Design of a corrugated antipodal Vivaldi antenna with stable pattern

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***Abstract*—An antipodal Vivaldi antenna (AVA) with tapered corrugated edge from 6 GHz to 18 GHz is designed and fabricated. This antenna can be used in ultra-wide band applications that need stable patterns such as in direction finding systems. The two tapered microstrip antennas are printed on the top and bottom sides of a substrate. The microstrip ground plane is eliminated since one of the tapered microstrip is used as a ground plane. In this technique, an unbalanced to balanced balun is not required. The measured antenna gain is 8 dBi while maintaining VSWR less than 2. There is a good agreement between the simulated and measured results.**

I. Introduction

Today, high speed communications, direction finding, wireless and radar systems are widely developed. Many of these applications require UWB and compact antennas [1], [2]. Several types of UWB antennas are discussed in the literature such as helical, bicone, bowtie, horn and Vivaldi [3]. Each antenna type has its disadvantages and advantages. For short pulse wireless and high RF power with linear polarization horn antennas are good candidates but they cannot be used near the ground and they are costly to fabricate. Bowtie antennas have higher gain than dipole antennas however for high gain applications they are not suitable. Bicone and helical antennas are not compact and cannot be used in miniaturized systems. Therefore, one of the best UWB and compact candidate is the Vivaldi antenna with a lot of advantages such as planar and small structure, low cost, ease of fabrication, high gain and low side lobe level (SLL). Two types of Vivaldi antennas were introduced: the coplanar Vivaldi antenna [4] and the antipodal Vivaldi antenna (AVA) [5], [6]. Coplanar Vivaldi antennas have exponentially tapered radiation parts printed on the same side of the substrate.

Different types of feeding networks were introduced such as using vias or coupled lines. The main problems of coplanar Vivaldi antennas are having a cross-polarized radiation and using an unbalanced to balanced balun to feed the antenna, so they cannot be suitable for radar systems. In AVAs one of the radiation parts is printed on the top and another one is printed on the bottom of the substrate. In AVAs, cross-polarization is removed so that they can be used in polarization sensitive systems. Different corrugated types have been proposed such as rectangular, circular and triangular to improve the antenna gain and VSWR.

In this paper, an AVA with linear tapered corrugated rectangular shape is proposed to improve the antenna gain. The antenna is fabricated on a 813 mm Rogers RO 4003 with $\epsilon_r = 3.55$. The frequency of operation is from 8 GHz to 18 GHz. By removing two semicircles from the ground plane, the return loss is improved and the antenna gain also is stable in the whole frequency bandwidth.

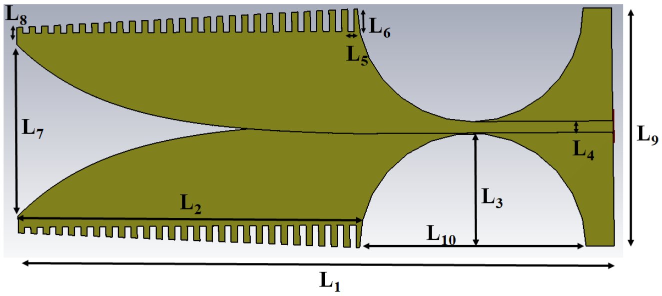
II. Antenna Design

The antenna structure including its dimensions is shown in Fig. 1Geometry of the proposed antenna. (a) dimension parameters in Table IDimensions of the antenna (mm)table.caption.2 (b) fabrication photo.figure.caption.1. In this design, the connector and the radiator are carefully considered to obtain a good matching condition because an unbalanced to balanced balun are not used. Therefore, a circular taper is used to match the connector to the antenna. The antenna input impedance is 50 Ω and should be constant. This explains why the taper rate is opposite at both antenna sides. Moreover, the antenna symmetry must be kept to minimize cross-polarization.

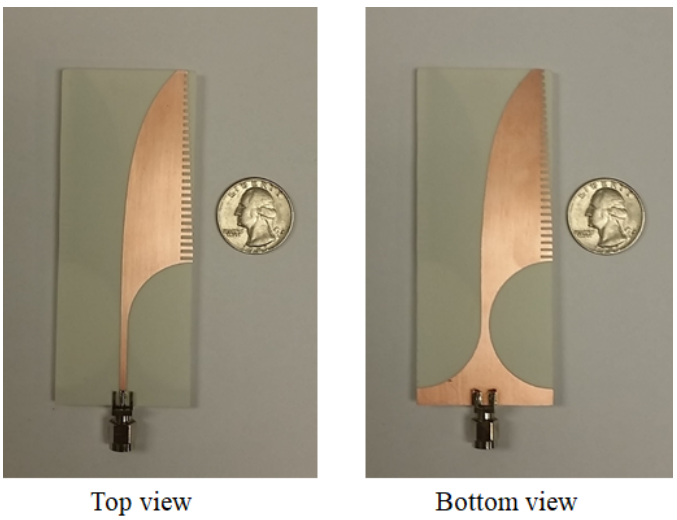
The tapered slots have an exponential profile. Several parameters were optimized to achieve minimum return loss and stable patterns such as L_1, L_2 and L_9. We also added

