Vivaldi Antenna Design using HFSS

Shrihari Mohan[1], Karthikeyan Murugan[2], Naveen Maharajan[3]

[1,2,3] Student, Electronics And Communication Engineering, Sri Sairam Engineering College, Chennai, India

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***Abstract*— The Vivaldi antenna is specified to operate in L-band (0GHz – 2GHz), S-band (2GHz – 4GHz), C-band (4GHz – 8GHz) from the range of 1 GHz to 8 GHz. The elements consist of an exponentially tapered slot, which radiates the wave by travelling wave principle and a microstrip feed line. The transition from microstrip feed line to slot transmission line has been done with microstrip open stub and slot line short stub. The suitable exponential taper has been employed to proper radiation and good impedance matching. This proposed antenna has been designed and optimized for its electrical performance and dimension by means of electromagnetic solver High Frequency Structural Simulator (HFSS). Ansys HFSS is a platform that includes multiple simulation technologies for component or system design. The base HFSS offering includes 3D and Layout interfaces, 2.5D Method of Moments, Eigen mode, and linear circuit simulation. It is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards.**

I. INTRODUCTION

The development in radar technology plays an important role as an application that is widely used for a variety of applications including flight, civil, and medical. Radar technology has the potential and the ability to detect the location and distance of an object, for instance is a cancer cell detection system in medical facilities and Ground Penetrating Radar (GPR) in civil engineering. One of important component in a radar is antenna. In designing an antenna, specification of the antenna will determine the performance of a radar. Some specifications that must be met in a radar antenna are high gain and wide bandwidth. Antenna that can meet these specifications is an ultra-wide band antenna. Ultra-wide band antenna design types can be in the form of Vivaldi antenna.

Radar works by using radio waves that is reflected from the surface of the object. Radar generating electromagnetic energy signal that is focused by the antenna and transmitted into the space. Due to the rapid development of wireless communication, ultra-wide band antennas/systems are becoming highly attractive in many wide band applications, such as broadband wireless communications, ultra-wide and interference, and imaging systems.

Several modifications have been carried out on the basic co-planar TSA structure, resulting in Antipodal Vivaldi antenna (AVA) which consists of two radiating arms on either side of the substrate with 180◦ differential excitation to obtain the best radiation characteristics. The AVA possess some advantages such as ultra wide band performance compared to other Vivaldi antennas.

Keywords: microstrip-fed vivaldi antenna;design parameters; dielectric substrate;resonant frequency;VSWR.

II. PARAMETERS SIMULATION AND RESULTS DISCUSSION

The antenna radiates through an aperture created by a tapered slot between the antenna arms. The investigated antenna was designed for the substrate FR4 Epoxy with

Height(h)= 1.6 mm,
Permittivity f the substrate(ε_r) = 4.4
Frequency(f) = 1 GHz

(A). PARAMETERS:

The parameters that determines the design of the antenna is given below:

The equations for the curve are

X= _u
Y= s*_v* exp(_u*rate)
Z= subT
Start_u =0 End_u=TL
Start_v= -1 End_v = 1

By using the above curve equations, the two curves are drawn.

TL – Tapering length = l/2 = 125 mm
MW- Width of the microstrip = 2.5 mm
ML- Length of the microstrip = 16.5 mm
SL- Slot length = 25 mm
S-Slot width = 1mm
QWS -Quarter wavelength of the slot = 13.5 mm
QWM - Quarter wavelength of the microstrip = 10 mm
Radius of the tapered slot circle= 6.5 mm
Thickness of the patch = 0.049 mm

