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Compact Vivaldi Antenna With Balun Feed For Uwb

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Abstract: *A minimized Vivaldi antenna balun feed operating at UWB frequency from 3 to 10 Ghz is designed. The antenna is developed from the linear tapered slot antenna (LTSA) with a constant curve slope rate. For the feeding configurations coplanar waveguide (CPW) to slot line transition and micro strip line to slot line transitions are used. The antenna balun performance characteristics are measured in terms of VSWR and return loss. To make the structure lossless Rogers RT/Duroid5880 substrate with permittivity 4.4 is used. The antenna modeling is analyzed using HFSS. The VSWR of the antenna is obtained with a value less than 2 for the entire operating frequency range. The obtained return loss also indicates the antenna is having good matching at the output port.*
Keywords: *Balun, , LTSA,UWB, Vivaldi antenna.*

I. Introduction

The Vivaldi antenna is the most popular directive antenna for commercial UWB applications due to its simple structure and small size. It is widely used in different applications such as microwave imaging, wireless communications, ground penetrating radars, satellite communications, remote sensing and radio telescope [1]. At different frequencies, different parts of the antenna radiate, while the size of the radiating part is constant in wavelength. The antenna has theoretically unlimited operating range. Practically, the operating bandwidth is limited by the transition from feeding transmission line to slot line of the antenna and by the finite dimensions of the antenna.

The constancy of the beam width against frequency depends on the correct design of the antenna. Thus, the design of Vivaldi antenna for operating in UWB, there are two major subjects: (a) The transition from the main transmission line (usually micro strip) to a slot line, for feeding the antenna, this should have a very wide operating frequency range and low reflection coefficient to match the potential of the antenna.(b) The dimensions and the shape of antenna to obtain the required beam width, side lobes and back lobes over the operating frequency range [2]. In order to achieve a transition that has low return loss over a wide frequency band, the impedances of the micro strip line and slot line must be matched to each other to reduce the reflections. The characteristic impedance of a slot line increases with increasing slot width, so the width of the slot line must be selected to be as small as possible to achieve an impedance value close to 50Ω [3].

II. Antennadesign

Dielectric constant and substrate thickness are the parameters determining the performance and radiation pattern, that is beam width, side lobe level and gain of the antenna. Higher dielectric constant substrates give the advantage of smaller antenna dimensions for same performance. However, a more efficient design and a wider bandwidth is possible with low dielectric constant substrates. Among the substrates with dielectric constant in the range of 2.2 to 10.2, RogersRT/duroid™ 5880 has the minimum tangent loss (tan δ = 0.0009) and a dielectric constant of ξr = 2.2. Rogers RT/duroid™ 5880 is chosen as the substrate material of design. The performance of the antenna also depends on the substrate thickness. An improvement in the performance is obtained using thicker substrates due to a decrease in the antenna reactance through the whole band. Besides, thicker substrate results in higher antenna gain narrowing the main beam and increasing the side lobes. However as the focus is on compact design lower substrate thickness is selected [4].

Following exponential relation explains the taper section:

$$\mathcal{Y} = C_1 e^{\mathcal{R}\mathcal{X}} + C_2 \qquad (1)$$

Where, C_1, C_2 are constants and R the opening rate of the exponential taper.

$$C_1 = (x_2 - x_1) / (e^{Ry_2} - e^{Ry_1})$$

$$C_2 = (x_{1b} e^{Ry_2} - x_2 e^{Ry_1}) / (e^{Ry_2} - e^{Ry_1}) \qquad (2)$$

Note that $(x_2, y_1)$and $(x_2, y_2)$are the coordinates of the origin and end of flare curve, respectively and the taper length L = x_2 - x_1.In the limiting case where approaches zero, the exponential taper results in a so-called linearly tapered slot antenna (LTSA) for which the taper slope is constant and given by s = $(y_2 - y_1)/(z_2 - z_1)$ The selection of a dielectric substrate is one of the most essential features of the design of a Vivaldi antenna. Effective thickness of the dielectric substrate (t_{eff}) need to be defined as follows:[4,9]

$$t_{eff}/\lambda_o = (-1)t \qquad (3)$$

Where, λ_0 is the free space wavelength at the center frequency, t is the thickness and εr is the dielectric constant of the substrate. The essential criteria for a TSA to possess travelling wave antenna characteristics is:

$$0.005 \leq t_{eff}/\lambda_o \leq 0.03 \qquad (4)$$

The micro strip is etched on one side of the substrate and the slot line on the other side of the substrate. The micro strip crosses the slot line and extends one quarter of a wavelength further from the slot line in the same way as the slot line extending one quarter wavelength further from the micro strip. The quarter wavelength micro strip stub is open circuited but appears as a short circuit at the crossing with slot line.

