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Analysis and Design of a Novel Multi Taper Slotted Vivaldi Antenna for Enhancing Directivity

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Abstract: Vivaldi antenna also known as end-fire tapered slot antenna (TSA) is a kind of tapered slot antenna works on the principle of travelling wave antennas having exponential tapered profile, which provide large bandwidth and end-fire radiation patterns with low profile is a good candidate. This single tapered slot end-fire vivaldi antenna (STSVA) possess low directivity. Hence there is a need to improve the directivity without altering the aperture space. This work proposes a novel structure of multi tapered slots of vivaldi antenna without altering the dimension of the aperture area which provided lower HPBW compared to STSVA. The multi-slot structure generates plane-like waves in the End fire direction. This further enhanced directivity of the multi-slot Vivaldi antenna. The simulated results show that impedance bandwidth of the multi tapered -slot Vivaldi antenna is from 2 to 18GHz.

Keywords: Multi tapered slots, Directivity, Half Power Beam Width (HPBW) and Aperture area.

I. INTRODUCTION

The first Vivaldi antenna invented in 1980's by Gibson. After several failures the antenna design pointed at V-shaped Linear Tapered slot antenna. Antennas operating in UWB with compact size, stable end-fire radiation patterns, and high gain has lots of applications like radar, microwave imaging, remote sensing, and UWB communication systems. To reach the above achievements, Vivaldi antenna also known as end-fire tapered slot antenna (TSA) is a kind of tapered slot antenna works on the principle of travelling wave antennas having exponential tapered profile, which provide large bandwidth and end-fire radiation patterns with low profile is a good candidate. Vivaldi is one of the end fire radiator that offers wide bandwidth. A conventional Vivaldi antenna provides poor directivity at low frequencies. So, there is a need to improve the directivity of the Vivaldi antenna without altering the bandwidth of operation. There are some approaches proposed to improve the directivity.

(i) By making an array of Vivaldi [3] is one of the conventional way to obtain high directivity, but it is complicated, costly, and bulky. (ii) Another method is to place a "director" in the aperture of the tapered slot, so that this director can focus the energy in the end fire direction for improving the directivity. The "director" can be made of a dielectric that has a higher permittivity than the antenna substrate [8] or anisotropic zero-index metamaterials on both sides of the antenna substrate [9]. (iii) A method having photonic band-gap structure that can be formed by micromachining the substrate with holes [6]. But this method is complicated as it requires optimizing the parameters of the holes and metal strips.

This work proposes a novel structure of Multi tapered slot antenna that has two or three or four slots with asymmetrical tapers. This introduces a novel Vivaldi antenna with 1,2,3,4 slots i.e. it has the single, dual, Triple and Quad asymmetrically exponential tapered slots. This structure of antenna is named as Multi Exponential Tapered Slot Antenna. (METSA). By using a T-junction power divider, these two or more slots are excited in uniform amplitude and phase. Parametric analysis of Multi-exponentially tapered slot Vivaldi antenna is done by varying the tapered slot length. Dielectric substrates with different relative permittivity's are used to analyze the effects of directivity and gain of Multi-exponentially tapered slot Vivaldi antenna.

The proposed Vivaldi antenna find many applications in UWB and EW. The Multi-slotted structure of Vivaldi antenna makes the distribution of aperture field at the end of the antenna more uniform, hence the gain of the double-slot structure of Vivaldi Antenna become higher than that of a conventional Vivaldi antenna with the same size. The Vivaldi antenna is simulated in the software (HFSS 13v) and fabricated on PCB. SIW technique takes the advantages of high -factor, low loss, mass-producible and easily be integrated with other planar circuits. There are different modes of H or E-Plane initiated, even at higher frequencies up to 18GHz can simulate the antenna in HFSS Software.

METSVAs provide wider bandwidth, Less HPBW and improved pattern characteristics compared to STSVA. Different types of slot Vivaldi coplanar models and other tapered slotted antennas configure the antenna at different frequencies. Generally, UWB application operates in

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between S, C & X–band. Finally, Designing the antenna exponentially tapering initiated and maintenance higher impact on the Vivaldi antenna.

II. MULTI TAPERED SLOT VIVALDI ANTENNA MODEL & DESIGN:

The different Tapered Slotted End-fire Vivaldi antenna as Shown in figure below. It gives clear idea about structures, half power beam width, Gain and Impedance bandwidth.