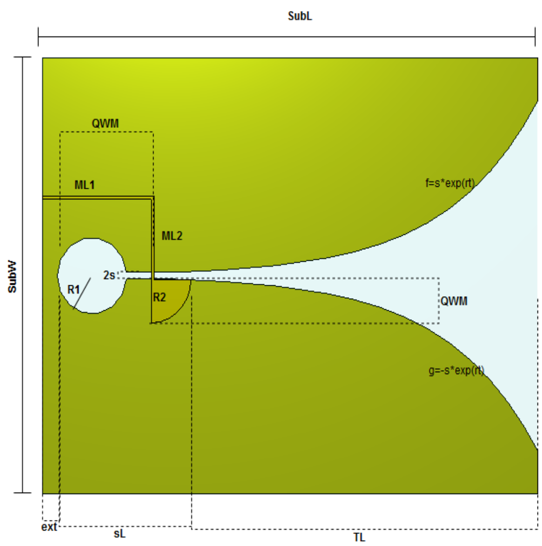

Figure 1. Geometric parameter model of Vivaldi antenna

The designed antenna is the slot microstrip antenna. Slot microstrip antenna is the development of the patch antenna concept which is excited by the stripline channel by releasing the patches and supply channel will radiate directly into the earth field through the slot. Early stage of designing an antenna is determining the characteristics or parameters of the desired antenna.The main advantage of microstrip antenna slot is a wider resulting bandwidth.Microstrip antenna slot also allows the performance of the antenna in circular polarization. The result of initial simulation has a return loss value that is above **-**10 dB in the frequency range of **1-8 GHz**. Figure 2 shows the VSWR of the antenna and Figure 3 shows return loss of antenna at 1-8 GHz.

(B). OPTIMIZATION OF VSWR ENHANCEMENT:

At this step, several modifications have been carried out on the basic co-planar Vivaldi structure resulting in antipodal Vivaldi antenna AVA which consist of **two radiating arms** on either side of the substrate with 180 ◦ differential phase excitation to obtain the best radiation characteristics.

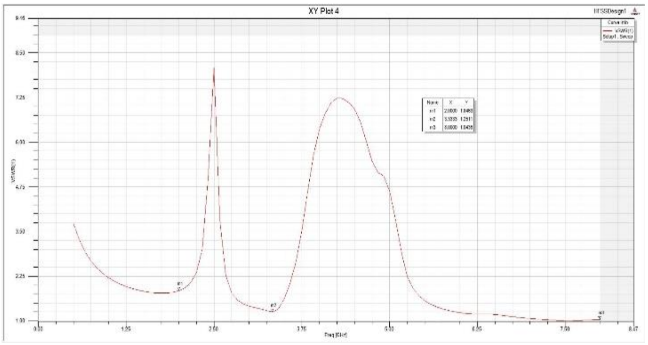

Fig:2 Antenna VSWR based on initial design

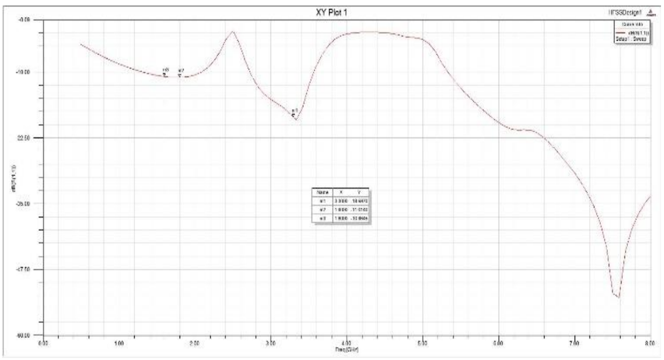

Fig: 3 Antenna Return loss based on initial design

III. DESIGN OF THE ANTENNA AFTER OPTIMIZATION.

At this step, several modifications have been carried out on the basic co-planar Vivaldi structure resulting in antipodal Vivaldi antenna AVA which consist of **two radiating arms** on either side of the substrate with **180** ◦ differential phase excitation to obtain the best radiation characteristics.

DESIGN EQUATIONS:

The description of the design procedure follows:
The lowest operational frequency f_D determines the width of the aperture W1 and the length of the antenna L.

$$W_1 = R_{S1} = L = \frac{c}{f_D}\sqrt{\frac{2}{\varepsilon_r + 1}}\ .$$

Here, c is the velocity of light, and ε_r denotes the relative permittivity of the substrate. The arms of the Vivaldi antenna are ellipses with radii R1 and R2 , R_{S1} and R_{s2}.

$$R_1 = \frac{W_1}{2} + \frac{W_2}{2},$$
$$R_2 = \frac{W_1}{2} - \frac{W_2}{2},$$
$$R_{S1} = W_1 = L,$$
$$R_{S2} = \frac{R_2}{2}.$$

W1 denotes the width of the aperture, W2 denotes the width of the feeding strip and L is the length of the antenna. The dimensions of the radiators are chosen so that the distance between the upper and lower radiator is equal to the effective wavelength of the lowest operational frequency. The length of each antenna radiator is equal to the half of the effective wavelength calculated for the lowest operational frequency. The width of the feeding strip W2 is given by,

$$W_2 = \frac{120\pi}{\sqrt{\varepsilon_r}}\frac{h}{Z_0}$$

W1	182.5 mm
W2	5.7511 mm
W3	3 mm
W4	4.490 mm
W5	30 mm
L	182.5 mm
L1	15.5622 mm
L2	0.9 mm
L3	30.782 mm
L4	229.744 mm
R1	94.1255 mm
R2	88.3744 mm
Rs1	182.5 mm
Rs2	44.1872 mm

Table: 1

Table 1 shows the parameters used to perform the microstrip Vivaldi antenna design that have been obtained based on the literature study.