The strip line to slot line transition consists of slots etched on both sides of the substrate and a strip line feeding the slot lines at the center of the substrate. The quarter wavelength stub mechanism of micro strip to slot line transition is also used for this structure. The most important advantage of strip line over the micro strip is the increased bandwidth [5].

The length of the Vivaldi antenna should be longer than one wavelength of the lowest working frequency of the design. An increase in length provides wider bandwidth. These requirements of the Vivaldi antenna guarantee excellent performance in terms of gain, directivity and beam width. In this study, the required bandwidth ranges from 3.5 to 11.5 GHz and the corresponding wavelengths range from26 mm to 85 mm. The width of the Vivaldi antenna should be longer than half of the wavelength ofthe lowest working frequency. A decrease in antenna width provides a wider bandwidth. The initial width is set at 30 mm [6].The geometrical specifications of the antenna are shown in Table 1.

Table 1: Geometrical specifications of the design

Specifications	Dimensions	Specifications	Dimensions
a	45mm	e	4.2mm
b	45mm	f	11.3mm
c	42mm	g	12.1mm
d	13.5mm	r	8.4mm

The geometrical configuration of the proposed compact Vivaldi antenna with the volume 45 ×45×0.46mmis shown in Fig. 1. In the antenna design the balun feed designing plays an important role in controlling the operating frequency.

For the 3.5–11.5 GHz operation, a tapered slot antenna with balun design was developed. The design parameters of the proposed LTSA are shown in Fig. 1. The top layer shows the micro strip line (indicated in red color) used for feeding the tapered slot antenna. The bottom layer indicates the linear taper profile which is defined by the opening rate *R* and it is determined by the first and last point of the antenna. The validity of the proposed design methodology is verified using HFSS which is based on finite element method. The obtained results are compared with the antenna without balun shown in Fig.2. These comparisons make sure that the designed balun is working properly.