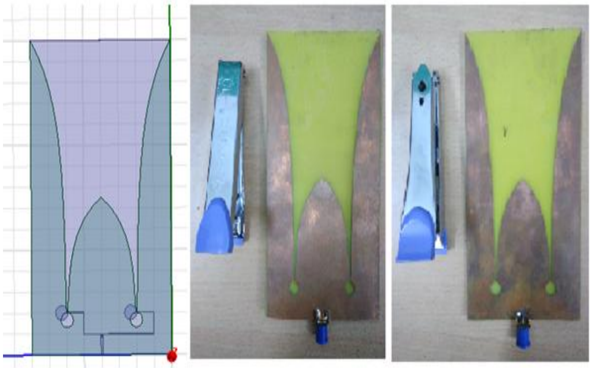

Fig1: Fabricated Dual Exponential Tapered Slot Vivaldi antenna

This DETSVA consists of two exponential tapered slots. The structure is designed on two Fr4 epoxy Substrates and each having thickness is 0.8mm permittivity (ε_r) 4.4 and size $150\times80mm^2$. i.e., Lower cost and Most Available Material. Coming to the design, design Equation is the Main Heart of the Antenna and moreover Equation analysis is given below.

$$Ex1: y = \frac{1}{2} * \left(W1 - g * \exp\left(\ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right)\right) 0 \le x \le l1$$

$$Ex2: y = \frac{1}{2} * \left(g * \exp\left(\ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right) - W1\right) 0 \le x \le l1$$

$$Ex3: y = \frac{1}{2} * \left(W1 + g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * \frac{x}{l}\right)\right) 0 \le x \le l$$

$$Ex4: y = \frac{1}{2} * \left(-W1 - g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * \frac{x}{l}\right)\right) 0 \le x \le l$$

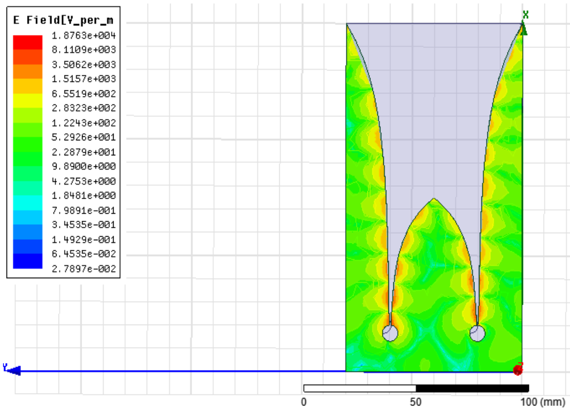

Fig2: E-field of DETSVA

On the one side of the substrate of Antenna, exponential tapered slot is designed with one end of the slot is a circular cavities and other end is opened. The cavity act as an open circuit that minimizes the reflections from microstrip line to slot-line transition. As well as two side of substrate with same exponential tapered slot designed.

Table1: Structure Parameters of the Vivaldi antenna

Parameters	Values(mm)
W	80
l	150
W1	40
l1	70
g	0.2
R_1	3.5
R	3.5

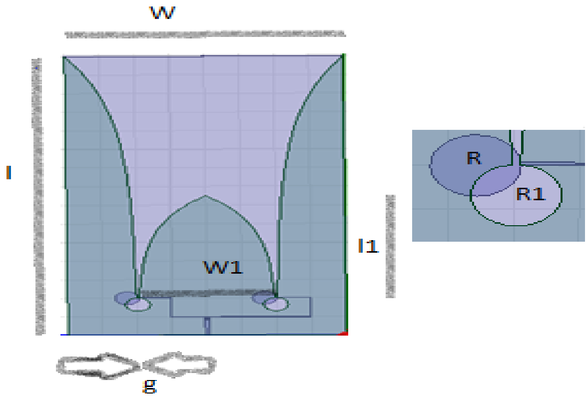

Fig3: Proposed Structure for DSVA.

Strip Line Transitions is used to feed the both antennas. A T- Junction between two Slotted Antennas which Varies Impedance from 100Ω to 50Ω as shown in the Fig1.
The Triple Exponentially Tapered slotted vivaldi antenna (TETSVA) is arranged like DETSVA. But, two tapered slots are kept between the Exponentials (l) which are varied from 25 mm to 150 mm and tapered slot length (l1) from 25mm to 75mm respectively as shown in the figure.

