Penerbit Akademia Baru

Journal of Advanced Research in Applied Mechanics

Journal homepage: www.akademiabaru.com/aram.html
ISSN: 2289-7895

Parametric Study of UWB Antipodal Vivaldi Antenna

Open Access

A.M.M.A Allam[1,*], Adham Mahmoud[2]

1 Department of Communication, Faculty of Information Engineering and Technology German University in Cairo, Cairo, Egypt
2 Institut d'Electronique et de Télécommunications de Rennes (IETR), UMR CNRS 6164 Université de Rennes 1, Rennes, France

ARTICLE INFO

Article history:
Received 5 June 2017
Received in revised form 10 July 2017
Accepted 4 December 2017
Available online 12 March 2018

ABSTRACT

This article presents the design of Vivaldi antennas for the UWB frequency range specified by the Federal Communications Commission FCC (3.1 - 10.6 GHz). An analysis on each parameter is done to describe its effect and gives a control parameter in designing the Vivaldi antenna. The return loss responses and radiation patterns are considered in the parametric study. The results of simulations realized using CST microwave studio. The simulated results of return loss are compared with those of the measured ones and gives good agreement. The information derived from this study provides guidelines for the design and optimization of the Vivaldi antenna which are widely used for UWB applications.

Keywords:
Vivaldi antenna, UWB, parametric study

1. Introduction

Vivaldi antenna is a planar travelling wave antenna with endfire radiation. It was first investigated by Gibson in 1979 [1] and many improvements to the initial design came later, namely in the works of Gazit in 1988 [2] and Langley, Hall and Newman [3] in 1996. Since then, it is widely used in different applications such as microwave imaging, wireless communications and ground penetrating radars. There are three fundamental types of Vivaldi antenna, which can be used to design the radiating structure. These types are: ttapered slot Vivaldi antenna, antipodal Vivaldi antenna and balanced antipodal Vivaldi aantenna [4-5]. Vivaldi antennas provide medium gain depending on the length of the taper and the shape of the curvature. The gain also changes with frequency, with values ranging typically from 4 dBi to 8 dBi [3]. Because of the exponential shape of the tapered radiating structure, antenna maintains approximately constant beamwidth over the range of operating frequency [1,2].The mechanism of radiation is a travelling wave propagating along the slots with a phase velocity less than the speed of light (i.e., vph ≤ c) which gives an endfire radiation [6]. To achieve a wider bandwidth to a Vivaldi antenna, a micro strip to slot transition and quarter wave radian strip line stubs is introduced [7, 8]. A miniaturization of Vivaldi is introduced in [9-12].

[*] *Corresponding author.*
E-mail address: abdelmegic.allam@guc.edu.eg (A.M.M.A Allam)

2. Antenna Design

This paper describes the parametric study of Vivaldi antennas regarding the design of an antenna with the given specifications. The effect of each parameter is investigated performing simulations with CST microwave studio. The objective is to design an antipodal Vivaldi antenna to operate in ultra-wide band satisfying the Federal Communications Commission (FCC) regulations for indoor applications from 3.1 GHz to 10.6 GHz.

The geometrical configuration of the proposed antennas is shown in Fig. 1. The antenna is designed on 1.524 mm thick Rogers RO4350 substrate with permittivity ( ) 3.66 and tangent loss 0.004. The overall antenna size is 82×80 mm2. The exponential function that defines taper profile determined by the two points p1(x1, y1) and p2(x2, y2) in equation (1)

$$y = C1 * e^{Rx} + C_2 \tag{1}$$

where

$$C_1 = \frac{x_2 - x_1}{e^{Ry2} - e^{Ry1}}, C_2 = \frac{x_1 e^{Ry2} - x_2 e^{Ry1}}{e^{Ry2} - e^{Ry1}}$$

C1 and C2 are constants and R is the opening rate of the exponential taper. Note that (x1, y1) and (x2, y2) are the coordinates of the origin and end of flare curve, respectively. The antenna dimensions are given in table 1. The fabricated antenna is depicted in fig. 2. The measured and simulated return loss is depicted in fig.3 while the radiation pattern is illustrated in fig.4.