The antenna was designed for the band of operational frequencies **f1 = 1 GHz to f2 = 8 GHz.**
The transition from the balanced twin-line to a coaxial unbalanced feed point is implemented using a linear microstrip taper. The unbalanced end of the tapered balun resembles a microstrip line of width W3 (**Z0 = 50 Ω**) over a finite ground plane of width W5. In order to approximate an ideal microstrip line, the ground plane must be much wider than the metallic strip. In the proposed design, the ratio of **W5 /W3 = 10**. The width W4 depends on the opening angle of the strip, which is equal to α = 6˚. The length **L1 = 0.182 λ_g** and the length **L3 = 0.36 λ_g** where, λ_g is the **wavelength** on the substrate **FR4 Epoxy**.

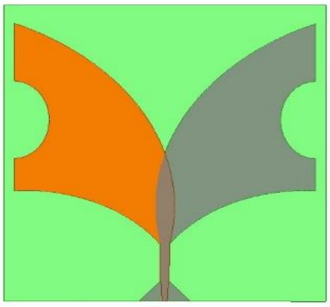

Fig: 4 Top view of antenna model after optimization

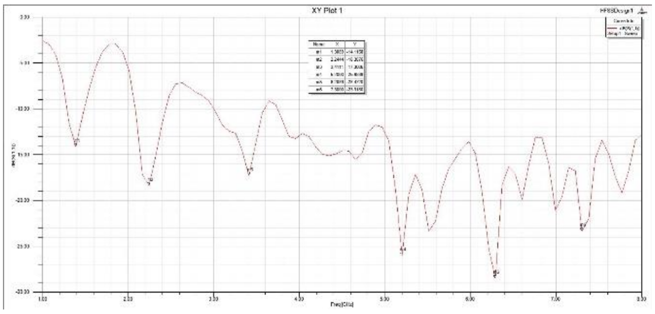

Fig: 5 Antenna return loss after optimization

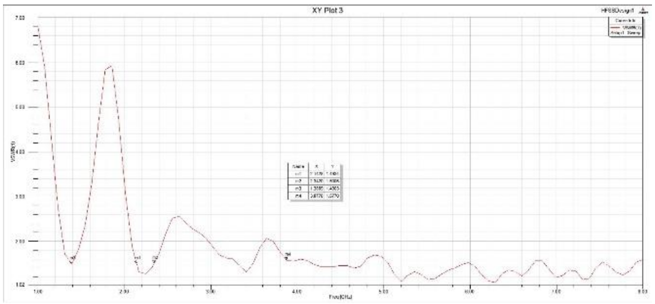

Fig: 6 Antenna VSWR after optimization

IV. CONCLUSION

In this paper, a summary of the effects of different parameters sizes on the antenna was presented. Based on the above results analyses, the conclusions are as follows:

1. Increasing the flare length and the width of slot will move the resonant frequency to low frequency, and the performance of the low frequency transmission is improved, while the high frequency is vice versa.

2. Increasing the substrate thickness and dielectric constant will make the antenna size smaller. On the contrary, a wider bandwidth can be achieved by reducing both, and better radiation efficiency and gain can be achieved in the operating band.

3. A better microstrip-fed Vivaldi antenna design can be obtained by appropriately decreasing substrate thickness and dielectric constant, increasing the flare length and the width of slot. We also designed and manufactured a microstrip-fed Vivaldi antenna for **1-8 GHz** which is used in stepped frequency continuous wave radar.

RESULTS:

1. Vivaldi microstrip antenna that works at a frequency of **1-8 GHz** have a stable directional radiation pattern with a bandwidth of **7 GHz**, **VSWR ≤ 2** and a gain of **7 dB.**
A good agreement between simulated and measured results illustrates that the proposed antenna is a good candidate for ultra-wideband measuring systems or other communication applications.

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