TABLE I: Dimensions of the antenna (mm)

Parameter	L_1	L_2	L_3	L_4	L_5
Dimension	105	60	20	2	1.1
Parameter	L_6	L_7	L_8	L_9	L_{10}
Dimension	4	30	1	42	45



(a)



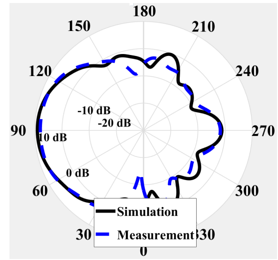
(b)

Fig. 1: Geometry of the proposed antenna. (a) dimension parameters in Table IDimensions of the antenna (mm)table.caption.2 (b) fabrication photo.

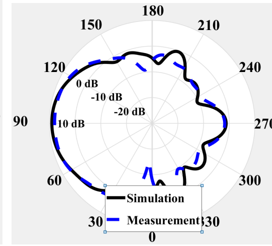
corrugated edges on the tapered slots to improve S_{11} and the antenna gain. In previous papers, Vivaldi antennas were designed using constant height rectangular or triangular corrugated edges that resulted in a gain that was frequency dependent. To reduce the frequency dependence of the gain, we introduced a taper in the height of the rectangular corrugation, which results in a gain curve that is more flat across the whole operation frequency. We compared the gain, return loss and SLL of several types of corrugations such as rectangular, circular and triangular.The best results were obtained with a linearly tapered rectangular shape. The tapered corrugation also improved the SLL compared to the constant corrugated edge by about 3 dB.

III. Simulation Results

The final dimensions are obtained using particle swarm algorithm with CST. The simulated and measured S_{11} are shown in Fig. 2dSubfigure 2dsubfigure.2.4. As shown in Fig. 2(a) Simulated and Measured radiation patterns in the yz plane at (a) 8 GHz, (b) 12 GHz, (c) 18 GHz, and (d) simulated and measured S_{11}.figure.caption.3, there is a good agreement between the simulated and measured results.



(a)



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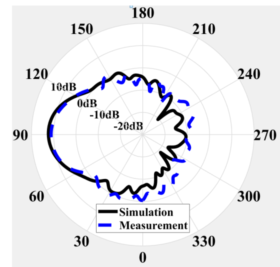
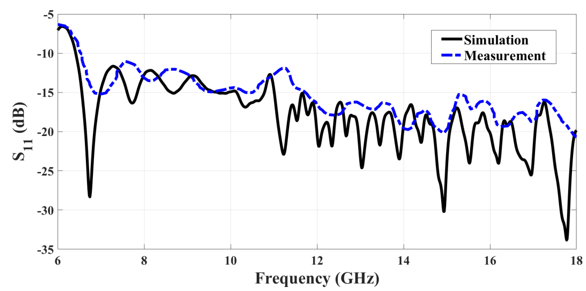


(c)



(d)

Fig. 2: (a) Simulated and Measured radiation patterns in the yz plane at (a) 8 GHz, (b) 12 GHz, (c) 18 GHz, and (d) simulated and measured S_{11}.

References

[1] A. Darvazehban, O. Manoochehri, M. A. Salari, P. Dehkhoda, and A. Tavakoli, “Ultra-Wideband Scanning Antenna Array With Rotman Lens,” *IEEE Transactions on Microwave Theory and Techniques*, vol. 65, no. 9, pp. 3435–3442, Sept 2017.

[2] M. A. Salari, O. Manoochehri, A. Darvazehban, and D. Erricolo, “An Active 20 MHz to 2.5 GHz UWB Receiver Antenna System Using a TEM Horn,” *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2432–2435, 2017.

[3] Omid Manoochehri, Amin Darvazehban, Mohammad Ali Salari, Seiran Khaledian, Danilo Erricolo, and Besma Smida, “A dual-polarized biconical antenna for direction finding applications from 2 to 18 GHz,” *Microwave and Optical Technology Letters*, vol. 60, no. 6, pp. 1552–1558.

[4] A. Sharma, A. T. Hoang, and M. S. Reynolds, “A Coplanar Vivaldi-Style Launcher for Goubau Single-Wire Transmission Lines,” *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2955–2958, 2017.

[5] S. Zhu, H. Liu, Z. Chen, and P. Wen, “A Compact Gain-Enhanced Vivaldi Antenna Array With Suppressed Mutual Coupling for 5G mm Wave Application,” *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 5, pp. 776–779, May 2018.

[6] F. Oktafiani, Y. S. Amrullah, Y. P. Saputera, Y. Wahyu, and Y. N. Wijayanto, “Analysis of corrugated edge variations on balanced antipodal Vivaldi antennas,” in *2015 International Conference on Radar, Antenna, Microwave, Electronics and Telecommunications (ICRAMET)*, Oct 2015, pp. 1–5.