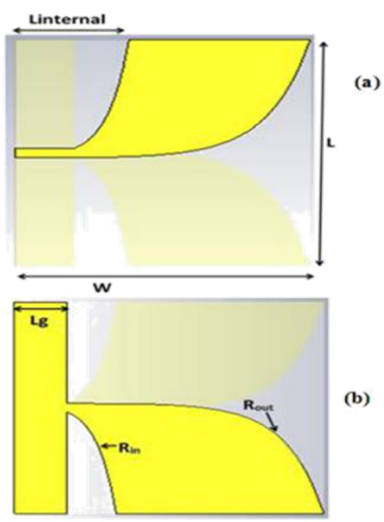


Fig. 1. The Antenna Design (a) Front view (b) Back view

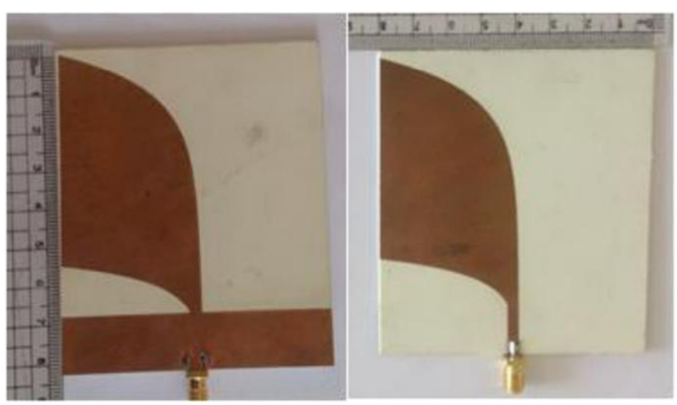


Fig. 2. The Fabricated Antenna

Table 1
Design Dimensions

Design Dimensions	Value
Substrate Material	Rogers RO4350
Substrate Thickness	1.524mm
Total Length	82mm
Total Width	80mm
Internal Length	14mm
Ground Length	27mm
Internal Radius	0.2mm
Outer Radius	0.1mm