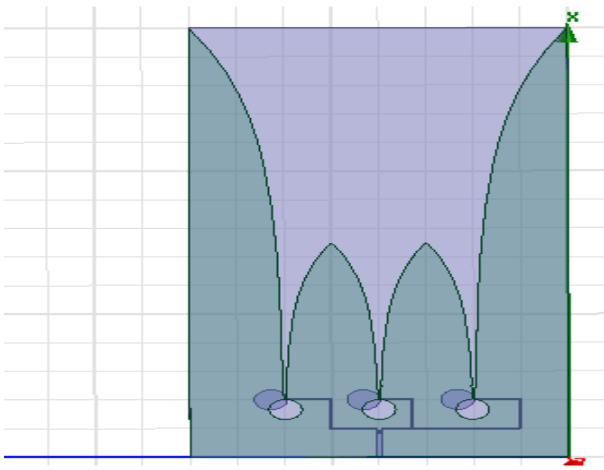

Fig4: Triple exponentially Tapered Slot vivaldi antenna

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The directivity of the TETSVA Decreases while comparing to DETSVA i.e., less directivity.

The equations of Triple Exponential Tapered Slot vivaldi antenna minimize the tapered slot length half of the DETSVA as given below.

$$Ex1: y = \frac{1}{2} * \left(W1 - g * exp\left(ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right)\right) 0 \leq x \leq l1$$

$$Ex2: y = \frac{1}{2} * (\frac{1}{2} * (g * exp\left(ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right) + W1)) \quad 0 \leq x \leq l1$$

$$Ex3, Ex4: y = \frac{1}{2} * \left(\frac{1}{2} * \left(g * exp\left(ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right) + W1\right)\right) \quad 0 \leq x \leq l1$$

$$\text{Ex5}: y = \frac{1}{2} * \left(\frac{1}{2} * \left(-W1 + g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * \frac{x}{l}\right)\right)\right) 0 \leq x \leq l$$

$$\text{Ex6}: y = \frac{1}{2} * \left(-W1 - g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * \frac{x}{l}\right)\right) 0 \leq x \leq l$$

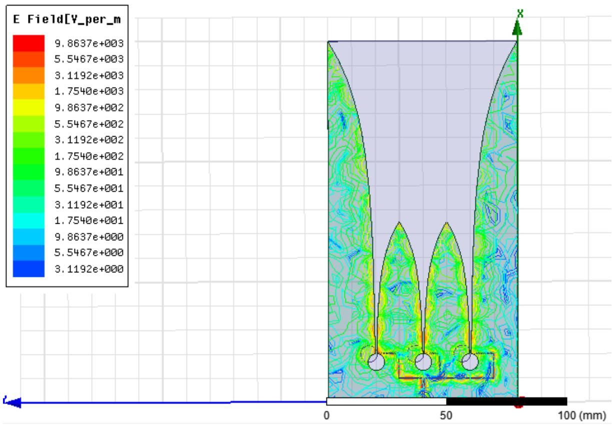

Fig5: E-field of TETSVA

For Quad Exponential Tapered slot vivaldi antenna is co-planar to DETSVA and QETSVA which maintains four tapered slots length, where the middle tapered slots length from varies 25mm to 75mm is shown in below figure.

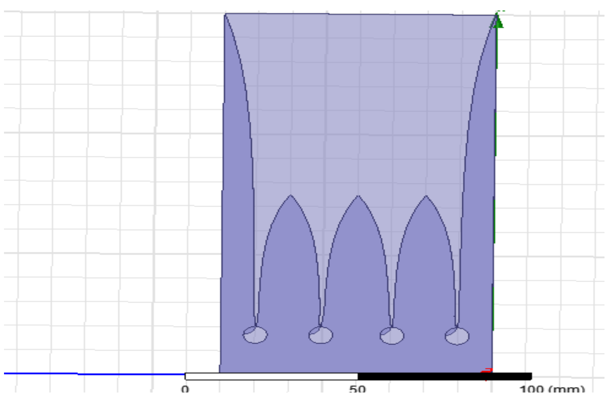

Fig6: Quad exponential Tapered slot end-fire vivaldi antenna

The equations of QETSVA minimizes by one-third of the tapered slot length of DETSVA is given as follows

$$\text{Ex1}: y = \frac{1}{2} * \left(W1 - g * \exp\left(\ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right)\right) \quad 0 \leq x \leq l1$$

$$\text{Ex2, Ex3}: y = \frac{1}{3} * (\frac{1}{2} * (g * \exp\left(\ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right) + W1)) \quad 0 \leq x \leq l1$$

$$\text{Ex4, Ex5}: y = \frac{1}{3} * (\frac{1}{2} * \left(g * \exp\left(\ln\left(\frac{W1}{g}\right) * \frac{x}{l1}\right) + W1\right)) \quad 0 \leq x \leq l1$$

$$\text{Ex6, Ex7}: y = \frac{1}{3} * (\frac{1}{2} * \left(-W1 + g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * xl\right) \right) \quad 0 \leq x \leq l$$

$$\text{Ex8}: y = \frac{1}{2} * \left(-W1 - g * \exp\left(\ln\left(\frac{W-W1}{g}\right) * \frac{x}{l}\right)\right) 0 \leq x \leq l$$

