Characterization of Printed Podal Vivaldi Antennas (8-18 Ghz) on Rt Duroid With Single and Double Cavity

P.Venu Madhav, M. Siva Ganga Prasad

Abstract: ***In today's modern communication systems, miniaturized and light weight sub-systems covering broad bandwidth are in much demand as they lead to realization of very compact and light weight systems. To accomplish this, small and light weight antennas which cover wide bandwidth without much degradation in their performance are required to be designed and realized. A printed podal Vivaldi antenna with single as well as double cavities fed with strip line transmission line and operating from X band to K_U band (8-18GHz) is proposed. The strip line transmission line is used in order to prevent the propagation of unwanted modes. The current distribution over both the radiating surfaces will be similar thereby maintaining the symmetry in radiation patterns. The comparison of antenna performance for single cavity and double cavity is also reported in this paper. Using double cavity, the miniaturization of antenna is possible as compare to single cavity Vivaldi antenna. The antenna is first designed using conventional theoretical approaches. Later simulated using 3D EM simulation software, CST Microwave Studio^{TM}. Optimization of antenna's various parameters are carried out to achieve the optimum values. Finally, the optimum design is physically fabricated using PCB technology for carrying out practical measurement. The antenna's input impedance characteristic is measured in the form of S-parameter and VSWR using Vector Network analyzer. VSWR less than 3:1 is achieved over the band from 8 GHz to 18 GHz. The radiation patterns measurements are carried out in Anechoic chamber. The proposed Vivaldi antenna is used for digital data transmission via satellites and for voice/audio transmissions.***

I.INTRODUCTION

The recent technology explosion in wireless communications has created many openings for enhancing the performance of systems under existing and new devices. Thus, providing a strong motivation for developing novel devices and systems.

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An indispensable element of any wireless communication system is the antenna. Transmission of data at higher rates requires wider bandwidths for the elements constituting a communication link. The requirement for the antenna which is the subject of interest in this thesis means wideband antennas need to be designed and used.

In today's modern communication systems, miniaturized and light weight sub-systems covering broad bandwidth are in much demand as they lead to realization of very compact and light weight systems. To accomplish this, small and light weight antennas which cover wide bandwidth without much degradation in their performance are required to be designed and realized. As antenna dimensions are governed by wavelength of operating frequency, antenna miniaturization is a challenging and difficult task. Planar / Printed antennas offers good solutions for the above class of problem. Vivaldi radiators are superior in many applications due to high gain, simple structure and easy manufacture [1]and broadband applications. Printed antennas are being increasingly used as they are low profile and can be integrated on any printed circuit easily.

The effects of co channel intrusion and multipath losses in wireless communication systems can be condensed by using antennas which propagate in uni-direction. Point-to-multipoint [2] systems use horn antennas for this reason, but horn antennas are large to be integrated with the system and also effects high cost of fabrication. Vivaldi antenna offers higher bandwidth and gain that make them to be widely used in commercial and military application. The TSA's (Vivaldi radiator) have been extensively used in phased and active arrays for radar systems because of the following reasons.

- Broadband operation
- Moderate gain
- Low sidelobes

II.PROBLEM DEFINITION

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Theobjective Is To Design the single cavity and double cavity Vivaldi antenna operating from 8 GHz to 18 GHz frequency to achieve VSWR less than 3:1 and comparison of antenna performance for single cavity and double cavity Vivaldi antenna.

III.VIVALDI ANTENNA DESIGN

The Vivaldi antenna is printed on both sides of the substrate with a dielectric constant, $\varepsilon r = 2.2$ and thickness of the substrate is h = 0.508mm. The procedure to be followed for creating a new project is discussed below. Model the proposed antenna with the dimension arrived from theoretical calculations. The length and width of the antenna has to be optimized is define as variables.

The objective of this paper is to compare Vivaldi antennaswhich have single cavity[4] and double cavity. The length and width of the single cavity Vivaldi antenna are 38.5 mm and 15 mm respectively. Fig.1. (a) & (b) shows the front and back view of simulated design of single cavity Vivaldi antenna which is excited using strip line[6] shown in Fig.1 (c).