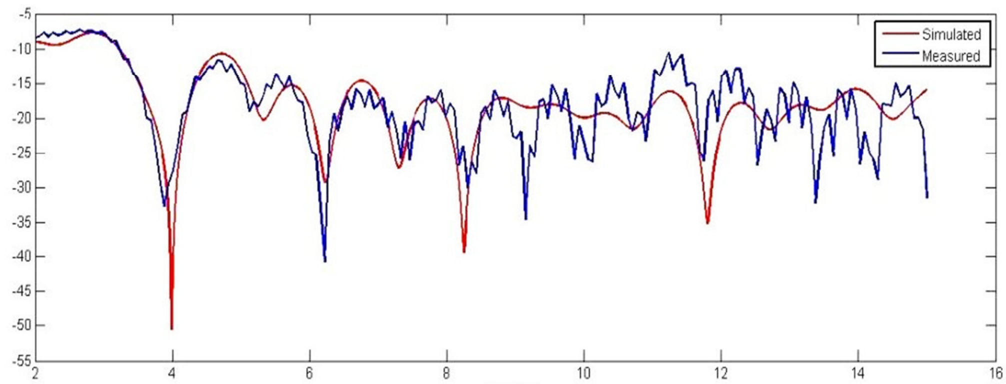


Fig. 3. The Measured and Simulated Return Loss

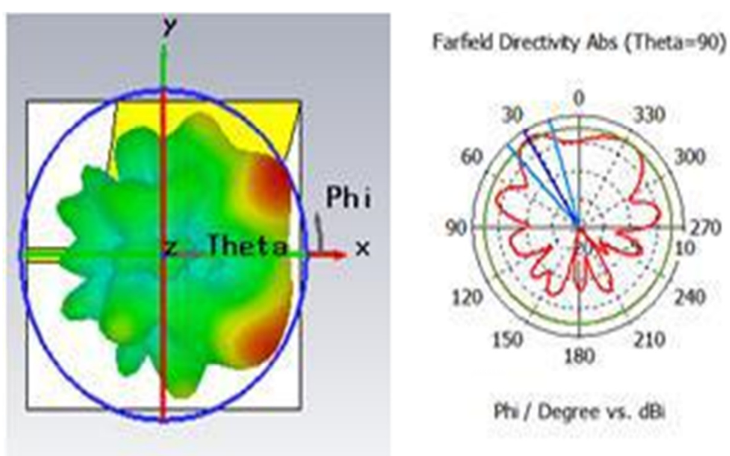


Fig.4. 3D and 2D Radiation Pattern a) 3D Pattern b) Antenna Plane Pattern

3. Parametric Study on Vivaldi Antenna

The antenna is simulated for different lengths and widths. Fig.5 and Fig.6 depict the return loss for different widths; 30mm, 40mm, 50mm, 60mm, 70mm and 80mm, keeping the length 82mm. The directivity and the radiation patterns for widths;30mm, 40mm and 80mm are illustrated in Fig.7 to Fig.9. It is concluded that increasing the antenna width, decreases the starting frequency of the antenna. The directivity is nearly constant while, the pattern is nearly endfire.

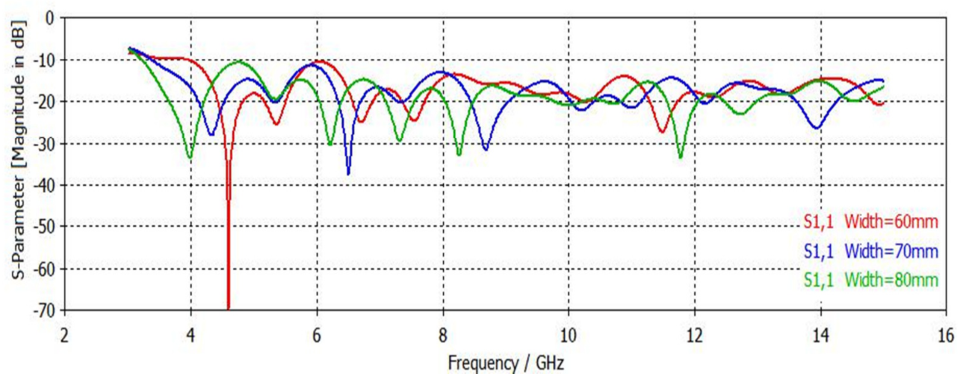


Fig. 5. Return Loss of Antipodal Antenna (Length=82mm, Width= 60, 70 and 80mm)

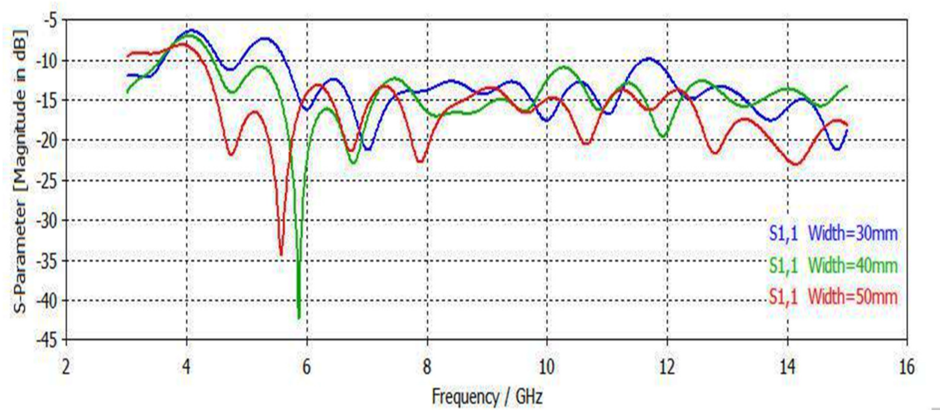


Fig. 6. Return Loss of Antipodal Antenna (Length=82mm, Width= 30, 40 and 50mm)

