Design and simulation double Ku-band Vivaldi antenna

Huda Ibrahim Hamd1, Israa Hazem Ali2, Ahmed Mohammed Ahmed1
1Department Electronic Engineering, University of Diyala, Diyala, Iraq
2Department of Communication Engineering, University of Diyala, Diyala, Iraq

ABSTRACT

Due to the tremendous development in the field of wireless communication and its use in several fields, whether military or commercial was proposed.

A novel tapered slot Vivaldi antenna is designed and simulated at double band frequency (Ku-band) using computer simulation technology (CST) software 2020. The dimensions of the antenna are $2.3 \times 1 \times 0.4$ mm$^3$ with a microstrip feed of 0.5 mm. The proposed antenna is improved by cutting a number of circle shapes on the patch layer in different positions. The simulation results are divided into more sections according to the number of circle shapes cutting. The results are good acceptance and make the improved Vivaldi antenna valuable in many future wireless communication applications.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Israa Hazem Ali
Department of Communication Engineering, University of Diyala
Diyala, Iraq
Email: pg_student75@yahoo.com

1. INTRODUCTION

The tremendous development in the field of wireless communication and its use in several fields, whether military or commercial led to the creation of an antenna with distinctive features such as multipath and bandwidth [1]-[5]. The Vivaldi antenna is planar antenna that Gibson discovered in 1979 with a notch or tapered slot aperture [6]-[8]. It is characterized by the width of the beam so that it covers the frequency of the microwave between 2-20 GHz [9]-[11].

The antenna is classified from the fire end antenna group because during operation it radiates from the open end of the notch in a direction away from the notch and along the axis of symmetry. This type is characterized by high bandwidth, directivity and is capable of producing similar radiation pattern. Easy to manufacture and has simple and versatile feeding line such as microstrip lines, stripline, fine lines or probes [12]-[14]. Vivaldi antenna is used in satellite communications, remote sensing, radio telescope, imaging, radar or through wall detection [9]-[10].

The Vivaldi antenna consists of two layers, the first is called substrate, made of an insulating material, and the second layer called conductor layer tops it. A notch in the conductive layer and a gap on either side of the hole widening of the minimum at the close end of the slot to the maximal. at the open end as shown in Figure 1 [15]-[17].

To improve the characteristics of Vivaldi antenna like gain, bandwidth and radiation pattern, there are many studies depend on the geometry of antenna such as length, width, feeding shape, radiator shape, substrate material and the slop of the tapered slot [11]. There are three types of Vivaldi antenna: coplanar, antipodal and balanced antipodal Vivaldi antenna according to notch or tapered slot [18]-[20]. More researchers study and design Vivaldi antenna in many years ago. [11], is design and simulated antenna for
Band frequency (2-6) GHz, [12], [13], are presented antipodal Vivaldi antenna for ultra wideband, with different shape design.

The array antipodal Vivaldi antenna is designed in [19]. The researchers measured all the characteristic of antenna for different types according to frequency band. While [20], the Vivaldi antenna is simulated in computer simulation technology (CST) software with different substrate materials. The antennas are covered the frequency band 2-18 GHz. In [21], the Vivaldi antenna was studied, analyzed and implemented to operate with a frequency band of (6-18) GHz. slots and cuts are made in patch layer to improve the characteristics parameter of the antenna.

In this type of antenna, corrugations are added at the edges of the radiating part of the antenna to operate at a frequency range of (0.5-12) GHz. A study and comparison is made between the changing antenna forms by changing the number of corrugations added to the patch [22]. While in [23], the Vivaldi antenna is designed to operate at a frequency of 3.5 GHz, and the results are improved and compared by adding circular sections and lines to the radiating layer.

This paper is presented a novel design an antenna, which is operable in Ku-Band spectrum and most suitable for the more mentioned applications. The design of Vivaldi antenna that is improved by cutting number of circle shapes on patch layer on different position. The simulation results are divided more section according to number of circle shapes cutting.