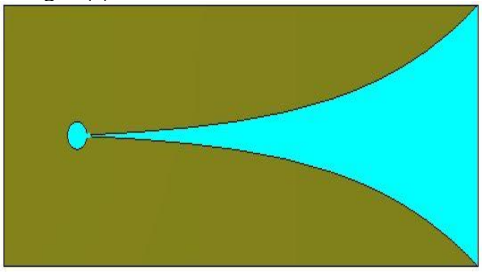

Fig.1 (a): Front view of single cavity Vivaldi antenna

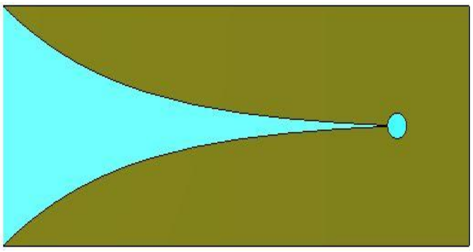

Fig.1 (b): Back view of single cavity Vivaldi antenna

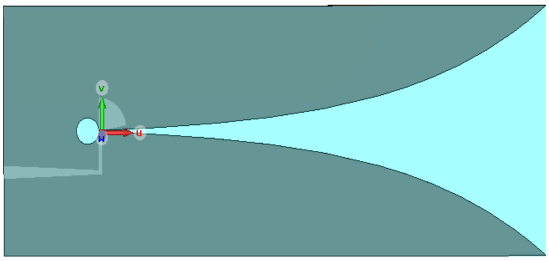

Fig.1 (c): Feeding arrangement of single cavity Vivaldi antenna

The double cavity Vivaldi antenna[3] is compared with this single cavity Vivaldi antenna. The size of single cavity antenna is more than the double cavity antenna, the stub angles of tapered strip line feed also change. The length and width of double cavity Vivaldi antenna are 37.5 mm and 15 mm respectively. Fig.2 (a), (b) &(c) show the front view, back view and feeding arrangement of double cavity Vivaldi antenna.

Parameter values for single cavity antenna is same as double cavity parameter list except some parameters are

Stub start angle = 90°
Stub angle = 80°
Taper length = 6.86455
Cavity diameter = 1.582

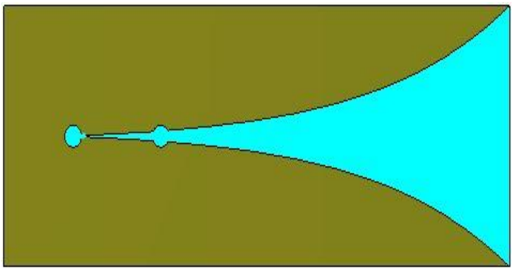

Fig.2 (a): Front view of double cavity Vivaldi antenna

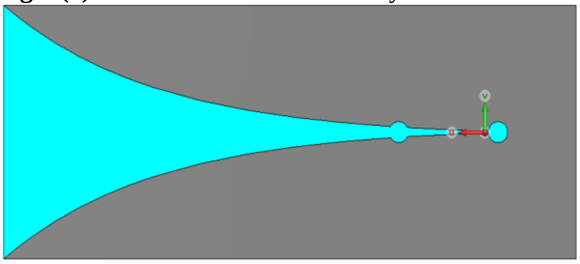

Fig.2 (b): Back view of double cavity Vivaldi antenna

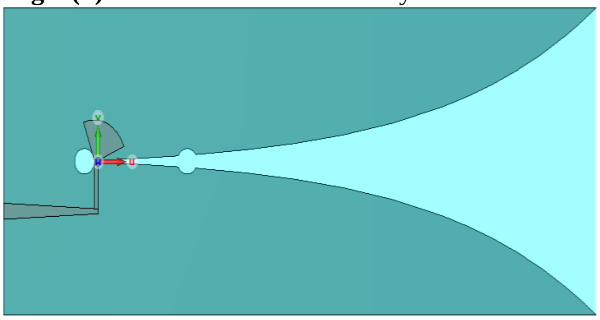

Fig.2 (c): Feeding arrangement of double cavity Vivaldi antenna

The VSWR-Frequency plot for the Vivaldi antenna without SMA connector seems to have a high VSWR, which means the reflection of power is more and also the reflected wave amplitude is high from frequency 8 GHz to 18 GHz.