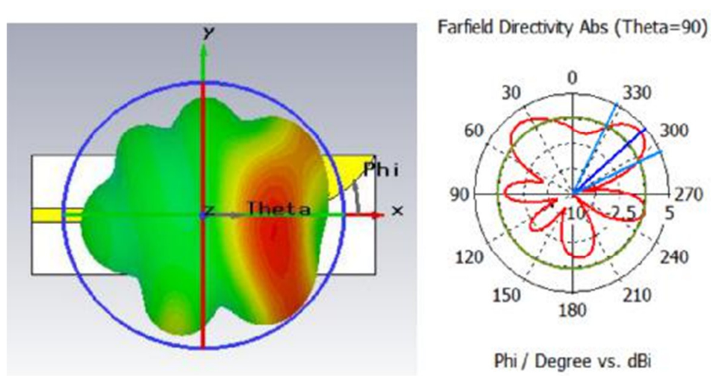


Fig. 7. 3D and 2D Radiation Pattern of Antipodal Antenna (Length=82mm, Width 30mm) a) 3D pattern b) antenna plane

Figure 10 and 11 depict the return loss for different lengths; 40mm, 50mm, 60mm, 70mm and 82mm, keeping the width 80mm. The directivity and the radiation patterns for lengths;40mm, 50mm and 70mm are illustrated from Fig.12 to Fig.14. It is concluded that increasing the antenna length, decreases the starting frequency of the antenna. Table 2 represents the directivity and the total efficiency of the antipodal Vivaldi antenna for different lengths and widths.

Concerning the fin of the antipodal Vivaldi antenna, there are two radii; the inner radius and the outer radius, where the inner radius is always greater than the outer one as shown in Fig.1. The antenna is simulated for different radii, we found out that increasing the radii results in an increase in the bandwidth, which means that the radii of curvature can tune the antenna to the required bandwidth as shown in Fig.15.

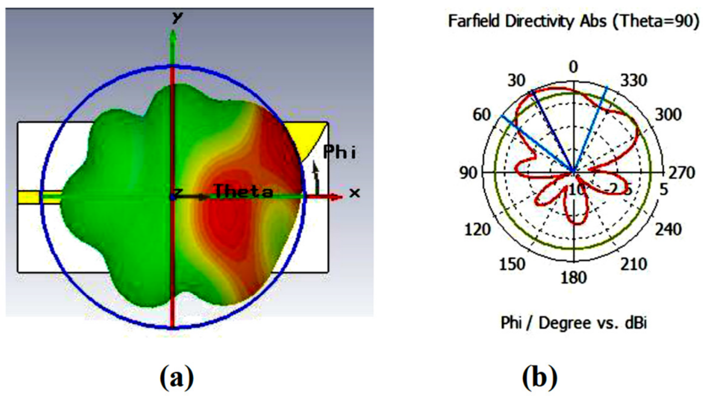


Fig. 8. 3D and 2D Radiation Pattern of Antipodal Antenna (Length=82mm, Width 40mm) a) 3D Pattern b) Antenna Plane

