A Modified Leaf Shaped Antipodal Vivaldi Antenna for UWB Applications

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***Abstract*—Here, a novel and compact modified leaf shaped antipodal Vivaldi antenna is presented for displaying explicitly broadband with multi-band functionalities. With persistence to that, it is operative at IEEE S-Bands (2.4 GHz with a bandwidth of 900 MHz), IEEE C-Bands (7.7 GHz with a bandwidth of 1700 MHz) and IEEE X-Bands (10.6 GHz with a bandwidth of 1300 MHz). GA was implemented as the EM parameter optimization method, where dimensions of MLSAVA were further optimized to 30%, without compromising out its operational benefits with concise to absolute miniaturization, before getting fabricated. It is fabricated on FR-4 substrate with epsilon value of 4.4 and a height of 1.6 mm, with a dimension of 30 x 25 mm^2 and operates from 2-12 GHz, covering a -10 dB impedance bandwidth of 10 GHz. The proposed antenna has low cross-polarization level (< -15 dB), flat gain (> 5 dBi) over frequency range (2-12 GHz). The simulated results & measured outcomes are in good agreement with each other. So, proper validation is presented in terms of initial design, simulation by EM solver, fabrication and most importantly its characterization.**

***Keywords*— FEM Solver, Genetic Algorithm (GA), MLSAVA, WLAN, UWB, Vivaldi Antenna**

I. Introduction

Since, Federal Communication Commission's choice of allowing unlicensed operation from 3.1-10.6 GHz in 2002, UWB has been progressively developed from academics to industry [1]. Small size, good impedance matching as well as minimum group delay, omnidirectional radiation pattern are the special features, which an UWB antenna should bear. In past few years, Vivaldi antennas have received considerable attention due to wide bandwidth characteristics. It belongs to the class of periodic and it continuously scaled up antenna structures with the exponentially tapered curve. In frequency range from 2-40 GHz, they exhibit significant gain & linear polarization [2-4]. It is widely used in the UWB applications: ground penetration radar, satellite communication, medical treatment and vehicular wireless communication [5-8]. In this tenure it shows out stability, constant group delay over large range of frequencies & wideband, high gain with the feature of integration [9]. Theoretically, it has a boundless scope of working especially in higher frequencies with the consistent beamwidth over the entire bandwidth [10]. In past, a lot of developments have been carried in areas of Vivaldi antenna for UWB. L-Tianming [11] has proposed a Vivaldi antenna, but due to its larger dimensions, it is considered to be bulky and its cross-polarization is high, making unviable for UWB. Hood [12] has proposed compact Antipodal Vivaldi antenna and had used two substrates: FR-4 and Rogers RO 3006, but resulted in the unperturbed outcomes in the spaces of group delay, phase response, far field pattern and gain. Prior to this, many other types of antennas [13-16] such as the microstrip, monopole and slotted antennas were designed, but they were unable to showcase significant impact in terms of bandwidth and gain. Taking into account these past references, authors would like to draw your attention towards this modified leaf shaped antipodal Vivaldi antenna for an explicitly witnessing multi-band characteristics. In order to carry out optimization & overcome earlier setbacks, GA [11] was implemented with the help of FEM Solver [12].

Here, the authors present a modified leaf shaped antipodal Vivaldi antenna, fabricated on FR-4 substrate. Here antenna is proposed in such a way that the two stubs are integrated in Top and Bottom Leaf, helps in achieving multiple resonating frequencies showing multi-band characteristics, are analyzed, in terms of input reflection coefficients, radiation pattern and gain. GA was implemented for optimizing the parameters like W, L etc. for achieving miniaturization and to synthesis the characteristics of stubs in such a way that we obtain three resonating bands: IEEE S-Bands (2.4 GHz) with a bandwidth of 900 MHz, IEEE C-Bands (7.7 GHz) with a bandwidth of 1700 MHz and IEEE X-Bands (10.6 GHz) with a bandwidth of 1300 MHz, without any sort of compromise with gain and efficiency. Antenna was fabricated and characterized in the lab, good agreement is noticed in simulation & measurement.