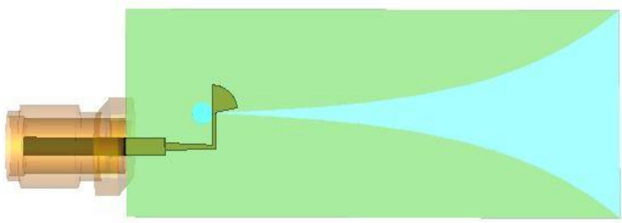

Fig.3 (a): Single cavity Vivaldi antenna with SMA connector

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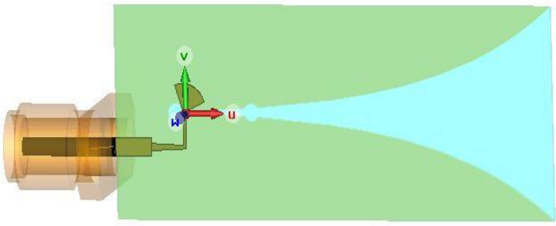

Fig.3 (b): Double cavity Vivaldi antenna with SMA connector

In order to lower the VSWR, a connector is attached to the antenna for the required band of frequencies. The above Fig.3 (a) and Fig.3 (b) shows the simulated single cavity Vivaldi antenna and double cavity Vivaldi antenna with SMA connector in CST software respectively. The designed SMA connector in CST software is shown in below Fig.3.

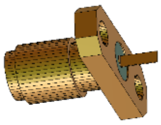

Fig.3: Design of SMA connector in CST Software

IV.FABRICATED VIVALDI ANTENNA

The single cavity and double cavity Vivaldi antenna operating from 8 GHz to 18 GHz are fabricated individually on the substrate. The two substrates are joined to form a dual layered Vivaldi antenna [4] for both cavities separately. FR4 substrate is used. Phase velocity of the propagating surface wave determines radiation performance. The radiation pattern and performance are dependent upon substrate thickness and dielectric constant. The primary outcome of the dielectric substrate is the thinning of the main beam of the antenna. Low dielectric constant substrates exploit the antenna radiation by reducing the dielectric discontinuity at the termination of the TSA [3].

Fig 4 (a) & Fig.4 (b) are shows the fabricated single cavity Vivaldi antenna and double cavity Vivaldi antenna respectively. These two antennas are tested individually.

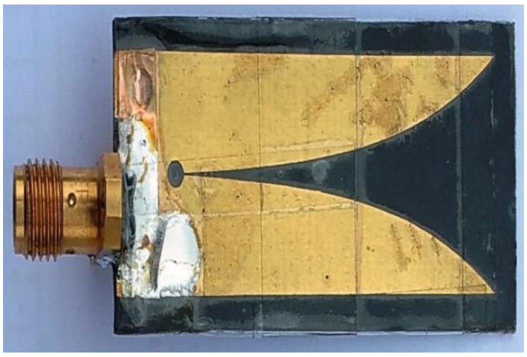

Fig.4(a): Fabricated Single cavity Vivaldi antenna

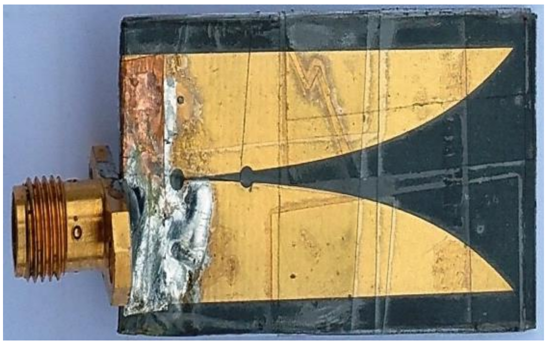

Fig.4(b): Fabricated Double cavity Vivaldi antenna

V. RESULTS

A.Vswr

The numerical simulation of directional antenna is done using CST software. The performance of the antenna does not improve monotonically as the parameters of the antenna changes. It must be optimized through analysis during simulation to get the optimum parameters.