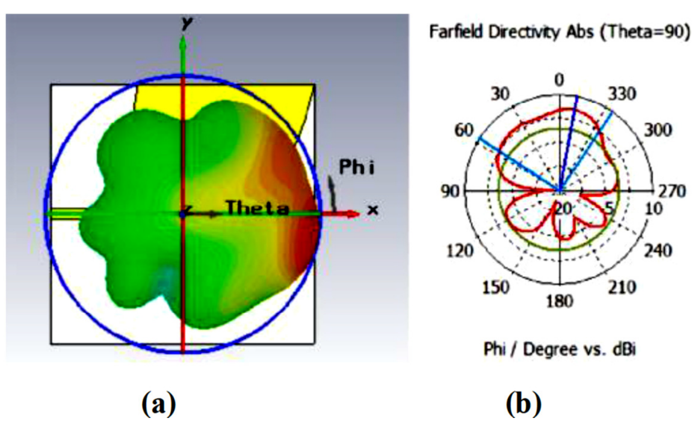


Fig. 9. 3D and 2D Radiation Pattern of Antipodal Antenna (Length=82mm, Width 80mm) a) 3D Pattern b) Antenna Plane

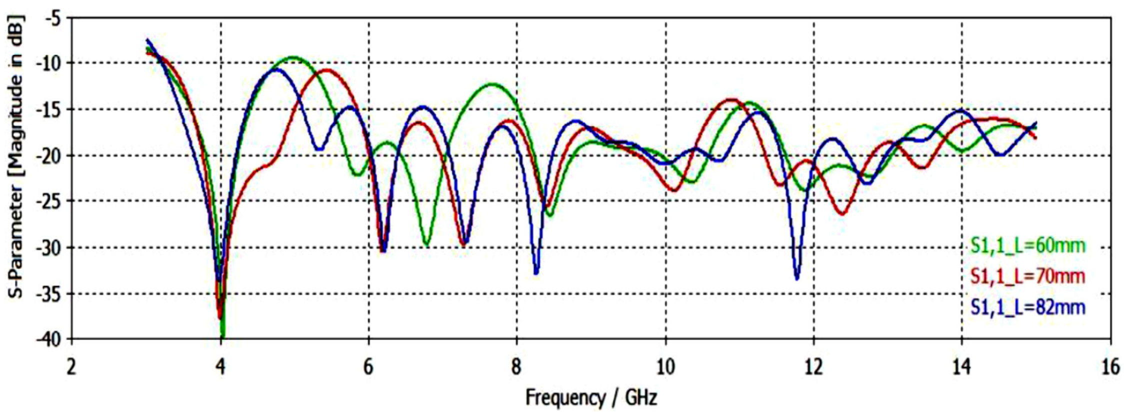


Fig. 10. Return Loss of Antipodal Antenna (Width=80mm, Length= 60, 70 and 82mm)

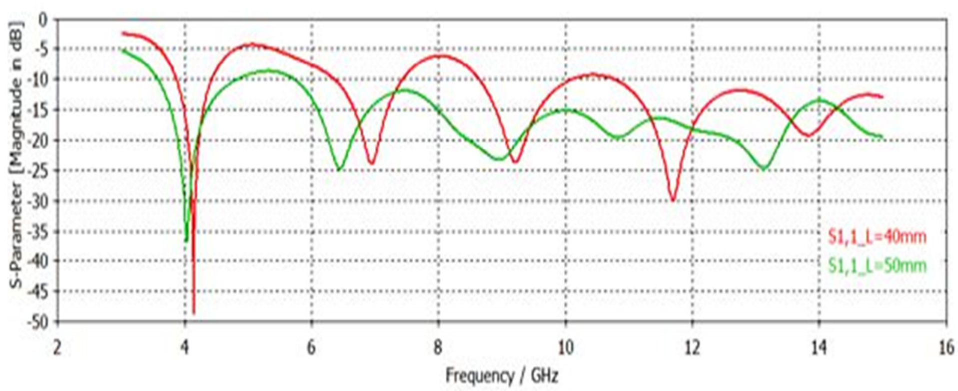


Fig. 11. The Return Loss of Antipodal Antenna (Width=80mm, Length= 40mm and 50mm)