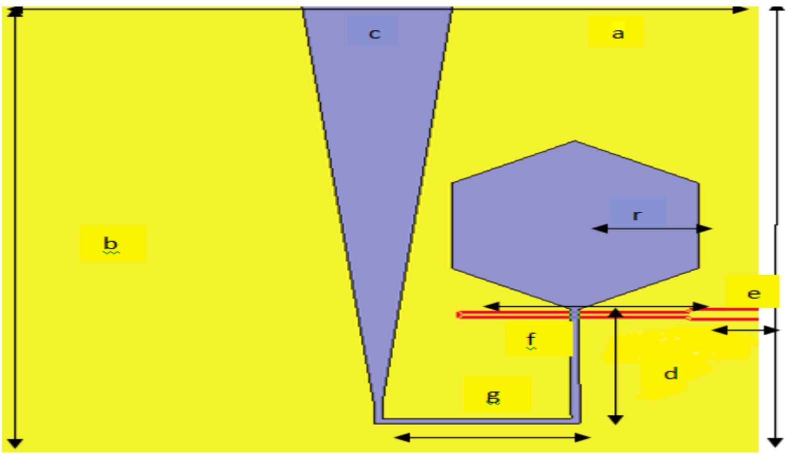


Fig. 1: The geometry of the Vivaldi antenna design

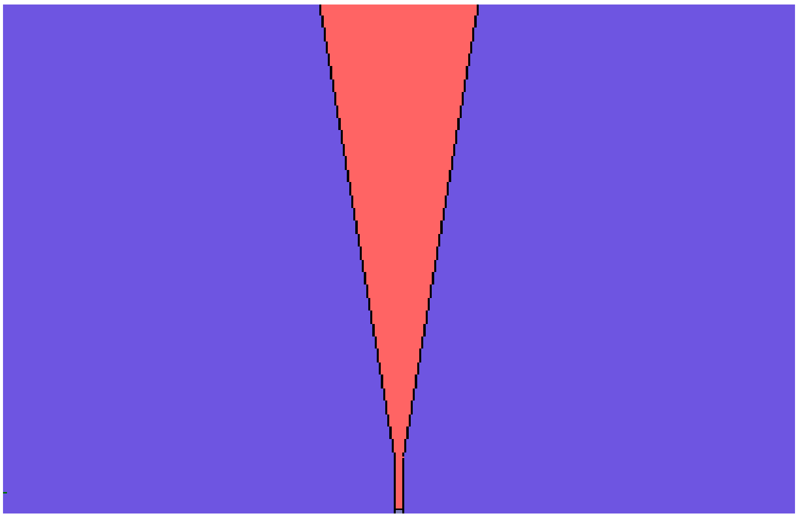


Fig. 2: Vivaldi antenna without balun

III. Simulated Results And Discussions

fig 3: Return loss of vivaldi antenna without balun

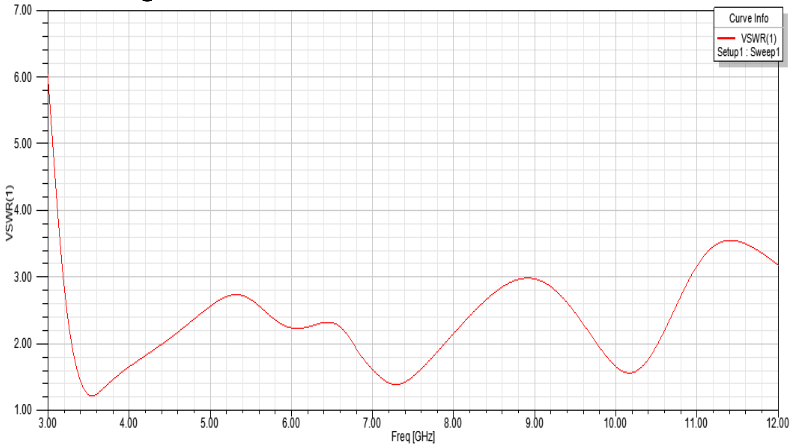
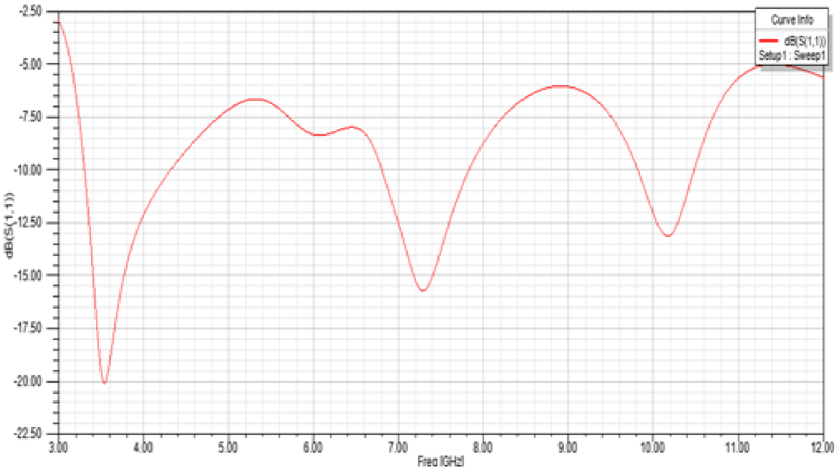


Fig 4: VSWR of vivaldi antenna without balun

From figures 3 and 4 it is evident that the antenna is not working properly because the return loss is not below -10dB in the ultra wide band region also the VSWR is not below value 2. To overcome this we have to balance the antenna output by designing a balun on the antenna.



