Indian Journal of Science and Technology, *Vol 9(31), DOI: 10.17485/ijst/2016/v9i31/85164, August 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Bandwidth Enhanced Antipodal Vivaldi Antenna for Wide Band Communication Applications

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Abstract

Objectives: To design high bandwidth and high gain compact antipodal Vivaldi antenna which can be applied for modern communication systems especially for military communication systems. **Methods/Analysis:** Antipodal Vivaldi antenna is designed with flared elements on both sides of the substrate. Top side patch element is oriented towards left side and bottom side defected ground structured element is oriented towards right side. Finite element method based HFSS-15 is used in the design and simulation. The simulated EM-Results of the return loss, VSWR, radiation patterns and field distributions are analyzed and optimized antipodal vivaldi antenna is designed with parametric analysis. Fire resistance PCB substrate material with dielectric constant 4.4 is used as substrate to prototype the antenna model and measured results are analyzed for validation on ZNB 20 vector network analyzer. **Findings:** In this work a novel antipodal Vivaldi antenna is designed to operate between L to KU-band communication and applications. The proposed antenna modal consisting of a special type of tapered slot edge structure in the design which enhanced the bandwidth of the antenna. To convert antenna into a wide band model, some modifications are done by placing slotted sections on the ground and patch elements. Antenna is showing 15 GHz huge bandwidth and impedance bandwidth of more than 65%. The proposed antenna is showing VSWR of 2:1 ratio in the operating band and peak realized gain of 7 dB. Omni directional radiation pattern with peak directivity of 5 dB is attained with the current model. Wideband characteristics with considerable gain grouping this antenna in to several communication applications in S, C, X, Ku-bands. **Novelty/Improvement:** Novelty with respect to defected ground structured flared element and huge bandwidth are advancements in the current design. Both patch and ground structures are designed in a way to enhance the bandwidth as well as gain which is advantageous in communication applications. Field distributions with excellent radiation characteristics are making this model as suitable candidate for future communication systems.

Keywords: Antipodal Vivaldi Antenna (AVA), Ansys High Frequency Structure Simulator (HFSS), Bandwidth, Tapered Slot (TS), Vector Network Analyzer

1. Introduction

Vivaldi antennas have considerable attention due to their wideband characteristics, simple structure, easy fabrication and wide use in UWB applications. Because of low price and ease of integration, tapered slot antennas are used in most of the modern designs. Vivaldi antennas can provide bandwidth up to several octaves. A printed Vivaldi antenna is end fire antennas with tapered step and provides large bandwidth and gain and as well as relatively easy to manufacture on standard printed circuit board substrates. The exponential function will decide the shape of the tapered slot.

The traditional way of Vivaldi antenna is generally fed from a slot line. To provide feed to the slot line of the Vivaldi antenna from a stripe line, a micro-strip circuit with transition is very much required. Such kind of transitions can take a number of forms in general, but typically include a quarter wavelength sections. This limits overall performance to a few octaves because of the frequency dependent nature of the transition.

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The antipodal version of the Vivaldi antenna generally overcomes the problem of bandwidth limiting transitions. This use a tapered micro-strip to symmetrical double sided stripline transition.

The original Tapered Slot Antenna (TSA) was proposed by[1–3]. There was not a good planar antenna element, which can produce a symmetric end fire beam, with appreciable gain and side lobes[4–5]. A Dual Exponentially Tapered Slotted Antenna (DETSA) is a modified form of Vivaldi radiator and it was first introduced. The DETSA is a tapered slot line antenna, where the slot tapering is described by an exponential function[6–8]. The Double Exponentially Tapered Slot Antenna (DETSA), which is a variation of the Vivaldi antenna with the outer edge exponentially tapered[9–12]. A typical Tapered Slot Antenna consists of tapered slot, which has been etched on the metallization on a dielectric substrate. TSA elements radiate along the long direction of the substrate and can also be easily combined into arrays[13,14]. Slotted antennas are potentially very needful for integrated phased array antennas, especially for applications requiring wide bandwidth and wide scanning[15–17]. Corrugated edges are also can be introduced to reduce the width of the TSA without degrading the radiation patterns[18–20].