II. Antenna Design

The geometry of proposed antenna is shown in Fig. 1. FR-4 substrate is used with epsilon value of 4.4, height of 1.6 mm. The top and bottom layer consists of copper material. Initially, simple leaf shaped antipodal Vivaldi antenna was developed, aimed for UWB applications, having resonance from 3.1-10.6 GHz. But in order to develop the proposed antenna in a more intuitive way, two stubs are integrated in the main part of the structure, making it to form a modified leaf shaped antipodal antenna for multi-band characteristics. All the developments are shown in Fig. 2. As a result of it, the proposed antenna was deemed witness flatter gain, wider bandwidth, throughout the 2-12 GHz frequency range. In order to strengthen them, in a precise way, GA/PSO as the parametric optimization method based on EM solver was implemented, in which the physical variables: W, L, L_d, W_f etc. are optimized, as shown in Fig. 3.

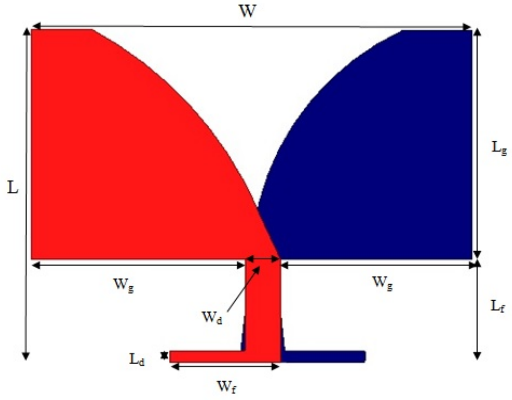

Fig. 1. Geometry of the Proposed Antenna (RED=Top and Bottom=Blue)

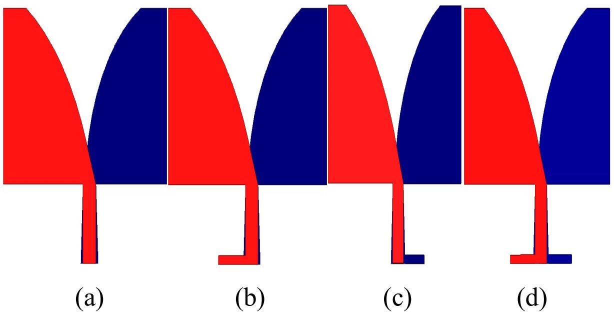

Fig. 2. Development Stages: (a) Leaf Shaped (b) Top Leaf with Stub (c) Bottom Leaf with Stub (d) MLSAVA (RED=Top and Bottom=Blue)

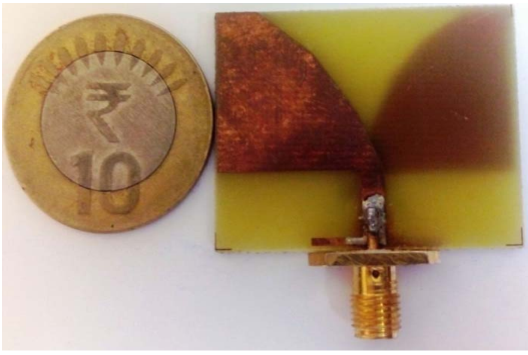

Fig. 3. Fabricated Prototype of MLSAVA

The calculated dimensions are tabulated in Table 1 along with GA-optimized dimensions where reduction in antenna size can be viewed from the reduction in dimension of W, L, L_d and W_f .

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA

Constructional Parameters	Calculated (in mm)	GA-Optimized (in mm)
W	40	30
L	35	25
L_g	20	15
W_g	18	11
L_f	9	7.5
W_d	3	2.8
L_d	2	0.8
W_f	8	6.5
Distance between Patch and Ground	26	---

The dimensions of the proposed antenna were calculated using the concepts by P. J. Gibson [3]. GA was implemented for miniaturization, characteristics of multi-band operations by optimizing W, L & characterization of stubs: L_d, W_f, etc. The calculated dimensions, along with optimized dimensions are tabulated in Table 1. It is obtained as intake from rigorous parameters sweeping, that is initiated in EM solver. Before utilizing these dimensions in fabrication, a specific target was set: an impedance bandwidth of > 5 GHz, gain > 5 dBi and volumetric reduction of antenna size > 25% with the advent of multi-band characteristics. From Table I, it can be observed that by implementing GA, the volumetric size of antenna is reduced by 30%, without affecting performance prospective. This can be visualized in the next section.