2. **ANTENNA DESIGN**

Figure 2, shows the illustrate the Vivaldi antenna using CST microwave studio software 2020. It is design to operate at 12.7, 15.77 GHz. The antenna is consists of three layers, upper layer patch is made of perfect electric conductor (PEC) material, zero resistivity, with thickness 0.035 mm. The other layer (substrate) is made of Taconic RF-60A, $\varepsilon_r=6.15$, with thickness $h=0.4$ mm. microstrip line is the bottom layer which is used to feed the antenna and made matching on 50 $\Omega$. It is located on the other side on substrate layer and it is made from same material of patch layer. The dimensions of the proposed antenna shown in Table 1.
To calculation the dimensions of vivaldi antenna, the (1) is presented the wavelength for antenna [12], [24], [25].

$$\lambda_g = \frac{c}{f_{min}\sqrt{\epsilon_r}}$$  \hspace{1cm} (1)

Where $c =$ speed of light,

$f_{min}= $ frequency minumum

$\epsilon_r= $ relative permittivity for dielectric material

and to calculate the maximal and minumum opening width, the (2) and (3) are presented them respectivly.

$$W_{max} = \frac{\lambda_g}{2}$$  \hspace{1cm} (2)

$$W_{min} = \frac{c}{f_{max}\sqrt{\epsilon_r}}$$  \hspace{1cm} (3)

Where $f= $ centre frequency,

The tapered slot line is given as exponential function and can be calculate as (4).

$$y_i = \mp C_i \exp(R_i x)$$  \hspace{1cm} (4)

Where, $y_i =$ the distance from the centre line of the slot to the inner slot line,

$C_i =$ line slot width at the feed port,

and $R_i =$ the slot widens

<p>| Table 1. Dimensions of Vivaldi antenna |</p>
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dimensions mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.25</td>
</tr>
<tr>
<td>R</td>
<td>9.2</td>
</tr>
<tr>
<td>SL</td>
<td>10</td>
</tr>
<tr>
<td>TL</td>
<td>50</td>
</tr>
<tr>
<td>W</td>
<td>50</td>
</tr>
<tr>
<td>EXT</td>
<td>1</td>
</tr>
<tr>
<td>h</td>
<td>0.4</td>
</tr>
<tr>
<td>MW</td>
<td>2.5</td>
</tr>
<tr>
<td>QWS</td>
<td>7.5</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Vivaldi antenna has been implemented and design using CST microwave studio 2020. The design of Vivaldi antenna that is improved by cutting number of circle shapes on patch layer on different position. The simulation results are divided more section according to number of circle shapes cutting. The cutting shapes are chosen according to current distribution results. The radius of the cutting shape is 0.3 mm.

3.1. Type A

In this type, 6 circle shapes are cutting on the edge of patch layer as shown in Figure 3. The Figure 4 shows the relation between frequency and return loss (RL). Two band frequencies are operated 12.7, 15.7 GHz with RL -22, -23 dB respectively. While the radiation pattern as directivity is shown in Figure 5. It is recorded the value of directivity at 12.7 GHz 2.93 dBi shown in Figures 5(a) and 5(b) shown at 15.7 GHz 0.924 dBi.
Design and simulation double Ku-band Vivaldi antenna (Huda Ibrahim Hamd)

3.2. Type B

In this type, two pairs of circles are added on both sides of the curve with the same diameter of the circles as for Type A as shown in Figure 6. The Figure 7 shows return loss for type B, also double band are worked. These values are -21dB and -24 dB for 12.7 GHz, 15.7 GHz respectively. While the directivity for this type is recorded in Figure 8 for double band frequency. Figure 8(a) shown at 12.7 GHz and Figure 8(b) shown at 15.7 GHz.

Figure 4. Relation between return loss and frequency for type A Vivaldi antenna

Figure 5. Radiation pattern for type A Vivaldi antenna: (a) at 12.7 GHz and (b) at 15.7 GHz

Figure 6. Type B of Vivaldi antenna

Figure 7. Relation between return loss and frequency for type B Vivaldi antenna
3.3. Type C

As shown in Figure 9, this type is obtained after adding 3 circles to the previous couple and on each side of the curve. The simulation results are recorded decrease in return loss at -16 dB for 12.7 GHz and increase in RL -33 dB at 15.7 GHz as in Figure 10. The Figure 11, representes the directivity for this type of vivaldi antenna at double band frequency 12.7GHz shows in Figure 11(a) and 15.7 GHz shown in Figure 11(b).