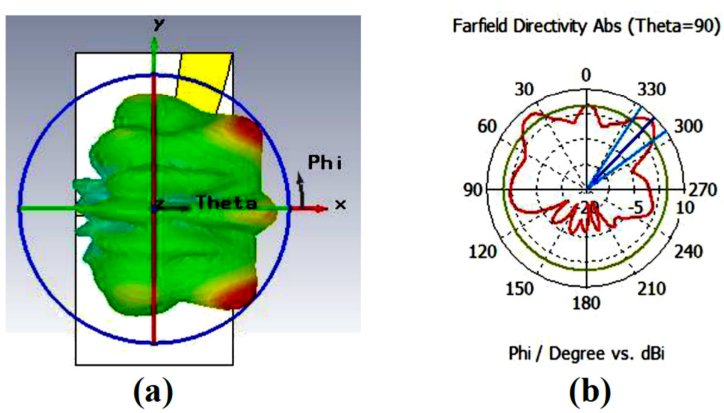


Fig. 12. 3D and 2D Radiation Pattern of Antipodal Antenna (Length=40mm, Width 80mm) a) 3D Pattern b) Antenna Plane

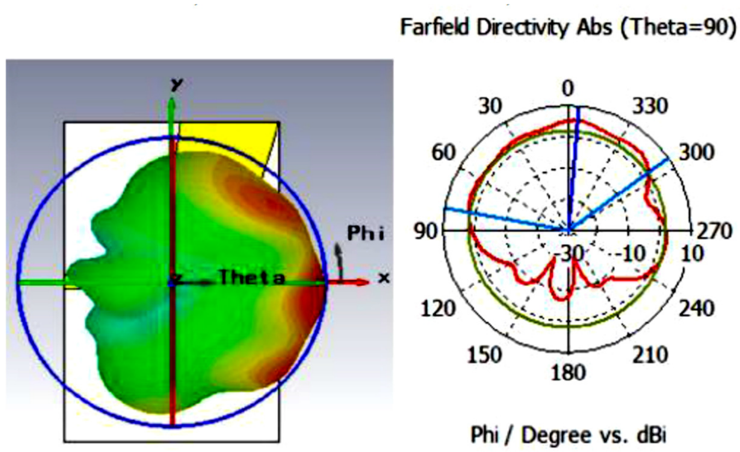
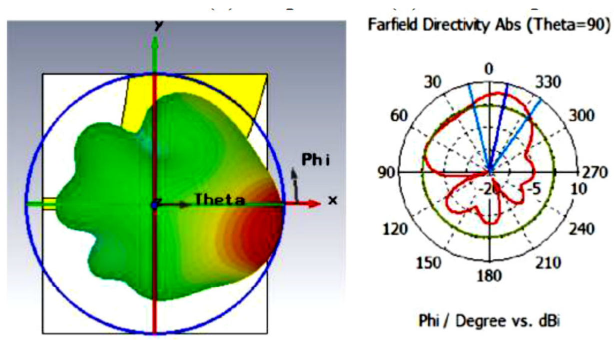


Fig. 13. 3D and 2D radiation pattern of antipodal antenna (Length=50mm, Width 80mm) a) 3D Pattern b) Antenna Plane



(a) **(b)**

Fig. 14. 3D and 2D Radiation Pattern of Antipodal Antenna (Length=70mm, Width 80mm) a) 3D Pattern b) Antenna Plane

Table 2
The Directivity and Total Efficiency of Different Configurations for Antipodal Vivaldi Antenna

L (mm)	W (mm)	Directivity (dBi)	Total Efficiency (dB)
82	40	4.392	-0.666
82	50	5.880	-0.3688
82	60	5.494	-0.4131
82	70	5.247	-0.2081
82	80	5.324	-0.1278
40	80	8.236	-0.6388
50	80	5.282	-0.3503
60	80	6.123	-0.2301
80	80	6.378	-0.1438
82	80	5.324	-0.1278