III. RESULTS, DISCUSSION AND ANALYSIS

The authors would like to draw your attention that the implementation of GA by FEM Solver is similar to that of previous cases for antennas with its equivalence procedure [12, 13]. At the time of implementing GA, authors kept vigil look for behaviour of antenna and its impact on parameters like S_{11}, Radiation Pattern, Gain. All the antenna parameters were measured with follow-up of measurement techniques.

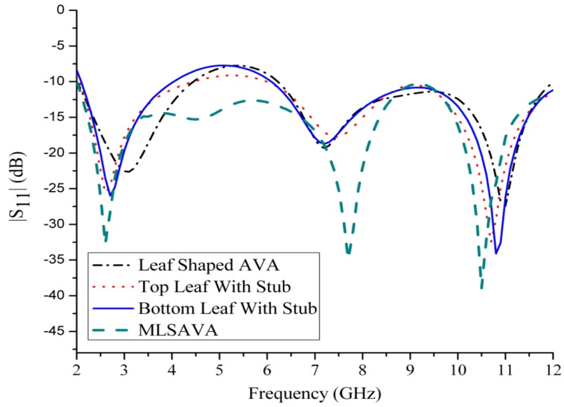

Fig. 4. S_{11} Characteristics of the Proposed Antenna-Developmental Stages

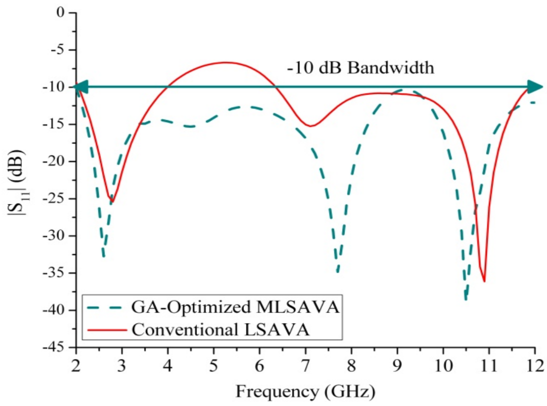

Fig. 5. S_{11} Characteristics of the Proposed Antenna-Optimization Stage

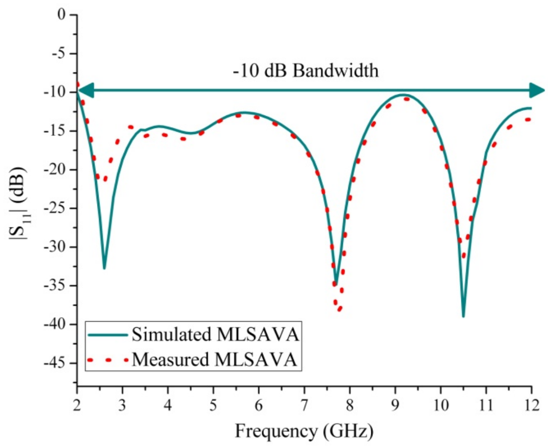

Fig. 6. S_{11} Characteristics of the Proposed Antenna-Final Stage

All the analysis has been carried out by using HFSS. The scattering parameters for all these above case are studied by the authors. Fig. 4-6 shows S_{11} characteristics of the antenna, stages by stages. The primitive motive of this work was to get multi-band characteristics. With added intuition to it, is to get miniaturization without compromising with multi-band and bandwidth. With the combination of both of these duo facts, this makes the antenna more vital for communication. In the addition to it, gain factor is found to better in this case, as in explained in the later part of the paper.

The normalized radiation pattern for the proposed antenna is shown from Fig. 7 (a)-(d). The behaviour of realized gain at Phi=0 and Phi=90 for E (θ, φ) is studied for 2.4 GHz, 7.7 GHz, 10.6 GHz and 12 GHz. It can be seen from above that, there is an figure of eight and omni-directional pattern obatined for the lower resonating frequency. As the range of taken resonating frequencies increases, the radiation pattern gets distorted, can be seen in Fig. 7 (b) - (d).