Figure 8. Radiation pattern for type B vivaldi antenna: (a) at 12.7 GHz and (b) at 15.7 GHz

Figure 9. Type C of Vivaldi antenna

Figure 10. Relation between return loss and frequency for type C Vivaldi antenna

Figure 11. Radiation pattern for type C Vivaldi antenna: (a) at 12.7 GHz and (b) at 15.7 GHz
3.4. Type D

In this type, 3 circles of the same diameter are added to the substrate layer from a center between the two curves as shown in Figure 12. As shown in Figure 13, the values of return loss is continued decrease at 12.7 GHz and increase in 15.7 GHz. The values are recorded -17dB, -47dB respectively. While the radiation pattern for these band frequencies are shown in Figure 14. Figure 14(a) shown at 12.7 GHz and Figure 14(b) shown at 15.7 GHz. The Table 2, represents the comparison among all types of Vivaldi antenna with respect to SWR, Z and Gain. It shows SWR values for all types are closed to 1.

Figure 12. Type D of Vivaldi antenna

![Figure 12](image)

Figure 13. Relation between return loss and frequency for type D Vivaldi antenna

![Figure 13](image)

Figure 14. Radiation pattern for type D Vivaldi antenna: (a) at 12.7 GHz and (b) at 15.7 GHz

![Figure 14](image)

<table>
<thead>
<tr>
<th>Ch./cs. Frequency GHz</th>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
<th>Type D</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7</td>
<td>15.77</td>
<td>12.7</td>
<td>15.77</td>
<td>12.7</td>
</tr>
<tr>
<td>RL dB</td>
<td>-22</td>
<td>-24</td>
<td>-21</td>
<td>-24</td>
</tr>
<tr>
<td>Directivity dBi</td>
<td>2.93</td>
<td>-0.924</td>
<td>3.33</td>
<td>1.54</td>
</tr>
<tr>
<td>SWR</td>
<td>1.3</td>
<td>1.8</td>
<td>1.25</td>
<td>1.7</td>
</tr>
<tr>
<td>Gain dBi</td>
<td>8.5</td>
<td>8</td>
<td>8.4</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 2. Dimensions of Vivaldi antenna

Design and simulation double Ku-band Vivaldi antenna (Huda Ibrahim Hamd)
4. CONCLUSION

The novel design of tapered slot vivaldi antenna is designed and simulated using CST software in 2020. The proposed antenna is improved by cutting a number of circle shapes on the patch layer in different positions and is worked at Ku-bands 12.7, 15.77 GHz. The results are good acceptances and make the improved Vivaldi antenna valuable in many future wireless communication applications.

REFERENCES


BIOGRAPHIES OF AUTHORS

Huda Ibrahim Hamd Received the degree in communication Engineering from college of Engineering/University of Diyala, in 2007. Master degree was received in 2013 from Almustansiriya University. Currently, she is a Lecturer at Electronic Engineering/collage of Engineering/University of Diyala. She can be contacted at email: ihh@uodiyala.edu.iq

Israa Hazem Ali Received the degree in Electronic Engineering from college of Engineering/University of Diyala, in 2005. Master degree was received in 2013 from Almustansiriya University. Currently, she is a Lecturer at Communication Engineering/collage of Engineering/University of Diyala. She can be contacted at email: pg@uodiyala.edu.iq

Ahmed Mohammed Ahmed B.Sc. Degree in Electrical (Electronic & Communication) Engineering-University of Technology-Baghdad, Iraq, 2006. Received the master degree in communication engineering from the college of engineering, UNITEN University, Malaysia, 2013. From 2006 to 2010 he was in charge labs. Of communication engineering at college of engineering, Diyala University. Since 2014 he is a senior lecturer at electronic department, college of engineering, Diyala University, with emphasis on advanced digital communication. He can be contacted at email: ahmedzydi@uodiyala.edu.iq.