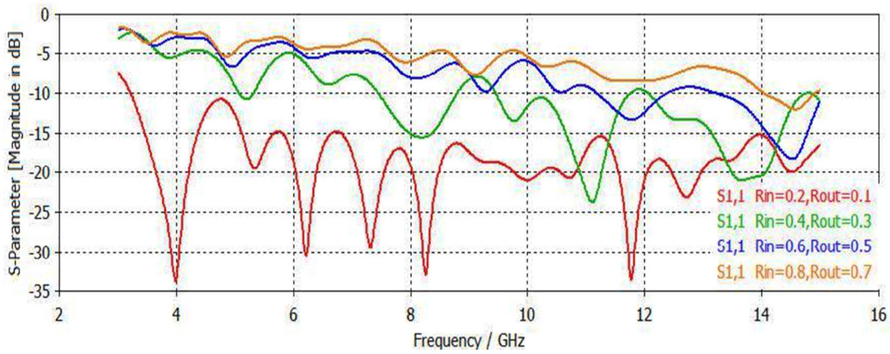


Fig. 15. Return Loss for Different Radii of Curvature for the Antipodal Antenna

Edge offset is the extra metallization at the end of fin of the antipodal antenna as shown in Fig.16. It prevents edge currents to come across a sharp end. It is found that adding an edge offset after the fin would not improve return loss response noticeably as shown in Fig.17.

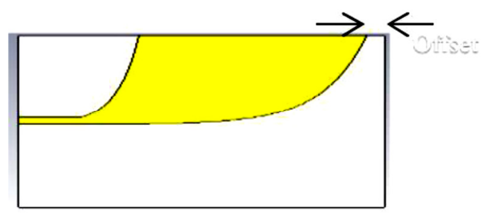


Fig. 16. Antenna Design after adding an edge offset

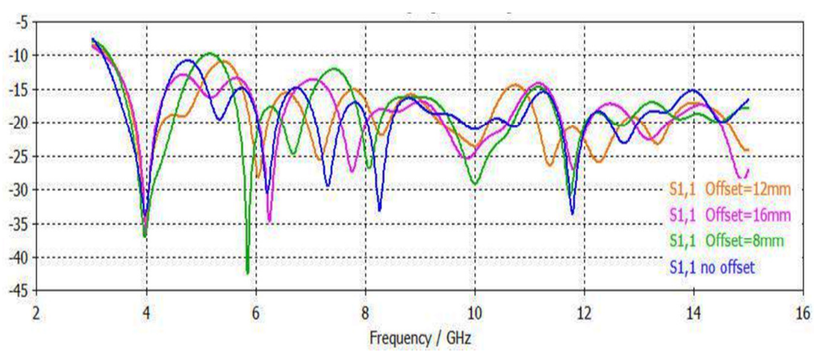


Fig. 17. Return Loss for Different Edge Offsets for the Antipodal Antenna

Moreover, vias are added to the antenna structure, where the two notched squares as depicted in Fig. 18. The edge of the square is 8.17mm and notch radius is 0.47mm. The separation distance between the square and the feed line is 0.2mm. The result is found to be that the vias notch some frequency of the operating band of the Vivaldi antenna as shown in Fig. 19.