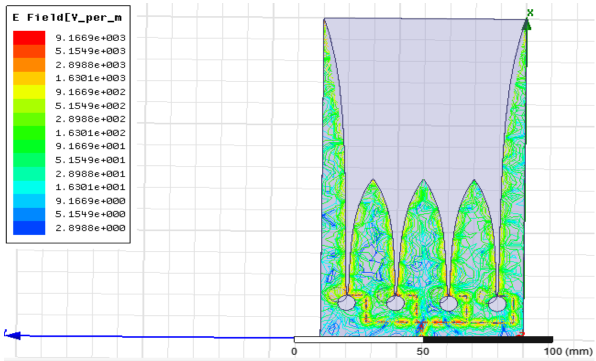

Fig7: E-field of QETSVA

Observed that when the tapered slots are loaded on the surface of the antenna then surface current is concentrated on the inner edge of the exponential tapering and add to the radiation in bore sight direction. Since the aperture length act like resistive loading therefore less current configuration is observed in the aperture length region while more current near edges of the tapered slot.

III. RESULTS

A.Return Loss:

The Obtained Return loss of the DETSVA, TETSVA, and QETSVA improved under -10db from 2GHz to 18Hz as shown in the Figure below.

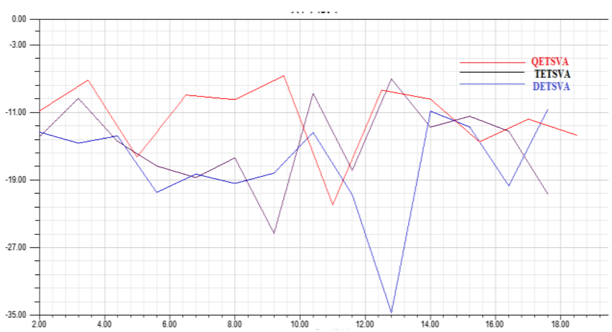

Fig8: Return loss of DETSVA, TETSVA and QETSVA

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A prototype DETSVA is fabricated and measured result of return loss is given below.

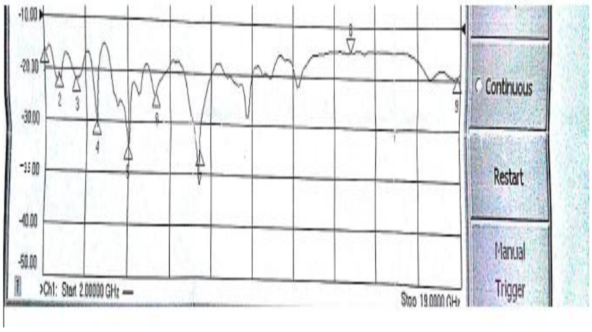

Fig9: Fabricated DETSVA return loss

B. Gain(3D):

The Obtained result of Gain 3D of DETSVA, TETSVA and QETSVA measured the pattern and polar plot as shown in Figure below. The pattern plotted specifies the end-fire type directional landscape of the antenna.

