International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Compact Antipodal Vivaldi Antenna for Short Range Communication

S. A. Adamu[1], Sahanunu Dahiru[1], Ibrahim Abba[2]
[1]Computer Engineering Department, Jigawa State Institute of Information Technology, KM 3, Kano – Daura Road, Kazaure, Jigawa State
[2]Electrical Engineering Technology Department, School of Technology, Matan Fada Road, Kano State Polytechnic, Kano State
Email address: aasaeed2 @ yahoo.com

Abstract— *For better range resolution, essential requirements of antennas for short range communication are wider bandwidth and a high directive beam. Thus an Ultra-wideband (UWB) Antipodal Vivaldi antenna operating at 3.09 GHz to more than 12 GHz and a high peak gain is designed and proposed for these applications. The proposed antenna is designed using a Rogers RT Duroid 5880 dielectric substrate with of 1.6 mm. Simulation results of the proposed antenna showed a nearly stable end-fire radiation pattern in the entire frequency range, with peak realize gain of 10.7 dB at 10 GHz. Surface current distribution is studied to further characterize the performance of the antenna.*

Keywords— *Antipodal Vivaldi Antenna, Dielectric Substrate, Perimeter Surveillance Radar, Reflection Coefficient, Ultra wideband.*

I. Introduction

The development of radar technology has an important role in several fields such as aviation, civil engineering, geology, medicine as well as security. Perimeter surveillance radar (PSR) is a class of radar sensors that monitor activities surrounding or on critical infrastructure areas such as airports, seaports, military installations, national borders, refineries and other critical industry and the like (Jasmine, et al., 2014). Such radars are characterized by their ability to detect movement at ground level of targets such as an individual walking or crawling towards a facility. An essential component of the radar system is the antenna (Rajesh, et al., 2017). The antenna enables the radio waves to be reflected from the surface of the object. A radar system that operates at higher frequencies and with narrower beams determines target positions most accurately (Liu, 2016). The resolution of a radar system is specified by the bandwidth of the antenna. The wider the bandwidth of the antenna, the higher the resolution of radar system. Additionally, radar system for security application requires antenna with directional radiation pattern. As such an antenna with wide bandwidth and directional radiation pattern is desired. Several UWB antennas meet this requirement, but desirable electrical features such as planar and simple structure, light weight and low profile, symmetric beam in both radiating planes, conformity with mounting host surfaces (Alhawari, et al., 2012; Dastranj, 2015; Namas & Hasanovic, 2012; Wang, et al., 2013) among others have combined to make the Vivaldi antenna more competitive in UWB applications compared other UWB antennas such as the Log periodic and the Horn antennas which are very bulky and non-planar. The Vivaldi antenna was first proposed by Gibson (Li, et al., 2016) as a travelling wave, coplanar, tapered slot antenna before being successively improved by Gazit (Fei, et al., 2011) and then Langley (Zhu & Gao, 2013) in order to overcome the limitations of the initial designs.

II. Proposed AVA Structure Design

Figure 1 shows the development of the proposed antenna. The antenna is designed on an RT Duriod 5880 dielectric substrate having relative permittivity (ε_r) of 2.2, dielectric loss tangent
$\delta = 0.0009$ and a thickness h of 1.58 mm.
The dimension of the proposed antenna can be obtained from (Moosazadeh, et al., 2017);

$$S_l = \frac{c}{f_{\min}}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Where S_l is antenna length, c is the speed of light, f_{min} *is* the lower frequency, and ε_r is dielectric constant.

The upper frequency limit has a theoretically infinite value whereas the width of the antenna at the open aperture determines the lower end frequency limit which was obtained from;

$$f_{\min} = \frac{c}{2S_w\sqrt{\varepsilon_{eff}}} \tag{2}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{S_w}\right)^{-\frac{1}{2}} \tag{3}$$

where ε_{eff} is the effective permittivity, h is the thickness of the substrate and S_w represents the antenna width.
While the Exponentially Tapered Slot Antenna (TSA) can be obtained from;

$$y(x) = C * e^{K_a x} \tag{4}$$

Constant C and opening rate K_a is given by

$$C = \frac{W_f}{2} \tag{5}$$

$$K_a = \frac{1}{L_a}\ln\left(\frac{W_a}{W_f}\right) \tag{6}$$

S. A. Adamu, Sahanunu Dahiru, and Ibrahim Abba, "Compact Antipodal Vivaldi Antenna for Short Range Communication," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 3, pp. 75-77, 2020.