2. Materials and Methods

FR4 substrate material with permittivity 4.4 and dielectric loss tangent 0.02 is used in the design of the antenna. The shape of the conventional Vivaldi exponential flare is defined by the equation y = a e ^ b x + c. At wave length the antenna radiates from a point on the exponential flare is defined by $y = \lambda / 4$. HFSS EM-Tool is used to design, simulate and verify the antenna model. Optimized simulated model is prototyped for real time measurement on ZNB 20 Vector network analyzer. The aim of this work is to produce a wide band Vivaldi antenna with huge band width and compact in size to place in communication systems to achieve the light weighted, compact design. To achieve this aim, slot structure is used in the design to shift the frequency of operation to lower band.

3. Antenna Design and Geometry

Figure 1 shows the structure of the antenna model and Table 1 show the dimensional characteristics of the proposed design. The proposed antenna is occupying an overall dimension of 48X60X1.6mm on FR4 substrate with dielectric constant 4.4.

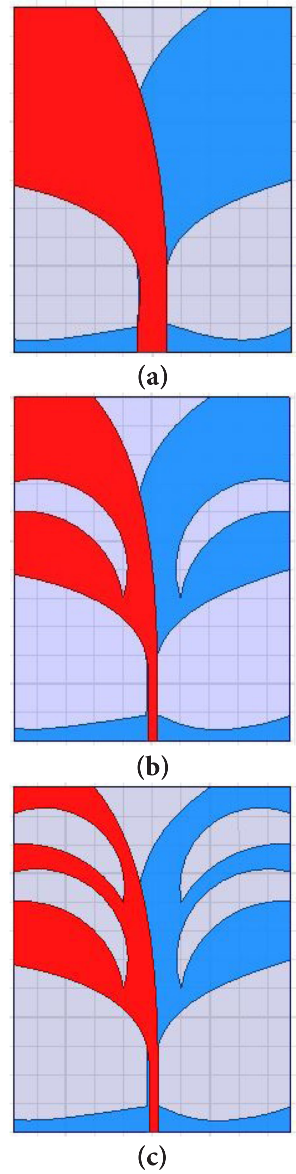


Figure 1. Vivaldi antenna iterations. **(a)** Flared vivaldi base model antenna. **(b)** Single slotted flared antenna. **(c)** Double slotted flared antenna.

Table 1. Antenna dimensions

Parameter	L	W	Wf	Lf	L1	WTs	WTs1	WTs2
In mm	60	48	1.9	15	29	14	19.8	5

4. Results and Discussion

A basic model of Vivaldi antenna with one flared element on topside has patch and another flared element on the ground side is constructed and its reflection coefficient is plotted in Figure 3. In this design different iterations

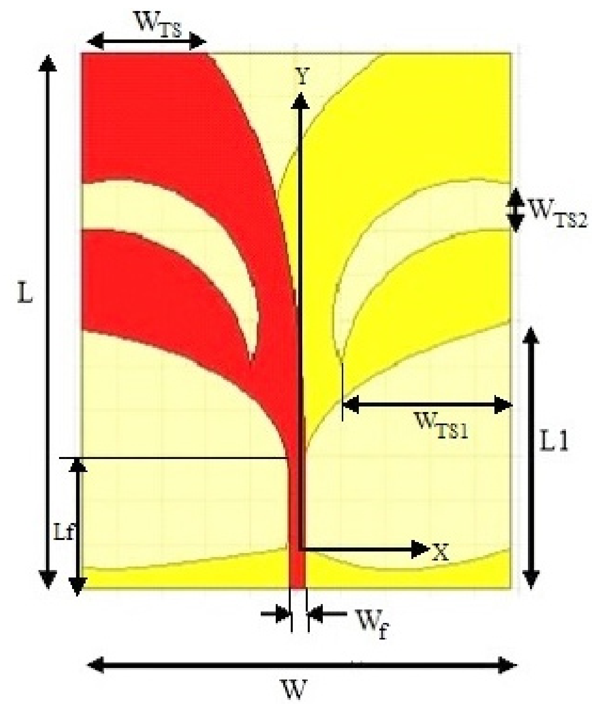


Figure 2. Proposed antipodal vivaldi antenna.