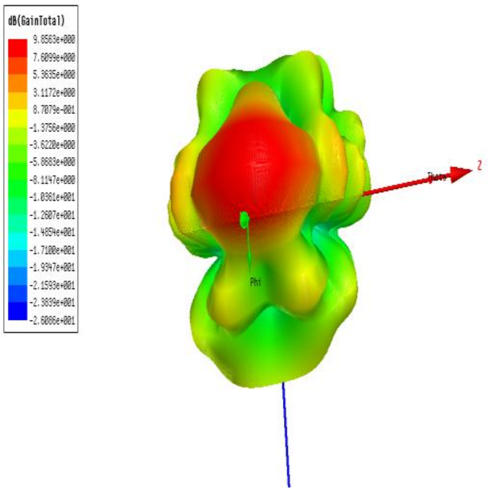

Fig10:3D-Gain of DETSVA with theta= 90 deg and phi= 0 deg

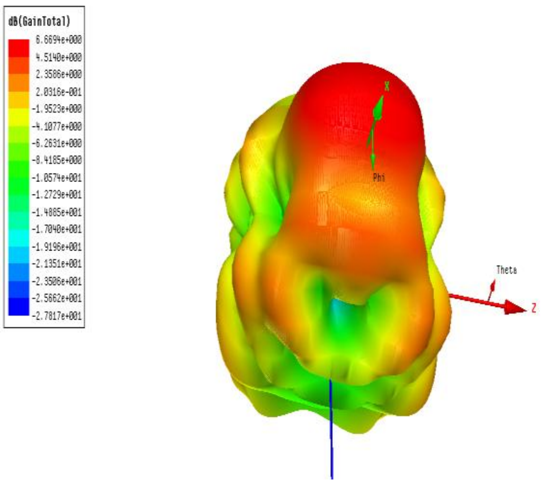

Fig11:3D-Gain of TETSVA with theta= 90 deg and phi= 0 deg

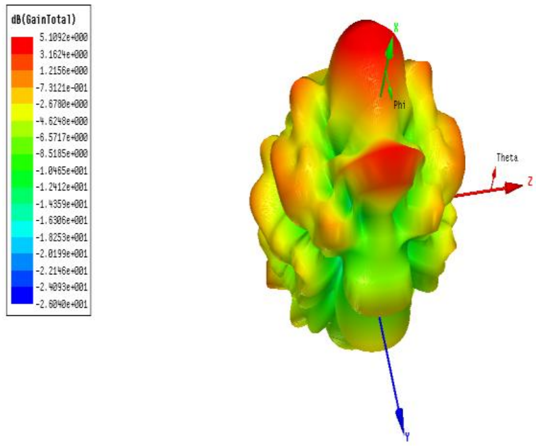

Fig12: 3D-Gain of QETSVA with theta= 90 deg and phi= 0 deg

C. Beamwidth

The Beamwidth of Multi tapered slot antennas are TSVA, DETSVA, TETSVA and QETSVA is observed at center frequency 9GHz as show in the Figures below.

Table2: HPBW

Number of tapered slots	Type of antenna	HPBW in deg.
1	STSVA	101.88
2	DETSVA	41.50
3	TETSVA	34.80
4	QETSVA	32.70

