ISSN 2347 - 3983
Volume 8. No. 9, September 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter161892020.pdf
https://doi.org/10.30534/ijeter/2020/161892020

A Novel Approach of Designing Insubstantial AVA operating in UWB for GPR Applications

A.Ushasree[1], Dr. Vipul Agarwal[2], Dr. M.Satyanarayana[3]
[1]Research Scholar, Department of ECE, Koneru Lakshmaiah Education Foundation, AP, India, ushasreemishra@gmail.com,
[2]Associate Professor, Department of ECE, Koneru Lakshmaiah Education Foundation, AP, India, agarvipul@gmail.com,
[3]Professor, Department of ECE, MVGR College of Engineering, AP, India, profmsn26@mvgr.edu.in

ABSTRACT

Ground Penetrating Radar (GPR) is one of the capable technologies for exposure and recognition of both metallic and non metallic objects masked under the ground. Bandwidth is one of the parameter for GPR system performance, very high frequencies are required for better resolution of microscopic objects. Ultra wide band GPR system can able to meet the current requirement with more efficiency. An Anti-podal Vivaldi Antenna (AVA) is proposed such that its operating frequency range varies from wideband to ultra wide band. A novel approach of designing Anti-podal Vivaldi Antenna is designed to increase the performance characteristics like gain, frequency of operation, radiation pattern, to reduce return loss, to reduce side lobes levels and to reduce the fabrication cost. In order to reduce the cost of fabrication, the substrate material preferred as denim material. The reason for choosing denim material is, it can be easily incorporated and it is homogeneous in nature. Anti-podal Vivaldi Antenna is designed, simulated using HFSS software and it is fabricated. The results obtained in the simulation process and the fabricated antennas are very relative to each other. The performance characteristics measured by simulation process achieves a maximum gain of more than 7dB and practical antenna achieves around 6.92dB with an operating frequency range from wide band to ultra wide band range from 5.2GHz to 13GHz.

Key words: Anti-podal Vivaldi Antenna, Ground penetrating Radar, Ultra wide band.

1. INTRODUCTION

Ultra wide band technology is on more demand now a day due to its attractive features. The applications of UWB include GPR, military, microwave imaging, radars etc due to its huge capacity, powerful penetration and accuracy [20]-[22], [34]-[36].In GPR system antenna frequency is one of the prominent factors which decide the performance of the system.GPR system comprises 3 components radar gram, antenna and power supply. The control unit or radar gram emits electromagnetic radiation in to the surface of investigation, the reflected signal is collected by the antenna and display results on screen which helps GPR operator to determine results accurately. As per the literature survey [27]-[33] higher the frequency of operation of antenna simplistic will be the penetration and better will be detection of minute particles. So considering all the design considerations a novel approach of Antipodal Vivaldi antenna which is also called as tapered slot antenna is proposed, which is co-planar broadband antenna, can be made from a solid piece of sheet metal. The name Antipodal refers to the geometry of the antennas. It refers to the antenna structure and also additional slots that are diametrically opposite to each other, one in top side (Patch) and another in bottom side (Ground).The main advantage of Vivaldi antennas are they are suitable from wide band to ultra wide band range of applications[18],[23],[25]. Theoretically also it was proved that it achieves infinite bandwidth. AVA can be widely used in many applications like radar, 5G communication devices, to identify voids in the concrete beam (civil), micrometer and millimeter-wave applications[1],[2],[24][26].With the growing demand of small, light weight and compact antennas with high end performances, the designing of antennas is the most challenging aspect [3],[8],[11].Referring to the exploitation of the Exponentially Tapered Slot Antenna, Antipodal Vivaldi antenna (AVA) proposed by Gazi, which used the alteration of micro strip line to balanced double sided slot line and spread out impedance bandwidth. Howbeit, its gain within the functional band was truncated and the maximum gain was not more than 8 to 9 dBi [4],[5],[9],[10].

2. ANTENNA DESIGN-1

Initially AVA is designed considering microstrip patch of proper dimensions, which depends on required frequency of operation of antenna along with the microstrip transmission line launched on denim jeans as substrate whose relative permittivity ε is 1.7 and tan ∂ of 0.025, respectively as shown in figure 3(a) [12]-[19].A balun structure is introduced to match 50Ω microstrip feed line and patch antenna as the AVA is of balanced structure. The balun structure is the parallel plate transmission line which is connected into patch and microstrip feed line by slotting and uniting them [6], [7].Generally the balun structure is developed based on the band width required, operating frequency and physical architecture. The following figure shows antenna design-1.