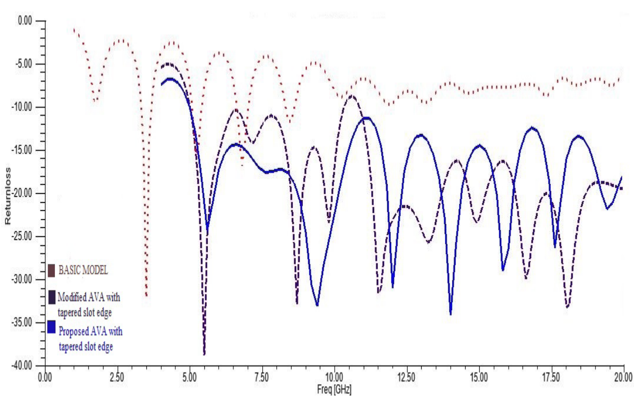


Figure 3. S11 performance of the proposed antennas.

are considered to design the proposed antenna, which can be observed from Figure 1. The base model is providing multiband characteristic rather than wideband behavior. A small modification on the base model is done by placing tapered slot edge for the improvement of the band width is proposed and its return loss is also presented in Figure 3. Compared with base model, tapered slot edge is behaving like dual band characteristic model with low band width at lower frequency and high bandwidth at higher frequencies. To convert antenna into a wide band model, some modifications are done by placing slotted sections on the ground and patch elements. The proposed antenna reflection coefficient S_{11} giving an evidence of wide band characteristics which are more suitable for communication and applications.

Figure 4 gives the VSWR characteristics of all the iterations and Figure 5 provides the gain characteristics of the proposed antenna with respect to frequency of operations. A peak released gain of 7 dB is attended from the proposed antipodal Vivaldi antenna. Figure 6 shows the prototyped antenna top view and bottom view on FR4 substrate.

The radiation characteristics of the antenna is showing quasi Omni directional and Omni directional in H-plane at lower frequency band and more directive in the E-plane at high frequency band. Three dimensional radiation parameters of the proposed antenna at different operating points in the wide band are shown in Figure 8.

The surface current distribution of the proposed antenna at low frequency band is more concentrated on the middle of the flared elements along with feed line but at high frequency most of the current density is distributed t the edge of the flared elements inside of the feed line.

Figures 10 and 11 shows the measured reflection coefficient S_{11} and VSWR of the proposed antenna on Z N B - 20 vector network analyzer at KL University. The simulated and measured results are having almost good agreement at each other except at lower band. This is due to the poor soldering connectivity on the prototype antenna model with SMA connector.

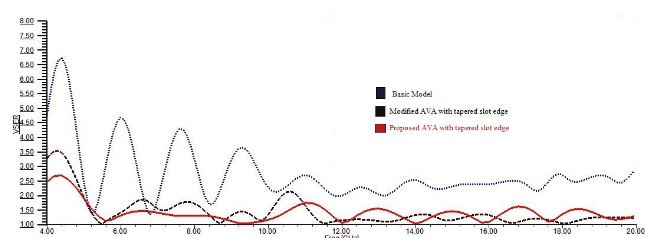


Figure 4. VSWR performance of the proposed antennas.