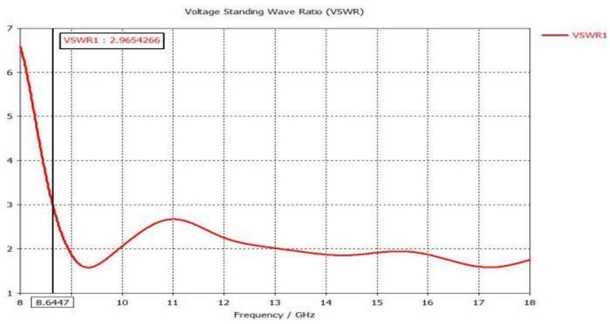

Fig.5 (a): Simulated VSWR for single cavity Vivaldi antenna without SMA connector

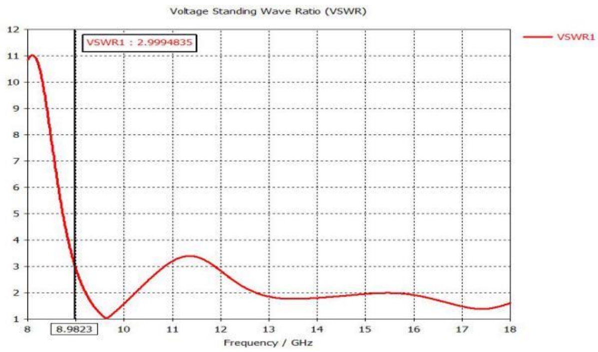

Fig.5 (b): Simulated VSWR for double cavity Vivaldi antenna without SMA connector

The simulations for Vivaldi antenna operating in the band 8 GHz to 18 GHz are done using CST. The obtained VSWR simulation results for the respective antenna are as shown in the Fig.5 (a) and Fig.5 (b).

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As shown in the Fig.5 (a) and Fig.5 (b), the VSWR-Frequency plot for the Vivaldi antenna without SMA connector seems to have a high VSWR, which means the reflection of power is more and the reflected wave amplitude is high from frequency 8 GHz to 18 GHz.

To lower the VSWR, a connector is attached to the antenna for the required band of frequencies. The above Fig.6 (a) and Fig.6 (b) shows the VSWR with SMA connector in CST software for single cavity and double cavity respectively.