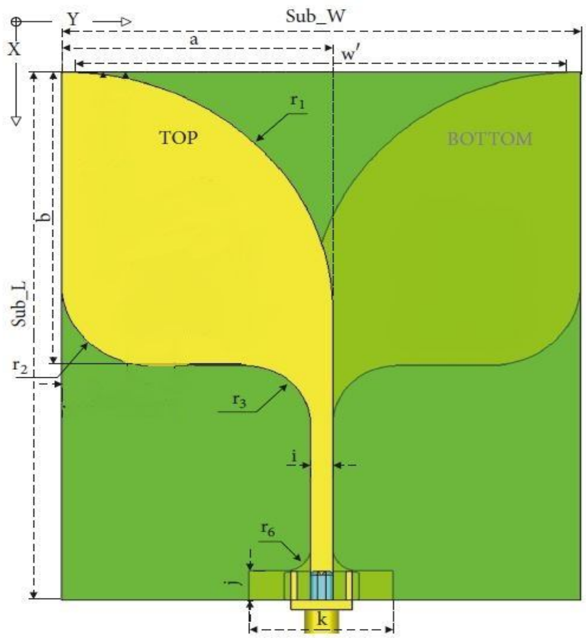


Figure 1: Designed structure of AVA without slots

2.1 Antenna Design-2

The novelty in the design of antenna is shown in figure 2 by creating a flower shape slots on patch and ground.

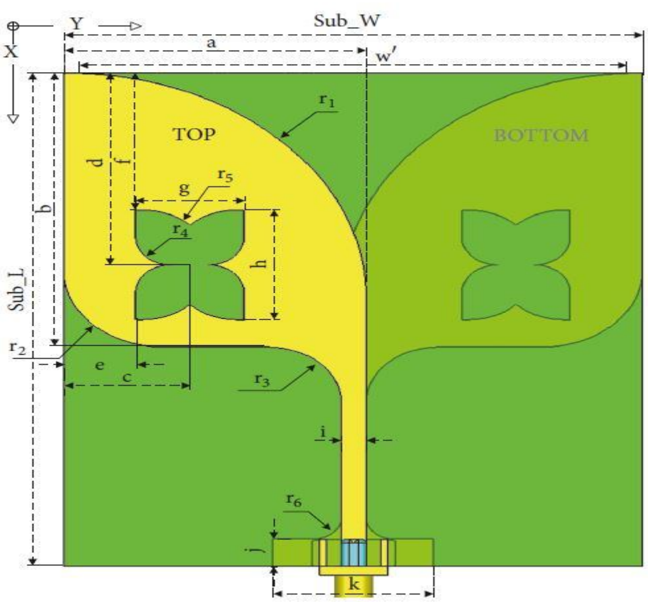


Figure 2: Designed structure of AVA with slots

The AVA should be designed in such manner that required overall impedance is obtained. An empirical method which is very studious procedure is done to meet required impedance. The flower type slot is made on the patch with fixed positions which is shown in figure 3(b), 3(c) and by proceeding the measurements given in the Table 1.As shown in figure 3(c) four Boxes A,B,C,D are initially positioned (f, e, Sub), (f, e+l/2, Sub), (f+m, e, Sub), and (f+m,e+l/2, Sub) respectively. The bottom Boxes ABCD are consequently placed on the ground plane just by making Sub as zero (f, e, 0),(f, e+l/2, 0),(f+m, e, 0), and (f+m,e+l/2, 0) respectively. The shapes are appropriately constructed by using the procedural options like chamfer and union. The patch and ground has same type of slots with exponentially tapered edges with substrate in between.

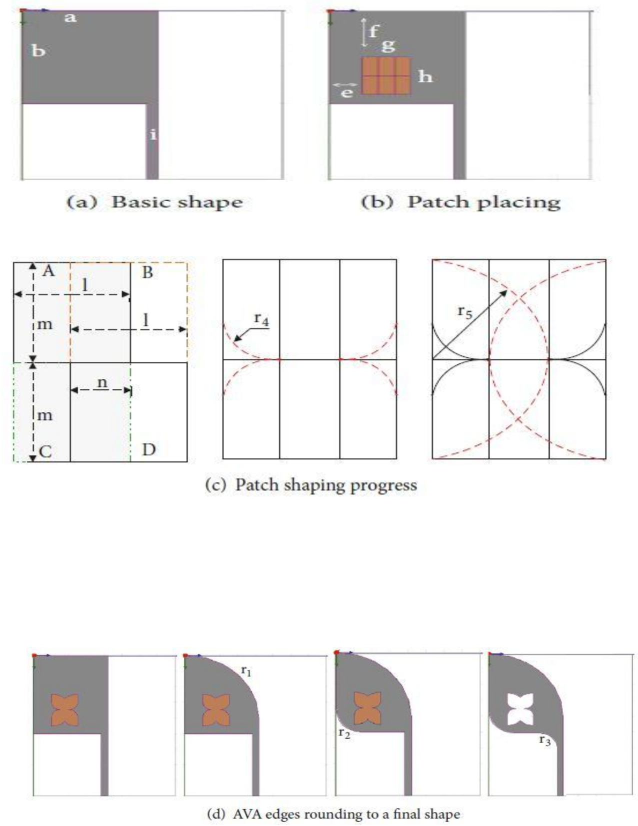


Figure 3: Designed procedure of AVA structure

The design equations for the exponentially tapered edge are given by (1)–(3).These tapering edges are decided by opening rate R , r_1 and r_2 ,where r_1& r_2 are the radius of center of chamfer edges, which are defined by starting and ending points given by (x_1,y_1) and (x_2,y_2) respectively.