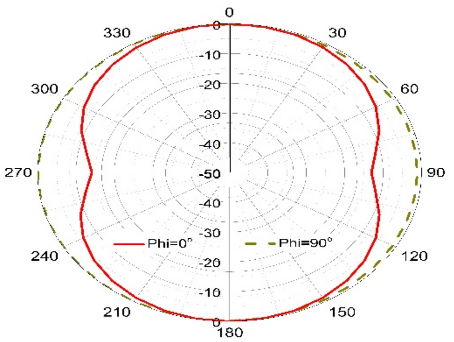

Fig. 7. (a) Radiation Pattern of the proposed antenna @ 2.4 GHz

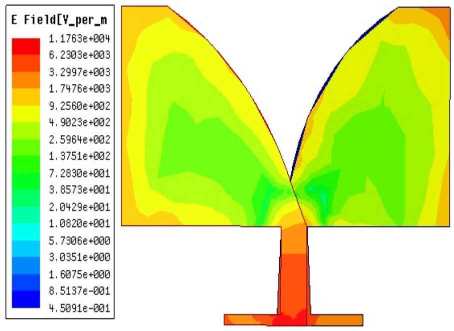

Fig. 8. (a) E-Field Distribution of the proposed antenna @ 2.4 GHz

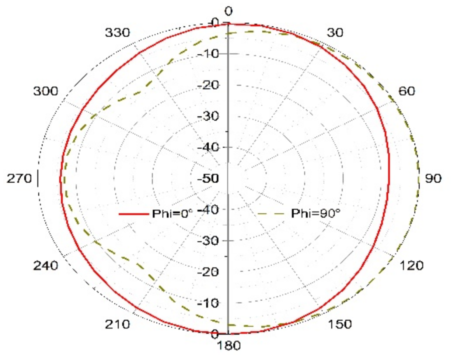

Fig. 7. (b) Radiation Pattern of the proposed antenna @ 7.7 GHz

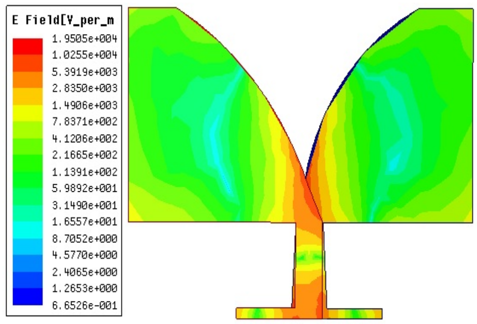

Fig. 8. (b) E-Field Distribution of the proposed antenna @ 7.7 GHz

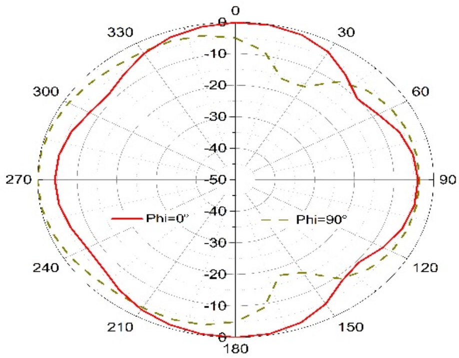

Fig. 7. (c) Radiation Pattern of the proposed antenna @ 10.6 GHz

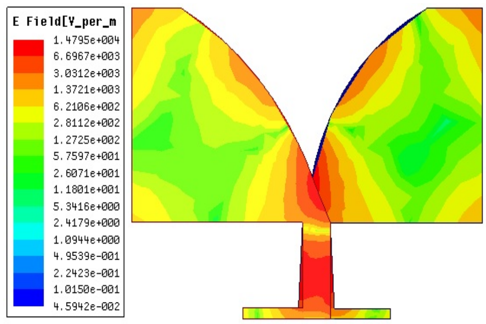

Fig. 8. (c) E-Field Distribution of the proposed antenna @ 10.6 GHz

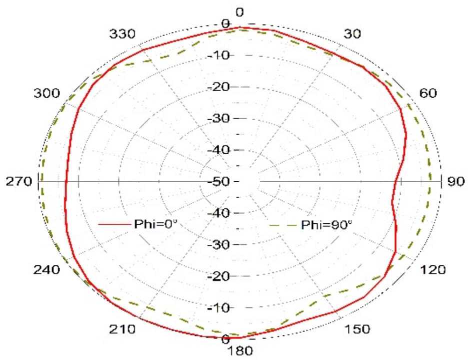

Fig. 7. (d) Radiation Pattern of the proposed antenna @ 12GHz

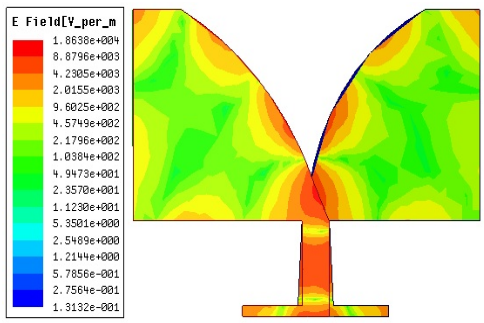

Fig. 8. (d) E-Field Distribution of the proposed antenna @ 12 GHz

The electric field distribution for the proposed antenna is shown in Fig. 8 (a)-(d). Their behaviour is studied for 2.4 GHz, 7.7 GHz, 10.6 GHz and 12 GHz. It is observed, there is a uniform distribution of electric fields on patch, ground with maximum fields in feed line near the power port. At higher frequencies, it is observed that maximum fields, flow in the flares of patch and the ground, resembling perfect outflow of distribution throughout the antenna.

Gain is one of the important factors in the case of antennas used in long-range applications. Previously it is observed that the monopole antenna [14] and planar antenna [15] used in UWB, would restrict for a gain within 5 dBi. But in the case of MLSAVA, it is more than 5 