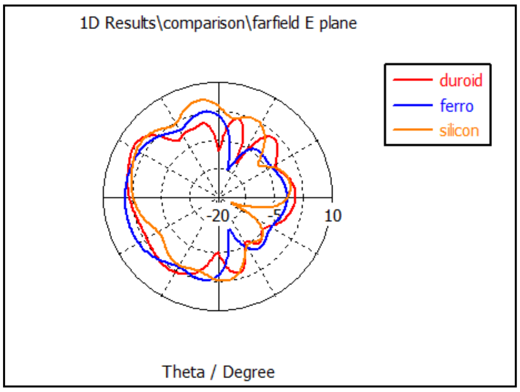


Figure 2: Gain result

From the results, it is obvious that the APVA antennas with the Duroid 5880 as a substrate have a higher gain compared to others, where the value is 5.8262dB. Ferro A6s have the lowest gain value which is 5.5387dB. The different value of gain for both materials is due to the characteristics of the substrate itself. Since Duroid 5880 has a low permittivity and tangent loss, this will give a better value in terms of gain. The lower the permittivity value, the lower the dissipation factor of the designed APVA.

B. Radiation pattern

Figure 3 and 4 show the radiation pattern of E and H plane obtained from the simulation of designed APVA. From the observation, for the radiation pattern for different types of antenna substrate, the opening elements of both antenna act as a good radiator with directional coverage. In order to get a good antenna that works at 60GHz frequency band, it is expected to have a directional radiation pattern. This is because the 60GHz is known as a short-range transmission limitation due to the larger propagation losses and reduced diffraction around obstacles. So, the directional radiation pattern will provide a higher transmission range. Directional radiation pattern means the lobes is pushed in a certain direction and only a little energy is on the back side of the antenna.

From the results shown, the H plane radiation pattern is more directional compared to the E plane radiation pattern where Ferro A6s is more directional in the E plane and Duroid 5880 is more directional in the H plane. However, all of the three APVA designed antenna with different types of substrate produced a directional radiation pattern which shows a good performance for the 60GHz wireless communications.

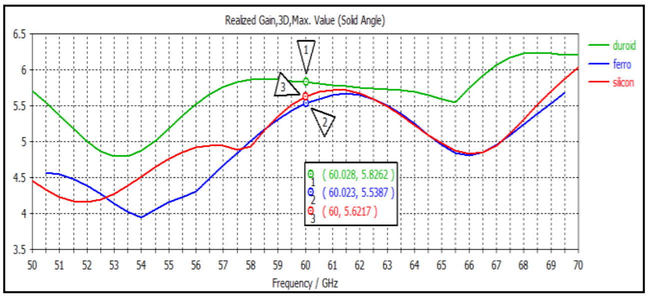


Figure 3: results of radiation pattern of E plane

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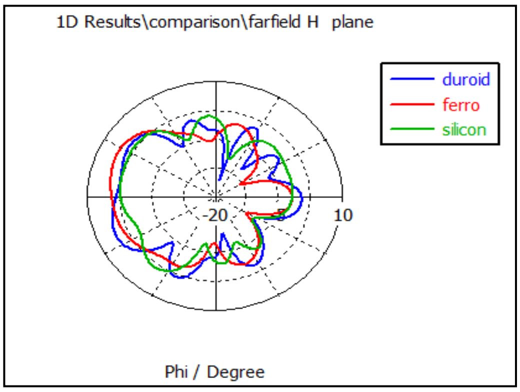

Figure 4: results of radiation pattern of H plane

C. Bandwidth

Bandwidth defined as the frequency range over which antenna radiates. Bandwidth can show the speed of data rates where the larger the bandwidth, the higher the data speed. 60GHz wireless communication is expected to have a gigabit data rates, so larger bandwidth is needed for wideband operation. Larger bandwidth offers many advantages to the antenna performance and wireless communications. For example, it offers a high performance on the multipath channel in order to deliver the data. Even in a bad condition, the strength of the signal is compromised with a larger bandwidth. Moreover, large bandwidth means large channel capacity which is used to support real time HD streaming and uncompressed file transfer.