$$y = C_1 e^{Rx} + C_2 \qquad (1)$$

Where C_1 & C_2

$$C_1 = \frac{y_1 - y_2}{e^{Rx_2} - e^{Rx_1}} \qquad (2)$$

$$C_2 = \frac{y_2 e^{Rx_1} - y_1 e^{Rx_2}}{e^{Rx_2} - e^{Rx_1}} \qquad (3)$$

The width of the opening of the flared edges $w'$is calculated by the cutoff frequency f_1 and the dielectric constant ε_r of substrate as given by below equation, Where value of c is given by $3x10^8$ cm/sec (or) $30x10^8$ mm/sec.

$$w' = \frac{c}{f_1\sqrt{\epsilon_r}}. \quad (4)$$

From the above equation considering the cutoff frequency as 2.2GHz and dielectric constant as 1.7 as the substrate used is denim jeans, width of flared edges is calculated as w'= 78.5 mm. The final prototype structure is designed, with widespread simulations and optimization process so that better and efficient results are achieved using HFSS. Final dimensions of designed AVA are tabulated in Table 1.

Table 1: Dimensions of Antenna

Sub_L	90.00mm
Sub_W	80.00mm
Sub_T	1.524mm
a	41.75mm
b	50.00mm
c	17.50mm
d	35.00mm
e	10.00mm
f	25.00mm
g	15.00mm
h	20.00mm
i	03.50mm
j	05.00mm
k	22.00mm
l	10.00mm
m	10.00mm
n	05.00mm
w'	78.50mm
r_1	41.00mm
r_2	14.00mm
r_3	10.00mm
r_4	05.00mm
r_5	09.00mm
r_6	03.70mm

3. ANTENNA DESIGN EVALUATION

In this section the performance of proposed antenna are analyzed and measured using HFSS. For the given design, HFSS software automatically generates a solution process and accurate mesh analysis. The antenna design-1 without slot and antenna design-2 with slots simulation results are compared to check superiority in design. Antenna design-1 works between the frequency range of 4.56GHz to 18.8GHz and antenna design-2 works between the ranges of 4GHz to more than 20GHz.So the proposed antenna successfully achieved ultra wide broadband. The important parameters duly considered for the analysis are namely Return loss (S_{11}), Gain, Radiation Pattern and VSWR are plotted for both antenna design-1 and antenna design-2.

3.1 Return Loss (S_{11}):

The attained return loss for the designed antenna-1 is shown in the figure 4 which is -24.3 dB at 7.07 GHz and -25.1 dB at 10.43 GHz and antenna design-2 shown in figure 8 which is-20.34dB at 12.4GHz,-30.61dB at 10.6GHz and -25.09dB at 6.9GHz. Return loss tells about how much power is being reflected by the port due to incident power.

3.2 Gain:

The term Antenna Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. The designed antenna is low power consuming since it has higher gain which is shown in three dimensional polar plot in figure 5. The gain of antenna design -1 is 6.31 dB at 7.07 GHz and 7.43 dB at 10.43 GHz and gain of antenna design-2 are 5.41dB, 6.82dB and 6.922dB with respect to 6.9GHz, 10.6GHz and 12.4GHz respectively as shown in figure 9. If an antenna's gain is 3 dB, it means that twice the amount of effective power will be sent in the direction of a target. Here, the gain is more than 3 dB which is appreciable value.

3.3 Radiation Pattern:

Radiation pattern (or) Antenna pattern (or) Far field pattern is the term used to represent the power radiated by antenna as a function of direction. A plot of gain as a function of direction is called radiation pattern is shown in figure 5 and figure 9 for antenna design-1 and antenna design-2 respectively.

3.4 VSWR:

The VSWR is defined as the amount of mismatch between antenna and the feeding line. The antenna design-1 has voltage standing wave ratio of 1.19 at 7.07 GHz and 1.21 at 10.43 GHz design and antenna design-2 of 1.06 for 12.4GHz.

4. GRAPHICAL REPRESENTATION OF SIMULATION RESULTS

The graphical representation of simulation results are shown below. Return loss S_{11} vs frequency is plotted which shows the operating frequency (S_{11} < -10dB).