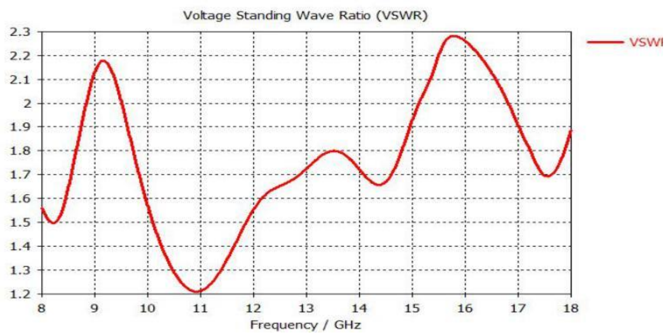

Fig.6 (a): Simulated VSWR for single cavity Vivaldi antenna with SMA connector

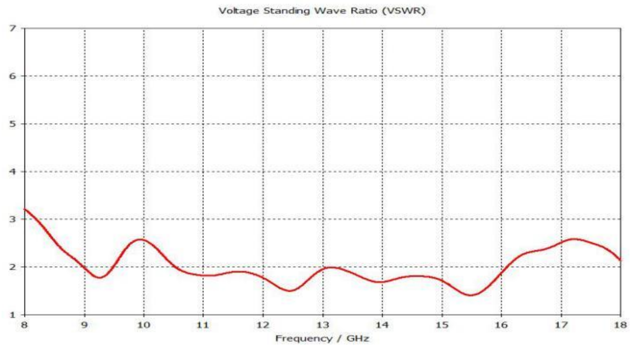

Fig.6 (b): Simulated VSWR for double cavity Vivaldi antenna with SMA connector

B. Return Loss

The obtained Return loss simulation results for the single cavity Vivaldi antenna and double cavity Vivaldi antenna are as shown in the Fig.7 (a) and Fig.7 (b) respectively.

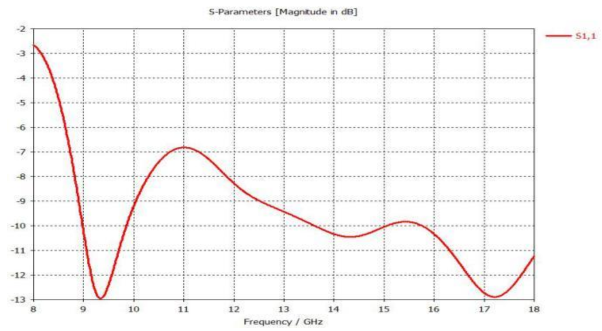

Fig.7 (a): Simulated Return loss for single cavity Vivaldi antenna

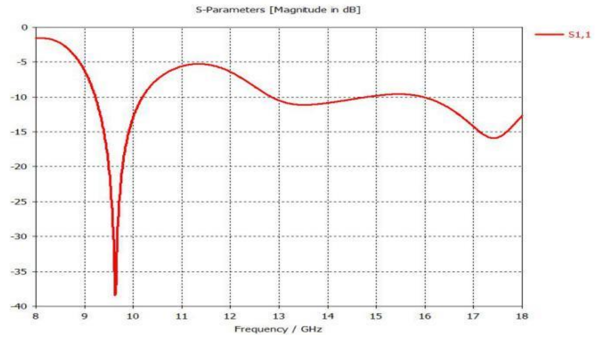

Fig.7 (b): Simulated Return loss for double cavity Vivaldi antenna

C. Radiation Pattern

The simulated 3D radiation patterns of printed Vivaldi antenna for single cavity and double cavity at frequency of 14 GHz is shown in Fig.8 (a) and Fig.8 (b) respectively.

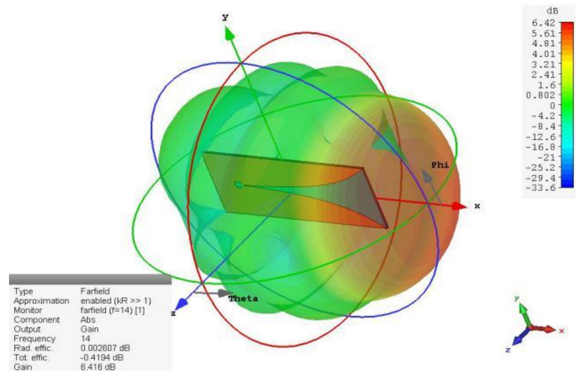

Fig.8 (a): 3-D radiation pattern of single cavity Vivaldi antenna at 14 GHz

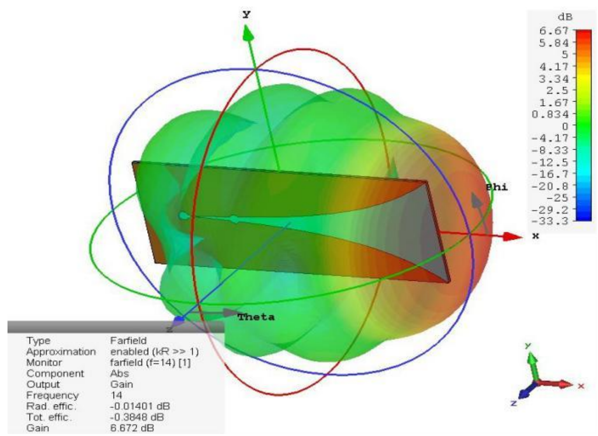

Fig.8 (b): 3-D Radiation pattern of double cavity Vivaldi antenna at 14 GHz

D. Plane Patterns

For linearly polarized waveguides, antennas and other microwave devices the E-plane and H-plane are taken as the

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reference planes. The E-plane and H-plane patterns are also called as the polar plots or gain plots.