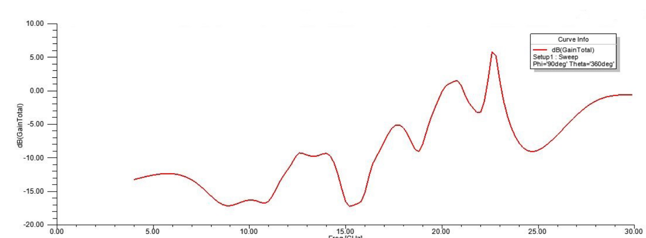
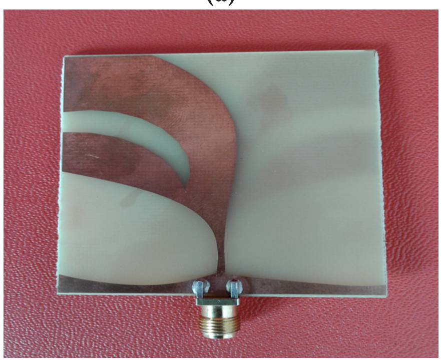


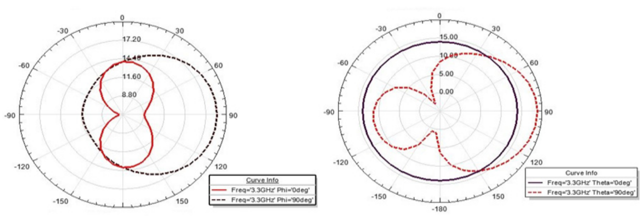
Figure 5. Simulated gain vs frequency of proposed antenna.

(a)

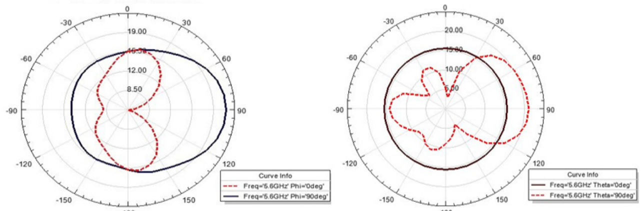


(b)

Figure 6. Prototyped AVA with tapered slot edge. **(a)** Top view. **(b)** Bottom view.



(a)



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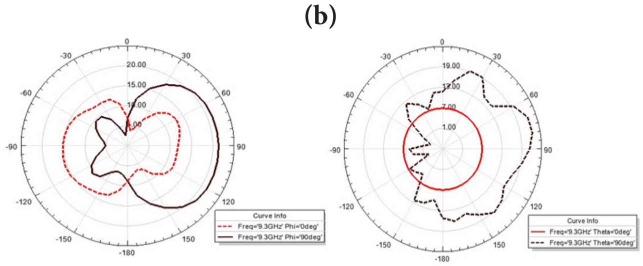
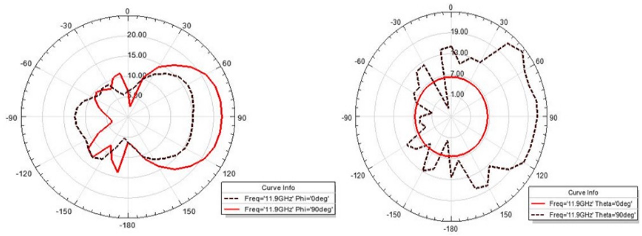
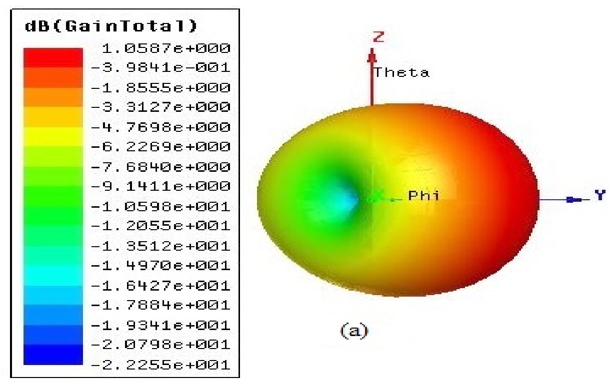


(c)

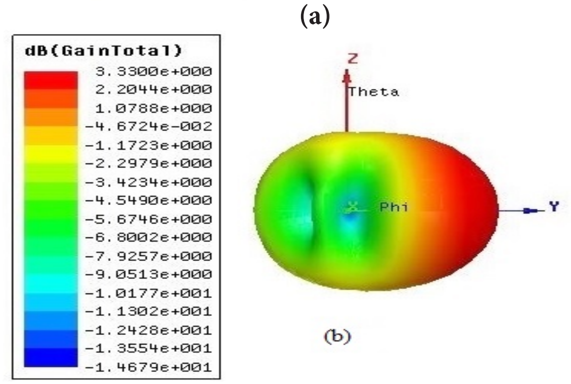


(d)