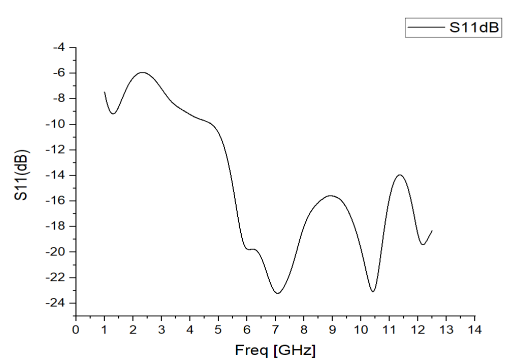


Figure 4: Frequency (GHz) vs Return loss (dB) antenna design -1

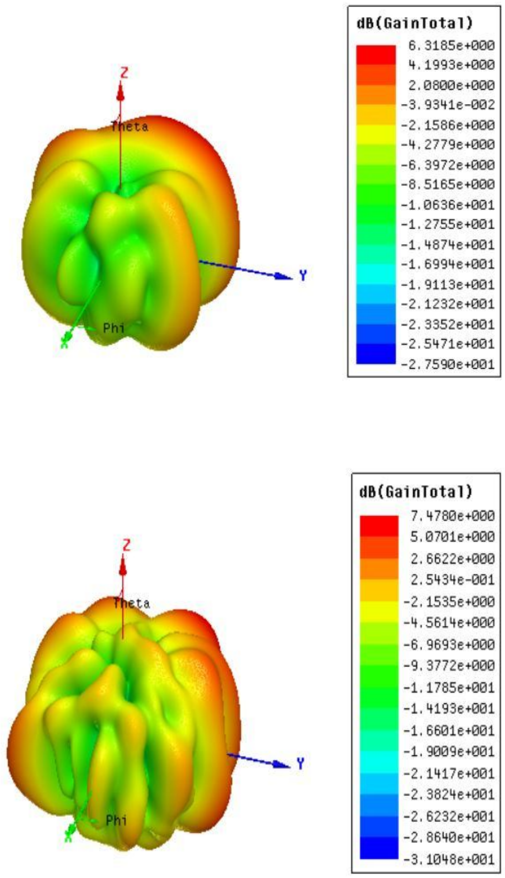


Figure 5: Gain of simulated antenna without slots in 3D view

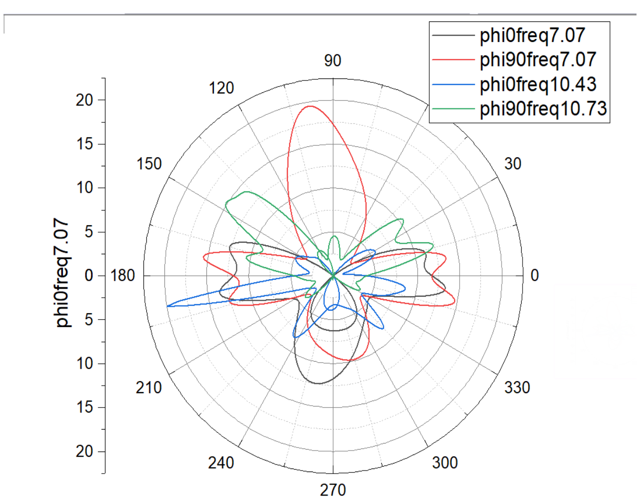


Figure 6: Overall radiation pattern of proposed antenna without slots.

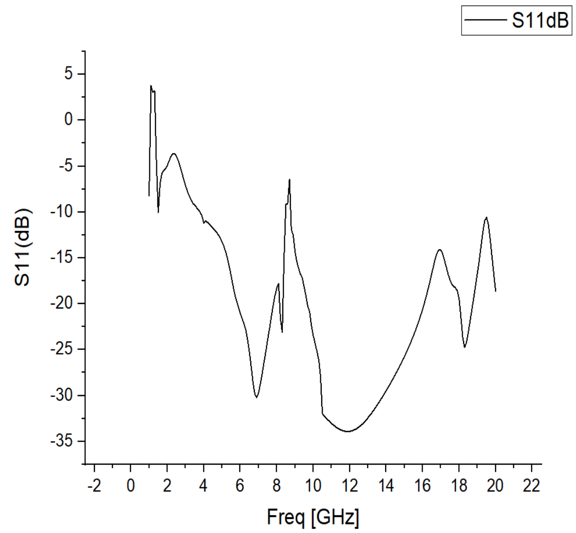
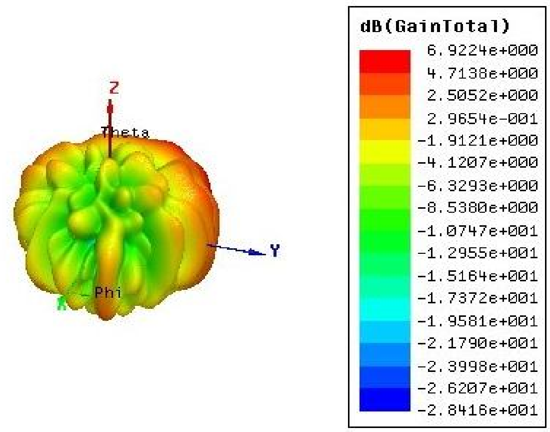
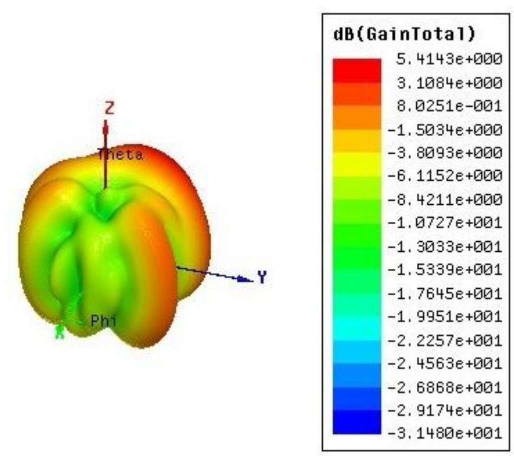