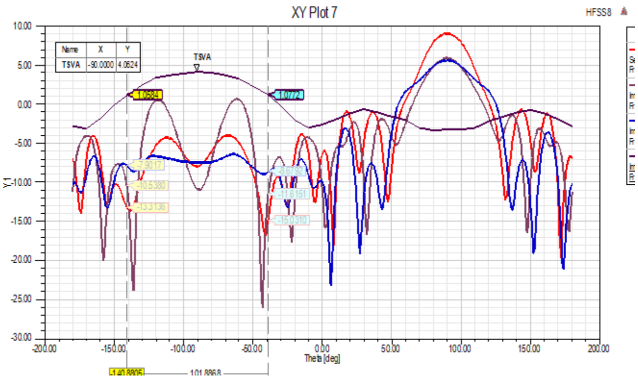

Fig13: Beamwidth of STSVA

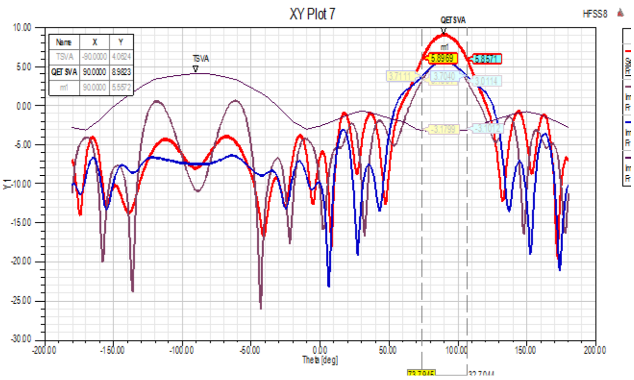

Fig14: Beamwidth of QETSVA

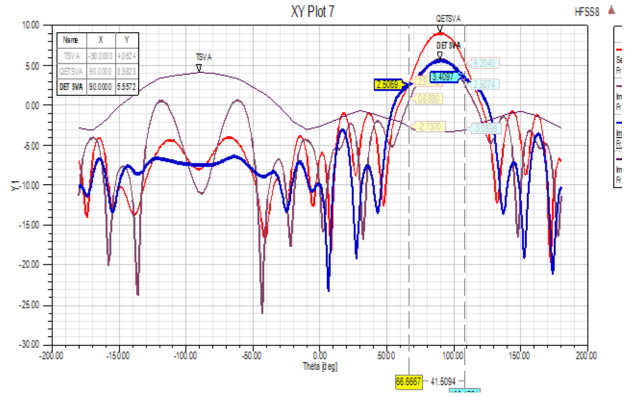

Fig15: Beamwidth of DETSVA

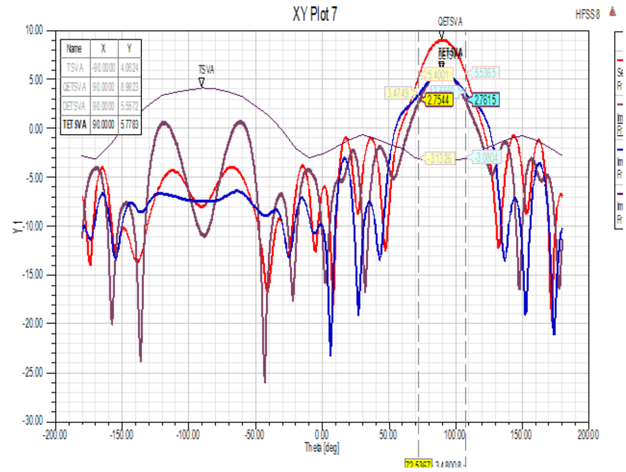

Fig16: Beamwidth of TETSVA

Increasing in the number of tapered slots of the antenna lowered the antenna half power beamwidth. Tapered slot end-fire vivaldi antenna is having wider beamwidth compared to other slot antenna.

D.Optimization

D.I Optimization of tapered slot length of DETSVA
The tapered slot length(l1) is varied 65mm,70mm,75mm and 80mm effect of directivity and gain is observed. Due to the parametric varying of tapered slot length varies gain and directivity plotted below.

D.I.1 Effect Directivity with varying tapered slot length
The Directivity varied with varying aperture length from 65mm,70mm ,75mm and 80mm as show in figure.

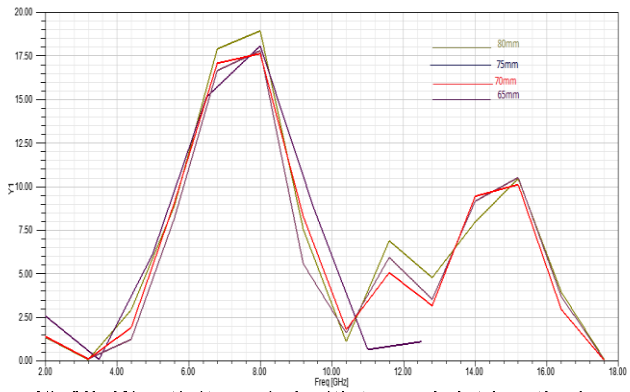

Fig18: Directivity varied with tapered slot length of DETSVA

D.I.2 Effect of 2D-Gain:
The Effect of gain is decreased with Decrease in the tapered slot length as shown figure below.

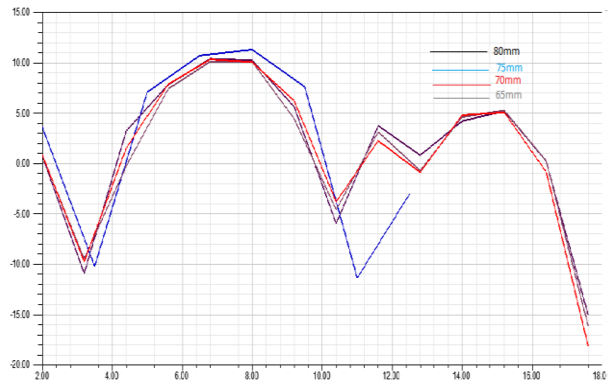

Fig19: 2D-Gain varied with tapered slot length of DETSVA

D.II Optimize of tapered slot length of TETSVA
The aperture length is varied 75mm is shown figure4 and 125mm effect of directivity and gain is observed. Due to the parametric varying of aperture length varies gain and directivity plotted below.