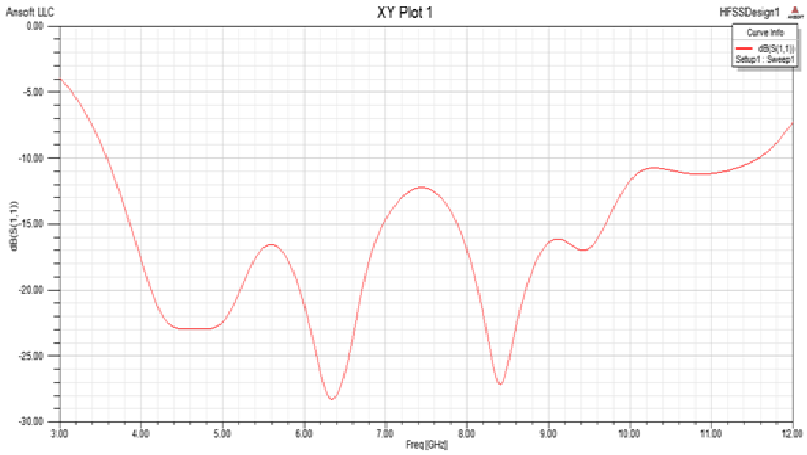


Fig. 5: Simulated return loss of linear tapered Vivaldi antenna

Fig.5displays the simulated return loss versus frequency for the Vivaldi antenna. A return loss less than or equal to -10 dB is acceptable for operation. It is this -10 dB threshold that determines the operational bandwidth. For the Vivaldi antenna, the operational bandwidth extends from 3.5 GHz to 11.5 GHz and the return loss is above -10 dB.

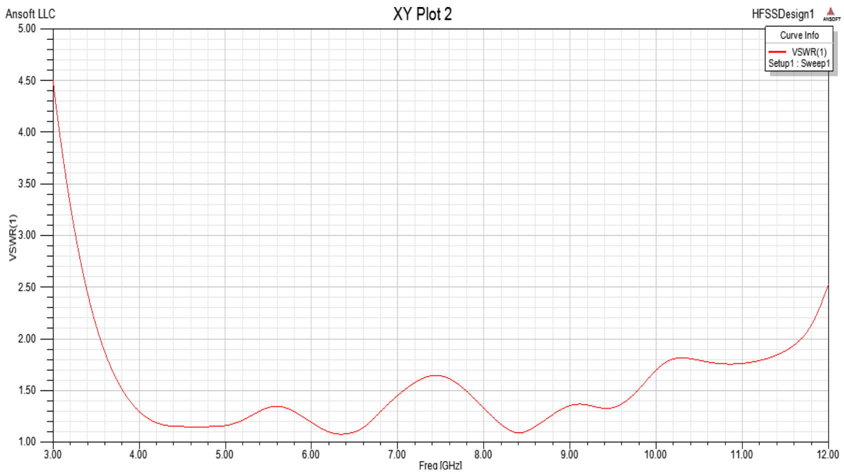


Fig. 6: Simulated VSWR of linear tapered Vivaldi antenna

Then Fig. 6 displays the simulated Voltage Standing Wave Ratio (VSWR) versus frequency for the Vivaldi antenna. A VSWR must be less than 2 in the specified frequency bands for the acceptable operation of an antenna. For the designed antenna VSWR is less than 2 for the frequency range of 3.5 to 11.5 GHz. Table 2 shows the value of S_{11} parameter and VSWR in the operating frequency range.

Table 2 : Simulated return loss and VSWR values

Frequency	Return loss	VSWR
3.5	-10.45	1.93
4.6	-22.94	1.15
5.6	-16.54	1.34
6.3	-28.22	1.08
7.4	-12.22	1.64
8.4	-26.99	1.09
9.1	-16.12	1.37
9.4	-16.88	1.33
10.3	-10.75	1.81
11.5	-10.04	1.95

V. Conclusion

In this paper the design of tapered slot antenna for use in ultra-wideband applications for a frequency range of 3.5-11.5 Ghz has been given. A small tapered slot Vivaldi antenna is designed on Rogers RT/duroid substrate with a dimension of 45 mm×45 mm×.46mm. The designed antenna operates across the entire UWB spectrum. The simulated performance of the proposed design was obtained with electromagnetic software simulator HFSS. Use of Rogers RT/duroid substrate makes the antenna very cost effective. A VSWR below 2 is obtained in the entire operating range. The antenna input impedance or matching impedance can be optimized by changing the dimensions of design. The main application of design include SKA feeding system, see through wall applications etc.

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