Figure 8: Frequency (GHz) vs return loss (dB) antenna design 2





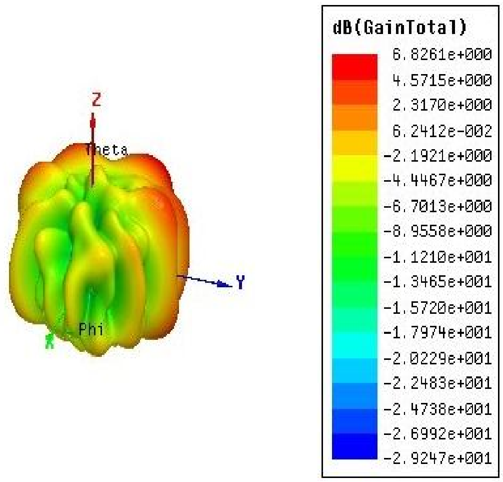


Figure 9: Gain of simulated antenna with slots in 3D view

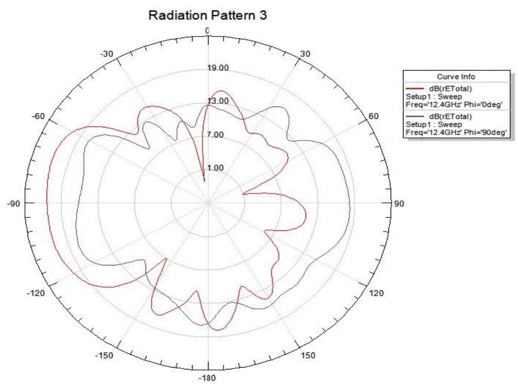
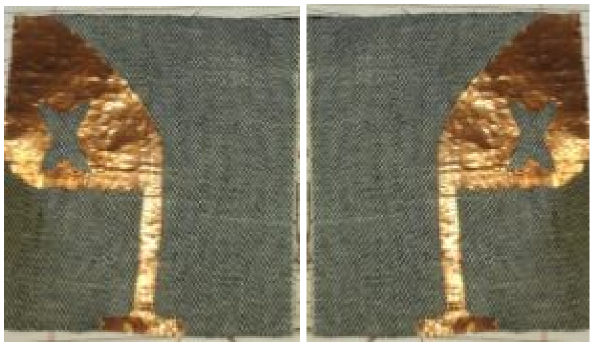


Figure 10: Overall radiation pattern of proposed antenna with slots



(c)With slot top view (d)With slot bottom view

Figure 11: Fabricated Antipodal Vivaldi Antenna

Figure 12: Testing AVA in Network Analyzer

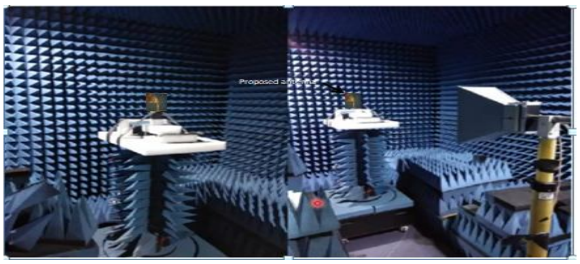
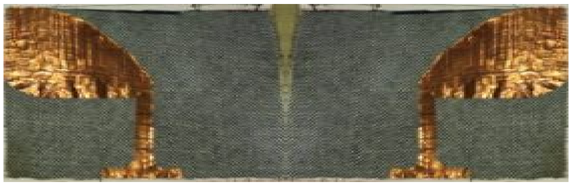


Figure 13: Testing AVA in Anechoic Chamber

5. ANTENNA FABRICATION AND PRACTICAL MEASURED RESULTS

This section displays the fabricated antenna shown in figure11(a,b,c ,d) verifies the performance characteristics of fabricated antenna using network analyzer as shown in figure 12 and then tested fabricated antenna in anechoic chamber as shown in figure 13 and the results are compared with simulation results at 12.43GHz as given from figure 14 to figure 16.