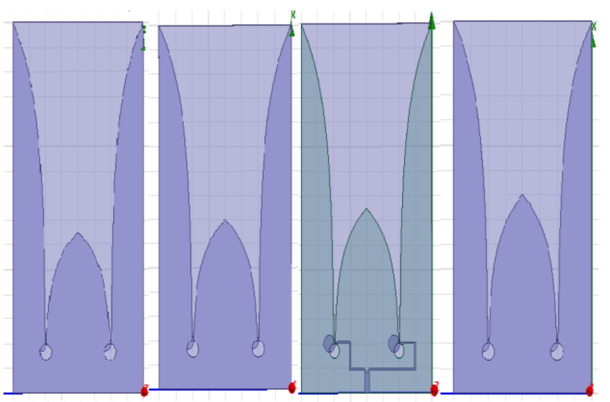
Fig17: DETSVA varying the tapered slot lengths

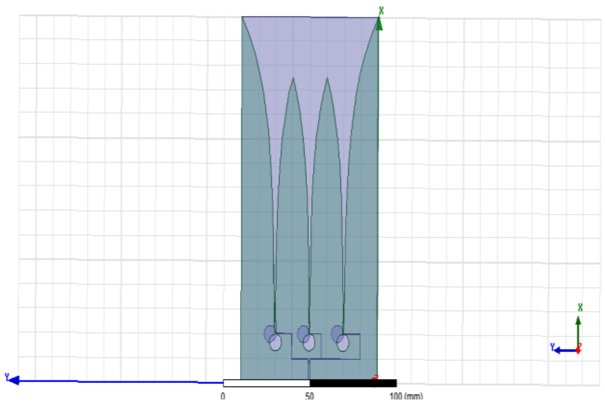
Fig20: 125mm tapered slot length of TETSVA

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D.II.1 Effect Directivity with varying tapered slot length

The Directivity varied with varying tapered slot length from 75mm and 125mm as show in figure.

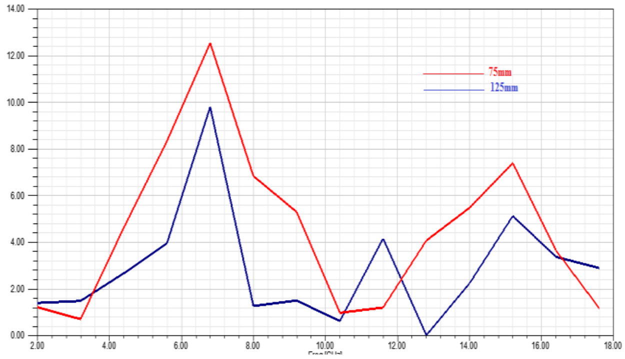

Fig21: Directivity varied with tapered slot length of TETSVA

D.II.2 Effect of 2D-Gain:

The Effect of gain is increase with decrease in the effective aperture length as shown figure below.

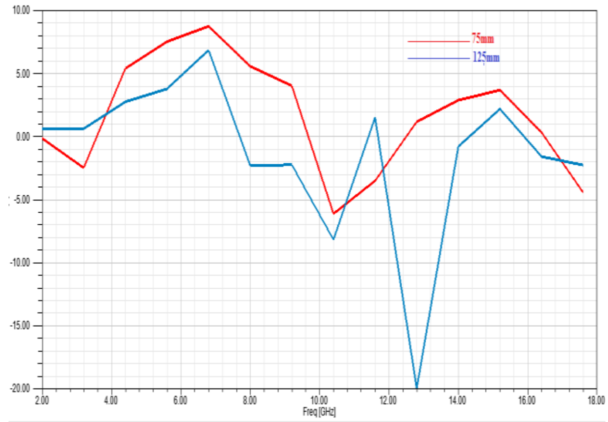

Fig21: 2D-Gain varied with tapered slot length of TETSVA

D.III Optimize of Aperture Length of QETSVA

The aperture length is varied 75mm is figure 6 and 125mm effect of directivity and gain is observed. Due to the parametric varies gain and directivity plotted below.

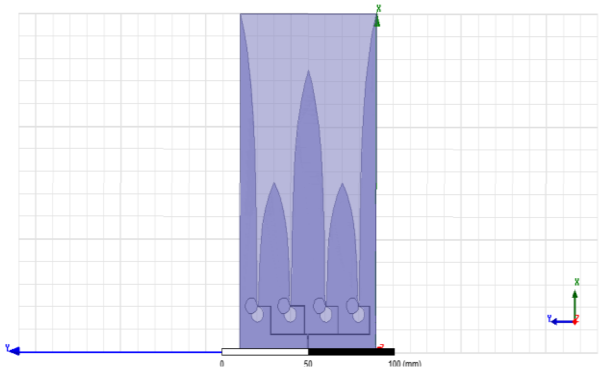

Fig22: 125mm tapered slot length of QETSVA

D.III.1 Effect Directivity with varying tapered slot length

The Directivity varied with varying tapered slot length from 75mm and 125mm as show in figure.