Figure 7. **(a)** E-plane and H-plane radiations pattern of the antennas at 3.3 GHz. **(b)** E-plane and H-plane radiations pattern of the antennas at 5.6 GHz. **(c)** E-plane and H-plane radiations pattern of the antennas at 9.3 GHz. **(d)** E-plane and H-plane radiations pattern of the antennas at 11.9 GHz.



(a)



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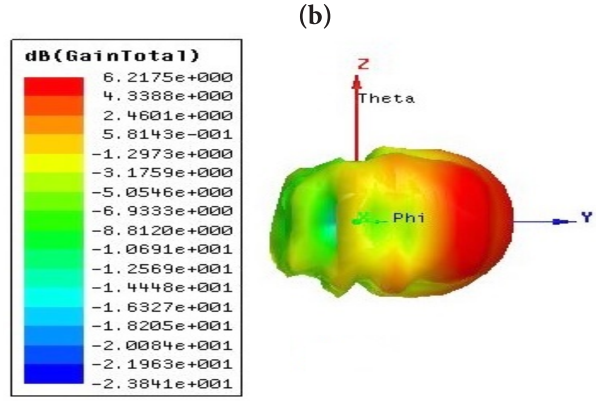

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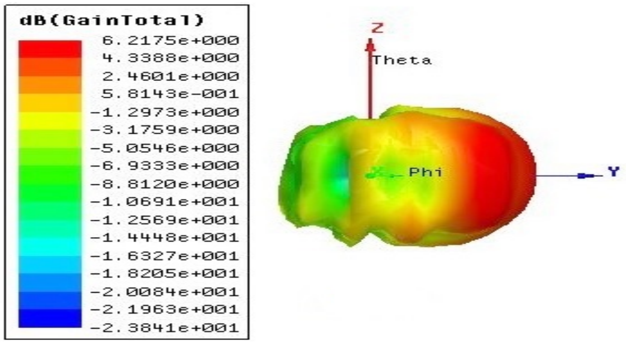
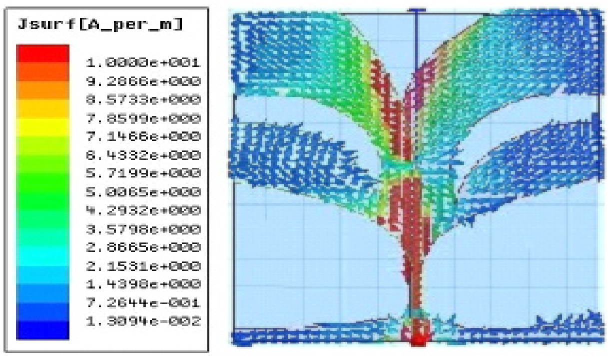
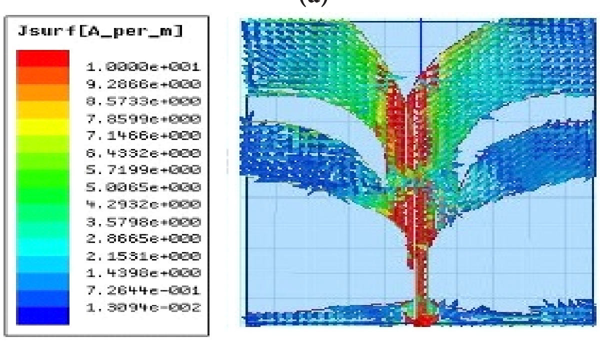


(d)

Figure 8. **(a)** 3-D polar plot at 3.3 GHz. **(b)** 3-D polar plot at 5.6 GHz. **(c)** 3-D polar plot at 9.3 GHz.**(d)** 3-D polar plot at 11.9 GHz.