(a) Without slot top view (b) Without slot bottom view

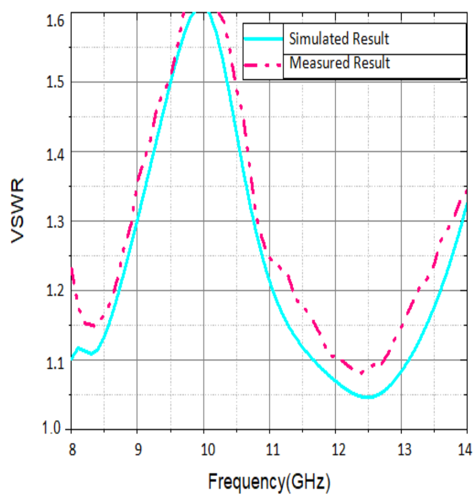


Figure 14: VSWR measured & simulated

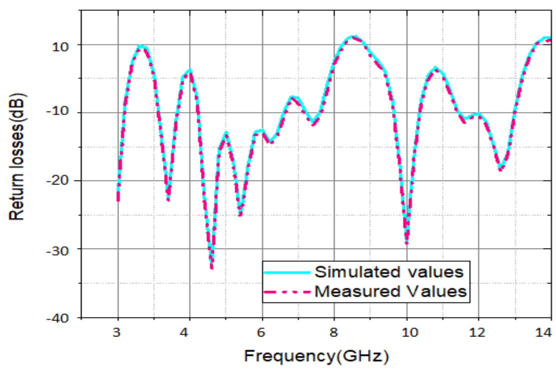


Figure 15: Return loss measured & simulated

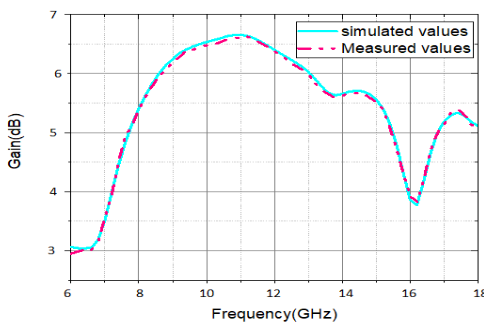


Figure 16: Gain measured & simulated

The following Table 2 compares performance characteristics the previous work done and present work done on Vivaldi Antennas and AVA for GPR applications.

Table 2: Previous and Present work done

Ref	Frequency of Operation	Gain	Return loss (dB)	Substrate Material
25	0.7 -2.1GHz	1dB	-20	FR4 ε_r=4.3 and δ=0.025
26	300 MHz to > 2GHz	4.4-1.5dBi	-43	Rogers RT/duroid 4350,ε_r=3.48,δ= 0.004
27	1.5GHz	2.83dB	-20	FR4 ε_r=4.3 and δ=0.025
28	2GHz	8.1dBi	-13	FR4 ε_r=4.3 and δ=0.025
29	260-340 MHz(Vivaldi original)	1.5dB	-13.2	FR4 ε_r=4.4 and δ=0.02
30	220-282MHz(Vivaldi original 6 DGS)	1.7dB	13.2	FR4 ε_r=4.4 and δ=0.02
31	220-263(Vivaldi original DGS)	4.2dB	>22	FR4 ε_r=4.4 and δ=0.02
32	7.52GHz	15dBi	13	Rogers RT/duroid 5880,ε_r=2.2,δ= 0.0009
33	6GHz	>3dB	>10	Rogers RT/duroid 5870,ε_r=2.33,δ= 0.0012
Present Work	Vivaldi antenna without slot at 7.07GHz	6.31dB	-24.3	Denim Jeans ε_r=1.7 and δ=0.025
	Vivaldi antenna without slot at 710.43GHz	7.47dB	-25.12	Denim Jeans ε_r=1.7 and δ=0.025
	Vivaldi antenna with slot at 6.9GHz	5.41dB	-25.09	Denim Jeans ε_r=1.7 and δ=0.025
	Vivaldi antenna with slot at 10.6GHz	6.82dB	-30.61	Denim Jeans ε_r=1.7 and δ=0.025
	Vivaldi antenna with slot at 12.4GHz	6.922dB	-20.34	Denim Jeans ε_r=1.7 and δ=0.025

6. CONCLUSION

A high gain Anti-podal Vivaldi Antenna (AVA) has been proposed which can be used for microwave imaging, ground penetrating radar and radar applications. The AVA with flower slot and without slot structure is designed, simulated, fabricated and tested. The simulated results and practical results are very similar to each other. By comparing the two design models the antenna with slot is having better performance results than without slot in terms of bandwidth. Therefore, the proposed antenna design-1has a bandwidth between 4.5GHz to 18.82GHz and antenna design-2 covers the ultra bandwidth range from 3.63GHz GHz to greater than 20GHz with better VSWR and gain almost remains constant

REFERENCES

[1]. Moosazadeh, M. (2019).**Antipodal Vivaldi Antennas for Microwave Imaging of Construction Materials and Structures-** Springer nature Switzerland AG 2019 Book.