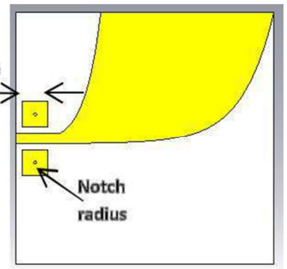


Fig. 18. The Vias design

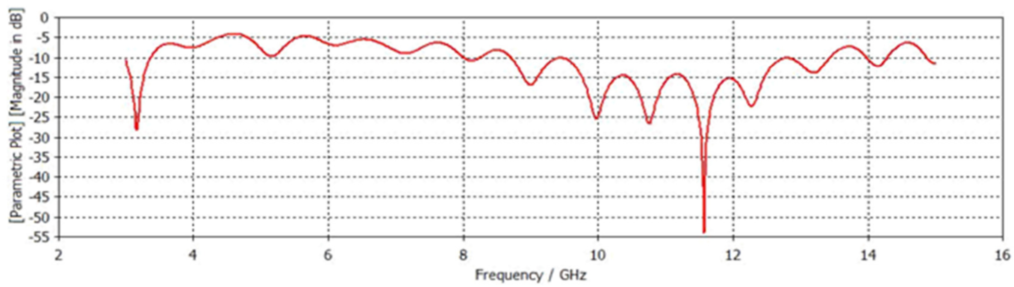


Fig. 19. Return Loss after Adding the Vias

5. Conclusion

The thesis presents the parametric study and implementation of Vivaldi antenna using CST microwave studio. The 1.524 mm thick Rogers RO4350 substrate is used to design the antipodal Vivaldi antenna with permittivity (3.66), tangent loss 0.004 and the overall size of the antenna 82×80 mm^2. It is concluded that increasing the antenna width, decreases the starting frequency of the antenna. The directivity is nearly constant and the pattern is nearly endfire, while increasing the antenna length, decreases the starting frequency of the antenna. Also we found out that increasing the radii results in an increase in the bandwidth, which means that the radii of curvature can tune the antenna to the required bandwidth. After adding notched squares, we notice that vias notch some frequency of the operating band of the Vivaldi antenna.

References

[1] Gibson, P. J. "The vivaldi aerial." In *Microwave Conference, 1979. 9th European*, pp. 101-105. IEEE, 1979.

[2] Gazit, Ehud. "Improved design of the Vivaldi antenna." In *IEE Proceedings H (Microwaves, Antennas and Propagation)*, vol. 135, no. 2, pp. 89-92. IET Digital Library, 1988.

[3] J Langley, J. D. S., P. S. Hall, and P. Newham. "Balanced antipodal Vivaldi antenna for wide bandwidth phased arrays." *IEE Proceedings-Microwaves, Antennas and Propagation* 143, no. 2 (1996): 97-102.

[4] Sarkar, Chittajit. "Some parametric studies on Vivaldi antenna." *International Journal of u-and e-Service, Science and Technology* 7, no. 4 (2014): 323-328.

[5] Pandey, G. K., H. S. Singh, P. K. Bharti, A. Pandey, and M. K. Meshram. "High gain Vivaldi antenna for radar and microwave imaging applications." *International Journal of Signal Processing Systems* 3, no. 1 (2015): 35-39.

[6] Oraizi, Homayoon, and Shahrokh Jam. "Optimum design of tapered slot antenna profile." *IEEE transactions on Antennas and Propagation* 51, no. 8 (2003): 1987-1995.

[7] Shuppert, B. "Microstrip/slotline transitions: Modeling and experimental investigation." *IEEE Transactions on microwave theory and techniques* 36, no. 8 (1988): 1272-1282.

[8] Zinieris, M. M., R. Sloan, and L. E. Davis. "A broadband microstrip-to-slot-line transition." *Microwave and Optical technology letters* 18, no. 5 (1998): 339-342.

[9] Yang, Yunqiang, Y. Wang, and Aly E. Fathy. "Design of compact Vivaldi antenna arrays for UWB see through wall applications." *Progress In Electromagnetics Research* 82 (2008): 401-418.

[10] Hood, Aaron Zachary, Tutku Karacolak, and Erdem Topsakal. "A small antipodal Vivaldi antenna for ultrawide-band applications." *IEEE Antennas and Wireless propagation letters*7 (2008): 656-660.

[11] Jolani, Farid, Gholamreza R. Dadashzadeh, Mohammad Naser-Moghadasi, and Abdolmehdi M. Dadgarpour. "Design and optimization of compact balanced antipodal Vivaldi antenna." *Progress In Electromagnetics Research* 9 (2009): 183-192.

[12] Fei, Peng, Yong-Chang Jiao, Wei Hu, and Fu-Shun Zhang. "A miniaturized antipodal Vivaldi antenna with improved radiation characteristics." *IEEE antennas and wireless propagation letters* 10 (2011): 127-130.