(a)



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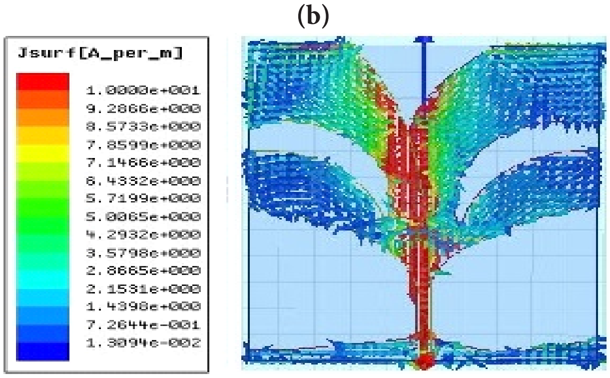

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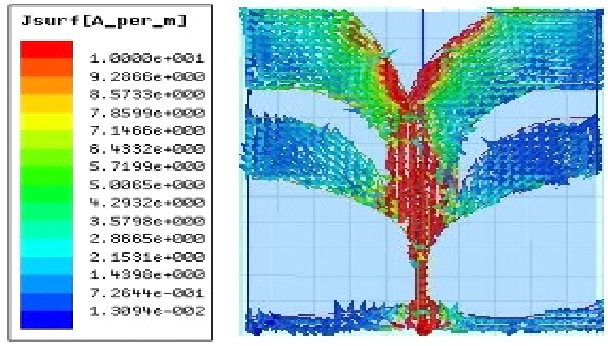

(d)

Figure 9. Surface current distribution of TSE AVA at 3.3 GHz. **(b)** Surface current distribution of TSE AVA at 5.6 GHz. **(c)** Surface current distribution of TSE AVA at 9.3 GHz. **(d)** Surface current distribution of TSE AVA at 11.9 GHz.

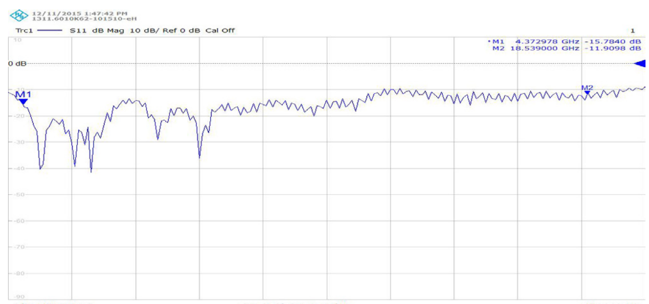

Figure 10. Measured reflection coefficient of the proposed antenna on ZNB 20 VNA.

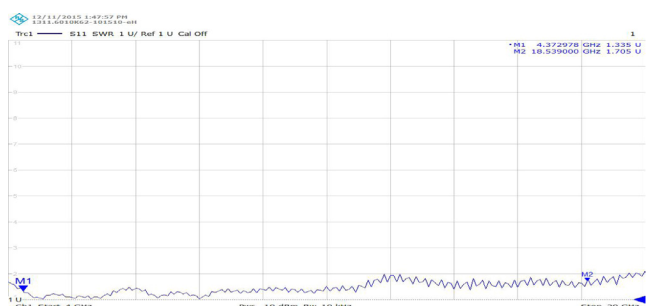

Figure 11. Measured VSWR of the proposed antenna on ZNB 20 VNA

5. Conclusion

Antipodal Vivaldi antenna with tapered slot is designed and experimentally verified its operational characteristics in this paper. The proposed antenna is showing huge bandwidth of 15 GHz and peak realized gain of 7dB.

Wideband characteristics with considerable gain grouping this antenna in to several communication applications in S, C, X, Ku bands. The radiation characteristics of the antenna is showing quasi-omni directional radiation pattern in H-plane at lower frequency band and more directive radiation pattern in the E-plane at high frequency band. Antenna is prototyped on FR4 substrate and tested on ZNB 20 vector network analyzer. The measured results are in good agreement with the HFSS simulated results.

6. Acknowledgements

Authors express their sincere thanks to department of science and technology through grant SR/FST/ETI-316/2012.

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