[2]. A. S. Dixit and S. Kumar, **A Survey of Performance Enhancement Techniques of Antipodal Vivaldi Antenna**, *in IEEE Access*, vol. 8, pp. 45774-45796, 2020.

[3].Gibson, P. J., **The Vivaldi Aerial**, *Microwave Conference, 1979.9th European*, vol., no., pp.101, 105, 17-20 Sept.1979.

[4].Marek Dvorsky, Harihara S. Ganesh, S.Sadhish Prabhu, **Design and validation of Antipodal Vivaldi antenna with Additional Slots** , *International Journal of Antennas and Propagation*, vol.2019, Article ID7472186,10pages,2019.

[5]. M. Amiri, F. Tofigh, A. Ghafoorzadeh-Yazdi and M. Abolhasan, **Exponential Antipodal Vivaldi Antenna With Exponential Dielectric Lens**, in *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 1792-1795, 2017.

[6].J. Bourqui, M. Okoniewski and E. C. Fear, **Balanced Antipodal Vivaldi Antenna With Dielectric Director for Near-Field Microwave Imaging**, in *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 7, pp. 2318-2326, July 2010.

[7]. Yang, Z., Jingjian, H., weiwei, W., & Naichang, Y. (2017) **An antipodal Vivaldi antenna with band-notch characteristics for ultra-wideband applications**, *AEU - International Journal of Electronics and Communications*, 76, 152–157.

[8]. Greenberg, M.C.; Virga , K.L , **Characterization and design methodology for the dual exponentially tapered slot antenna**, *Antennas and Propagation Society International Symposium*, 1999. IEEE, vol.1, no., pp.88, 91 vol.1,11-16 July1999.

[9] Z. Wang, Y. Yin, J. Wu, and R. Lian, **A miniaturized CPW fed antipodal Vivaldi antenna with enhanced radiation performance for wideband applications**, *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 16–19, 2016.

[10].L. Chen, C.Wang, H. Li, and S. Lan, **A miniaturized antipodal Vivaldi antenna for microwave imaging**, in

Proceedings of the *International Symposium on Antennas and Propagation* (ISAP '17*)*, pp. 1-2, Phuket,Thailand, 2017.

[11]. P. Fei, Y. Jiao, W. Hu and F. Zhang, **A Miniaturized Antipodal Vivaldi Antenna With Improved Radiation Characteristics**, in *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 127-130, 2011.

[12].Vallozzi, L., Hertleer, C. and Rogier, H., 2016.**Latest developments in the field of textile antennas**. *Smart textiles and their applications* (pp. 599-626). Woodhead Publishing

[13].Cicchetti, Renato, Emanuela Miozzi, and Orlandino Testa, **Wideband and UWB antennas for wireless applications: A comprehensive review,** *International Journal of Antennas and Propagation* (2017).

[14]. Turkmen, Mustafa, and Husnu Yalduz, **Design and Performance Analysis of a Flexible UWB Wearable Textile Antenna on Jeans Substrate,** *International Journal of Information and Electronics Engineering* 8.2 (2018).

[15]. Sharma, D., Dubey, S. K., & Ojha, V. N. (2018, December), **Wearable Antenna for millimeter wave 5G Communications**.In 2018 *IEEE Indian Conference on Antennas and Propagation* (In CAP) (pp.1- 4).

[16]. H. Azodi, Xiaodong Zhuge and A. Yarovoy, **Balanced antipodal Vivaldi antenna with novel transition from feeding line to the flares**, Proceedings of the 5th *European Conference on Antennas and Propagation* (EUCAP), Rome, 2011, pp. 1279-1283.

[17].Padmanabharaju, M., Madhav, B.T.P., Kishore, D.P. and Prasad, P.D., 2019. **Conductive fabric material based compact novel wideband textile antenna for wireless medical applications**. *Materials Research Express*, *6*(8), p.086327.

[18]. Nath, G.V., Rao, K.N. and Kishore, K.H., 2018. **A slot loaded compact antipodal Vivaldi antenna design for RADAR applications.** *J. Adv. Res. Dyn.Control Syst*, 10(7), pp.1342-1346.

[19]. Madhav B.T.P., Subbareddy V., Venkateswara Rao M., Mahalakshmi Y.N., Hasanjama S., Chaluvadi, Renuka N.V.S., Rameswara Rao M.V.V. (2017).**A high gain metamaterial inspired vivaldi antenna for ultrawide band applications.***Journal of Advanced Research in Dynamical and Control Systems*,9(Special Issue 14),PP.2078-2086.