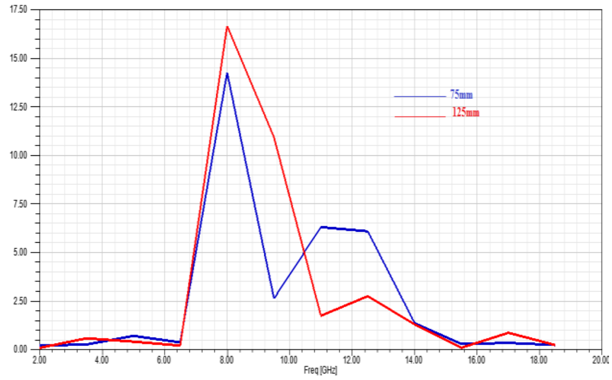

Fig23: Directivity varied with tapered slot length of QETSVA

D.III.2 Effect of 2D-Gain:

The Effect of gain is increase with decrease in the tapered slot length as shown figure below.

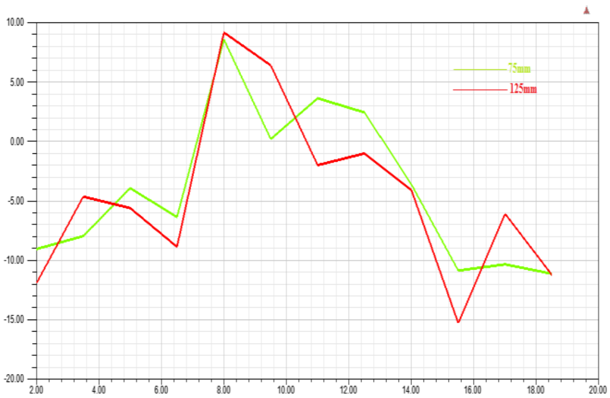

Fig24: Gain varied with tapered slots length of QETSVA

IV. CONCLUSION

Without altering the aperture area, optimum design of multi tapered slot vivaldi antenna achieved enhancement in the directivity with increasing in the number of tapered slots at the expense of small reduction in gain at all frequencies. The Multi tapered slot vivaldi antenna offered the impedance Bandwidth of 2-18GHz that covers S, C, X and Ku band and pattern bandwidth of 4-10.6 and 12-17GHz.

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REFERENCES

[1] P. J. Gibson, “The Vivaldi aerial,” in Proc. the 9th European Microwave Conference, 1979, pp. 101-105.

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[2] A. Lazaro, R. Villarino, and D. Girbau, "Design of tapered slot Vivaldi antenna for UWB breast cancer detection," Microwave Opt. Tech. Lett., vol. 53, no. 3, pp. 639-343, Mar. 2011.

[3] A. Atiah and N. Bowring, "Design of flat gain UWB tapered slot antenna for on-body concealed weapons detections," Prog. in Electromag. Res. Online, vol. 7, no. 5, pp. 491-495, 2011.

[4] Y. Yang, Y. Wang, and A. E. Fathy, "Design of compact Vivaldi antenna arrays for UWB see through wall applications," Prog. in Electromag. Res. Online, vol. 82, pp. 401-418, 2008.

[5] T. A. Milligan, Modern Antenna Design, 2nd ed. New York, NY, USA: Wiley-Interscience, 2005.

[6] T. J. Ellis and G. M. Rebeiz, "MM wave tapered slot antennas on micromachined photonic bandgap dielectrics," in IEEE MTT-S Int. Microw. Symp. Dig., 1996, pp. 1157–1160.

[7] T. G. Lim, H. N. Ang, I. D. Robertson, and B. L. Weiss, "Integrated millimeter-wave tapered slot antenna using conductor strip gratings," Microw. Antennas Propag., vol. 4, no. 9, pp. 1216–1223, Apr. 2010.

[8] A. Elsherbini, C. Zhang, S. Lin, and M. Kuhn, "UWBantipodal Vivaldi antennas with protruded dielectric rods for higher gain, symmetric patterns and minimal phase center variations," in Proc. IEEE Antennas Propag. Soc. Int. Symp., 2007, pp. 1973–1976.

[9] B. Zhou and T. J. Cui, "Directivity enhancement to Vivaldi antennas using compactly anisotropic zero-index metamaterials," IEEE Antennas Wireless Propag. Lett., vol. 10, pp. 326–329, 2011.

[10] RF tools and software exemplary model of the two substrate antenna www.leleivre.com.

BIOGRAPHIES

T. Sumanth, hails from Kanuru (AP) has pursued M. Tech from VR Siddhartha engineering college and graduated in [B. Tech (ECE)] of Sri vani school of engineering. JNT University Kakinada. Having 03 International Journals publications.

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