E. E-Plane

The E-plane (XY-plane at θ=90°) radiation patterns at different frequencies from 8 to 18 GHz for single cavity and double cavity are as shown in the Fig.9(a) and Fig.9(b) respectively.

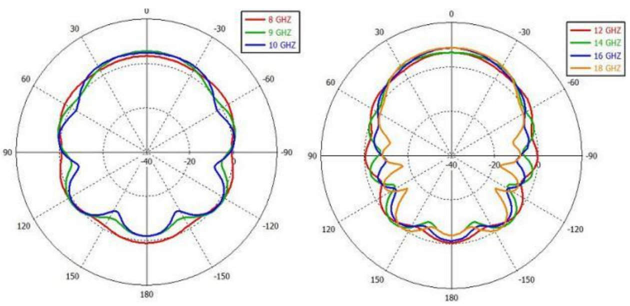

Fig.9 (a): E plane patterns for single cavity Vivaldi antenna

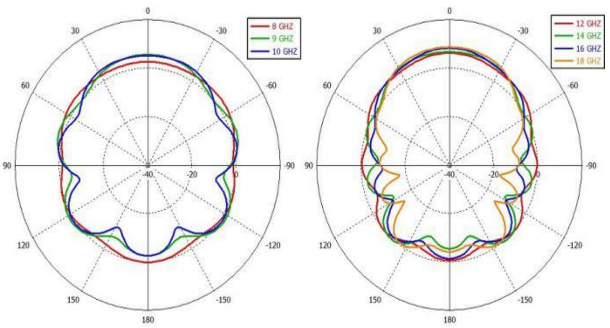

Fig.9 (b): E plane patterns for double cavity Vivaldi antenna

F. H-Plane

The H-plane (ZX-plane at ϕ=0°) radiation patterns at different frequencies from 8 to 18 GHz for single cavity and double cavity are as shown in the Fig.10(a) and Fig.10(b) respectively.

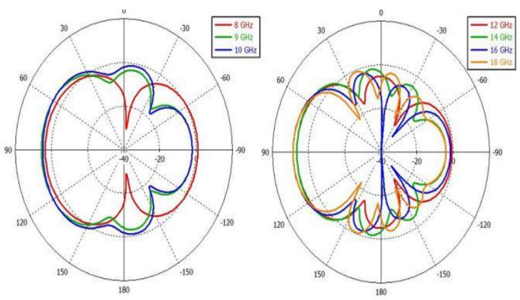

Fig.10 (a): H plane patterns for single cavity Vivaldi antenna

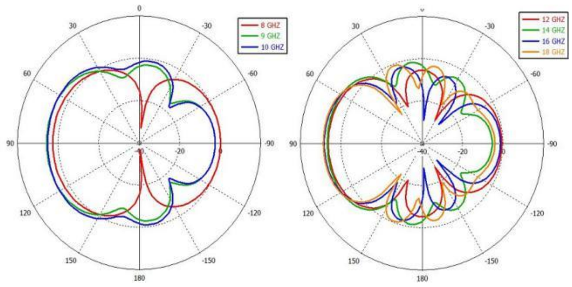

Fig.10 (b): H plane patterns for double cavity Vivaldi antenna

H. Gain of the Antenna

The Transfer method is used for the gain measurement. In this technique the standard gain antenna which is known is used to determine the test antenna. The simulated gain of single cavity Vivaldi antenna varies from 3.36dBi to 8.55dBi over the design frequency band as shown in Fig.11 (a). The simulated gain of double cavity Vivaldi antenna varies from 2.62dBi to 8.65dBi over the design frequency band as shown in Fig.11 (b).