dBi in most of the resonating frequencies. Thus, authors would like to draw the attention of the readers that the proposed MLSAVA, is better in the case of previously used monopole and planar antennas. The gain is shown in Fig. 9. A comparison has been done in between simulated & measured gain, where we find a good agreement in between them. It is very much clear that the proposed antenna has flat gain for all pass bands and has a maximum gain of 11.45 dBi at 9.5 GHz with an average gain of more than 9 dBi which is of the higher side as compared to that of already reported paper [16].

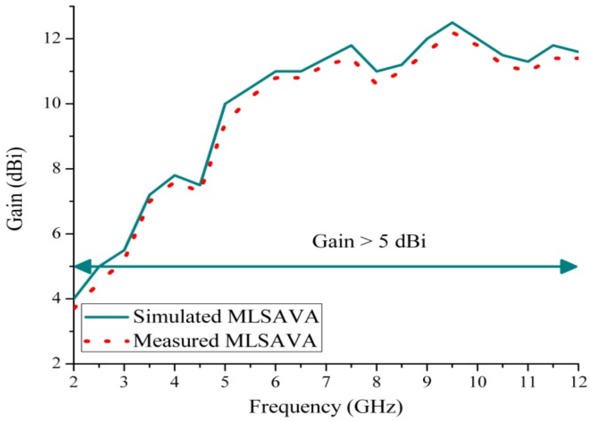

Fig. 9. Gain Characteristics of the proposed antenna

IV. CONCLUSION

Here, a novel and compact modified leaf shaped antipodal Vivaldi antenna is designed, fabricated and characterized. The journey from a leaf shaped AVA to MLSAVA, shown in the developmental stages. It can be used for UWB, right from 2-12 GHz, impedance bandwidth of 10 GHz. With addition of stubs, multi-band antenna with wideband characteristics, having resonating frequencies: IEEE S-Bands (2.4 GHz) with bandwidth of 900 MHz, C-Bands (7.7 GHz) with bandwidth of 1700 MHz and X-Bands (10.6 GHz) with bandwidth of 1300 MHz). Besides, it has low cross polarization level (< -15 dB), gain > 5 dBi from 2-12 GHz. GA was implemented for miniaturization and to obtain characteristics of multi-band operations in a better way. The antenna was fabricated and characterized in lab, still it is a promising candidate for the futuristic applications in UWB.

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