The Figure 5, 6 and 7 shows the bandwidth for different types of substrate for designed APVA. It is expected for 60GHz wireless communication antenna to have a bandwidth more than 1GHz. Thus, these three substrates have a bandwidth larger than 1GHz. Ferro A6s have a larger bandwidth which is around 11GHz and Silicon has a smaller bandwidth with values of 1.7GHz while the Duroid 5880 have 5GHz bandwidth values. The aperture length and the permittivity of the substrate are the parameters that give a big impact on the bandwidth value. As from the optimized parameter, aperture length of the Vivaldi antenna using antenna substrate if longer and have the lowest value of permittivity

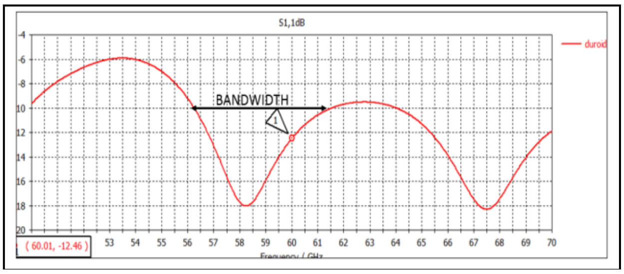

Figure 5: Results bandwidth for Duroid 5880

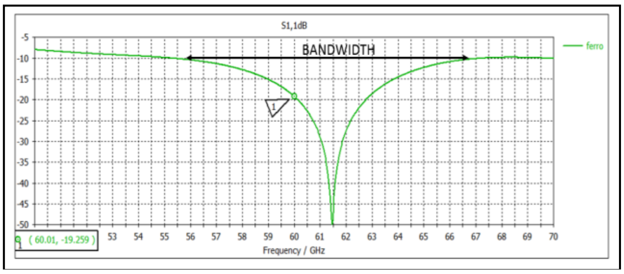

Figure 6: Results bandwidth for Ferro A6s

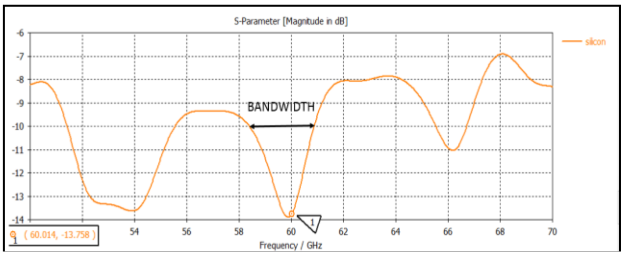

Figure 7: Results bandwidth for Silicon

D. Directivity

Directivity defined how directional an antenna radiation pattern. In other words, it shows the wellness of radiated energy from an antenna to transmit in a specific direction or well defined as a ratio of radiation intensity. Radiation intensity is obtained is a given direction if the power is accepted by the antenna where radiating isotropic ally. Figure 8 shows the directivity of the designed antenna.

Based on the results, it shows that Duroid 5880 as a substrate has high directivity value which is 6.1822dB while Ferro A6s has lower directivity value relies on 5.7dB. Thus, this makes APVA with Duroid 5880 can operate well in terms of radiated the energy from an antenna.

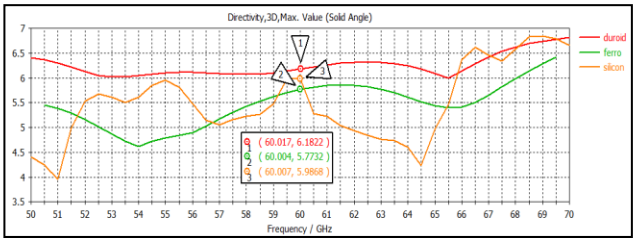

Figure 8: Results of directivity

E. Return loss

Figure 9 shows the comparison of the return loss between three different types of the substrate which are Silicon, Ferro A6s, and Duroid 5880. There is a different value of return loss for different types of the substrate but these three substrates achieved below -10dB, which means that all of the designed antenna have a good antenna performance. Ferro A6s shows a good return loss at 60GHz where it relies at -19.259dB which means that only 1% of power is reflected back to the source. Silicon has the least antenna performance at 60GHz where the return loss relies at -12.46fB. However, the APVA designed with silicon still going to works at 60GHz. Most probably, the different value of thesubstrate thickness will give a different return loss.

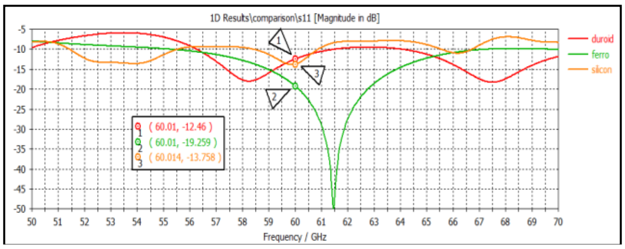

Figure 9: Results of return loss

IV. Conclusion

All of the results is analyzed by using Tapered Slot Antenna (TSA) known as antipodal Vivaldi antenna, that is theoretically have a good performance over 60GHz frequency band where it is expected to have a higher gain in order to support the gigabit data rates in 60Ghz wireless communications. This antenna also has a good performance with a better supported by the used of the lower permittivity of the substrate. In terms of the radiation pattern, it is needed to have a further research on antipodal Vivaldi antenna design. As the 60GHz wireless communications is a short-range wireless with gigabit rate, the antenna should have more directional radiation pattern. Directional radiation pattern means there is only a little energy at the back lobes of the radiation pattern.

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