[20]. Madhav B.T.P., Sai Santosh T., Venkateswara Rao M., Sai Manikanta S., Srinivas K.B.V., Hanumath Sastry J. (2017).**A novel ultra wideband mimo antenna with wimax band notch characteristics.***Journal of Advanced Research in Dynamical and Control Systems* 9(Special Issue 14),PP.2094-2103.

[21]. Sri P.A.V., Yasasvini N., Anjum M., Manikanta A.V., Harsha D.N.S.S., Dattatreya G., Naik K.K. (2017).**Analysis of wideband circular ring with rectangular patch antenna for airborne radar application.***Proceedings of the International Conference on Electronics, Communication and Aerospace Technology*, ICECA 2017,0(),PP.459-461.

[22]. Sandhya Rani S., Naik K.K. (2019).**Analysis of vivaldi antenna etched with the circular patch and complementary split ring resonator slot**.*International Journal of Innovative Technology and Exploring Engineering*, 8(7), PP.2959-2961.

[23].Prudhvi Nadh, B., Madhav, B. T. P., Siva Kumar, M., Venkateswara Rao, M., & Anilkumar, T. (2019). **Circular ring structured ultra□wideband antenna for wearable applications.** *International Journal of RF and Microwave Computer□Aided Engineering*, 29(4), e21580.

[24].Kolusu, S.S.R., Modala, A.B., Madhav, B.T.P. and Nadh, B.P., 2019. **Concentric Circular Ring Loaded Triple Band Antenna for Wireless Applications**. *complexity*, *242*.

[25].Madhav P.V., Siva Ganga Prasad M. (2019). **Characterization of printed podal vivaldi antennas (8-18 Ghz) on rt duroid with single and double cavity**. *International Journal of Recent Technology and Engineering*, 7(6), pp. 1984-1989.

[26]. Chandra, K. V., Satyanarayana, M., & Battula, K. T. (2020).**A novel miniature hexagonal shape switched pattern and frequency reconfigurable antenna**. *International Journal of Communication Systems*, *33*(5), e4264.

[27].M. Moosazadeh, **High-Gain Antipodal Vivaldi Antenna Surrounded by Dielectric for Wideband Applications**, in *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 8, pp. 4349-4352, Aug. 2018.

[28].H. Cheng, H. Yang, Y. Li and Y. Chen, **A Compact Vivaldi Antenna With Artificial Material Lens and Side lobe Suppressor for GPR Applications**, in *IEEE Access*, vol. 8, pp. 64056-64063, 2020.

[29]. J. Guo, J. Tong, Q. Zhao, J. Jiao, J. Huo and C. Ma, **An Ultra wide Band Antipodal Vivaldi Antenna for Airborne GPR Application**, in *IEEE Geo science and Remote Sensing Letters*, vol. 16, no. 10, pp. 1560-1564, Oct. 2019.

[30]. M. A. Pumallica-Paro, J. Luis Arizaca-Cusicuna and M. Clemente-Arenas, **Optimizing Cutoff Frequency in an Antipodal Vivaldi Antenna for GPR applications through a novel balun**, 2018 *IEEE XXV International Conference on Electronics, Electrical Engineering and Computing* (INTERCON), Lima, 2018, pp. 1-4.

[31]. M. Pasternak, **Lambert W function application for construction of antipodal Vivaldi-type antenna**, 2018 14th *International Conference on Advanced Trends in Radio electronics, Telecommunications and Computer Engineering* (TCSET), Slavske, 2018, pp. 624-627.

[32].D. Peñaloza-Aponte, J. Alvarez-Montoya and M. Clemente-Arenas, **GPR Vivaldi antenna with DGS for archeological prospection**. 2017 *IEEE XXIV International Conference on Electronics, Electrical Engineering and Computing* (INTERCON),Cusco, 2017, pp. 1-4.

[33]. N. Chakrabarti, S. Kalra, S. Saxena and M. R. Tripathy, **Ultra-wideband antenna for a ground penetrating radar**, 2016 *Thirteenth International Conference on Wireless and Optical Communications Networks* (WOCN), Hyderabad, 2016, pp. 1-6.

[34].Bachiri, T., Alsharahi, G., Khamlichi, A., Bezzazi, M., & Faize, A. (2020). **GPR application in Civil Engineering to search and detect underground Networks**. *International Journal*, *8*(5).

[35].Hamdaoui, M., Faize, A., Rochdi, M., & Alsharahi, G. (2020).**Effect of electromagnetic parameters of the medium on the GPR data**. *International Journal*, *8*(5).
[36]. Sarma, Ch. (2020). **Effect of Ground Etching, Inset Feed and Substrate Height on Elliptically Shaped Patch Antenna.** *International Journal of Emerging Trends in EngineeringResearch*.8.3145-3149.