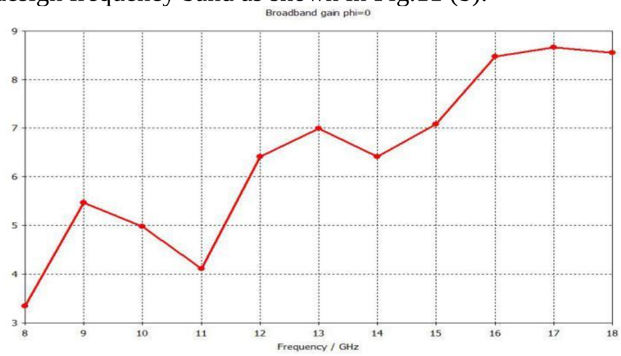

Fig.11 (a): Simulated gain plot of single cavity Vivaldi antenna

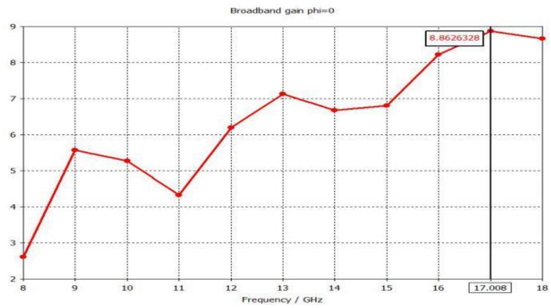

Fig.11 (b): Simulated gain plot of double cavity Vivaldi antenna

For measuring the gain of the Antenna Under Test (AUT), formula is given by

Gain of AUT (dB) = Antenna power (dB) - Reference antenna power (dB) + Gain (Reference antenna)

The measured gain plots of single cavity Vivaldi antenna and double cavity Vivaldi antenna are shown in Fig.12 (a) & Fig.12 (b) respectively.

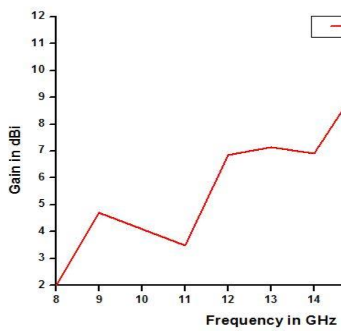

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Fig.12 (a): Measured gain plot of single cavity Vivaldi antenna

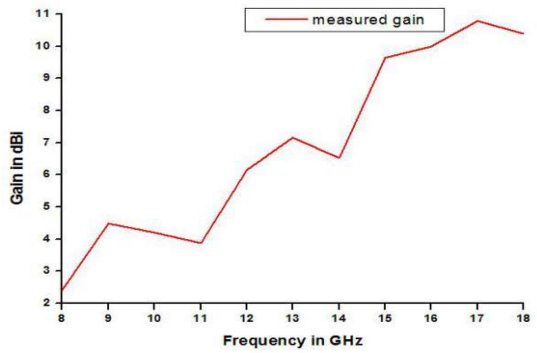

Fig.12 (b): Measured gain plot of double cavity Vivaldi antenna

Finally, single cavity Vivaldi antenna gives the efficient impedance bandwidth than the double cavity Vivaldi antenna.

V.CONCLUSION

The comparison of antenna performance for single cavity Vivaldi antenna and double cavity Vivaldi antenna are reported. The single cavity and double cavity have same performances, but single cavity gives efficient impedance bandwidth than the double cavity. The gain of double cavity is better than single cavity at higher frequencies and antenna miniaturization also possible. The simulated and measured results of the proposed antenna were compared and found to be in good agreement. The optimum performance of the antenna in simulation is obtained by using parametric analysis. VSWR less than 3:1 is achieved over the band from 8 GHz to 18 GHz. The antenna due to its compactness and light weight serves its applications in radio communications, avionics, spectrum monitoring and military system. It also finds applications in digital data transmission via satellites and for voice/audio transmissions.

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