Table 1 shows the parameters used to perform the microstrip Vivaldi antenna design that have been obtained based on the literature study.

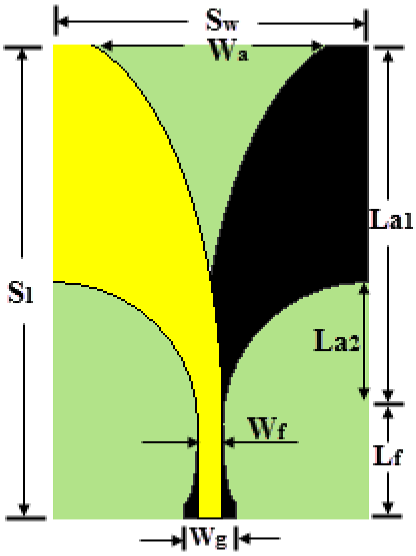


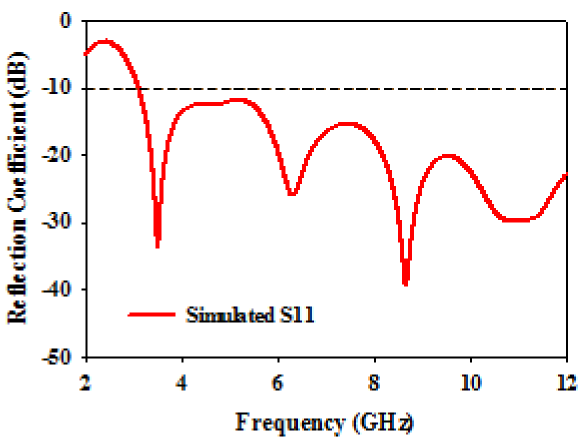
Figure 1. Geometry of Proposed Antipodal Vivaldi Antenna Structure

TABLE 1. Parameters used in designing Vivaldi antenna.

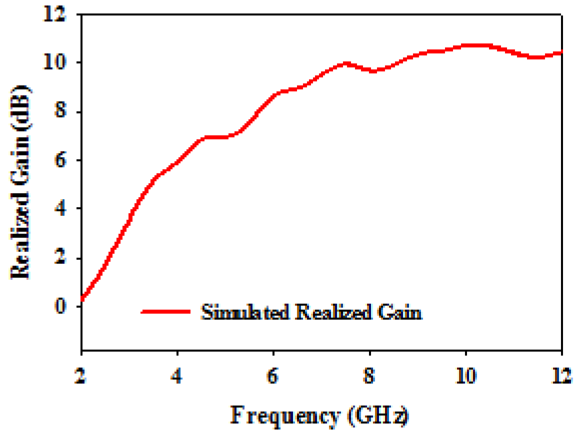
Parameter	Dimension (mm)	Note
Sl	60	Substrate Length
Sw	45	Substrate Width
Wa	44	Aperture Width
Wg	8	Ground Plane Width
Wf	3.2	Feed Line Width
La1	45	Inner Taper Profile Arc Length
La2	14	Outer Taper Profile Arc Length
Lf	15	Feed Line Length

III. RESULTS AND DISCUSSION

The Reflection coefficient S11 is an indicator of how well an antenna is matched to the input transmission line which defines the quality of signal transmission. Simulation result of the variation of reflection coefficient (S11) with frequency is shown in Figure 2(a). From this result, it can be observed that proposed antipodal Vivaldi antenna has an impedance bandwidth from 3.09 GHz to more than 12GHz.



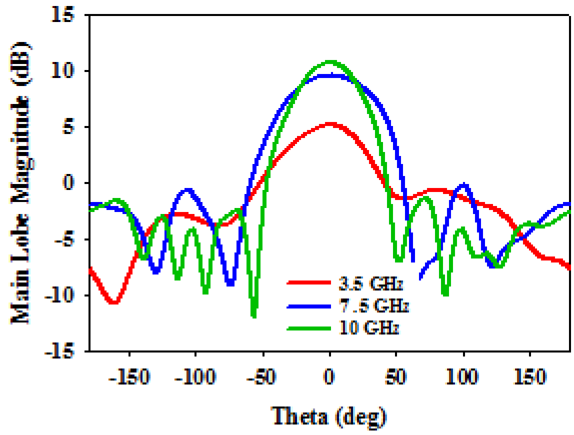
(a)



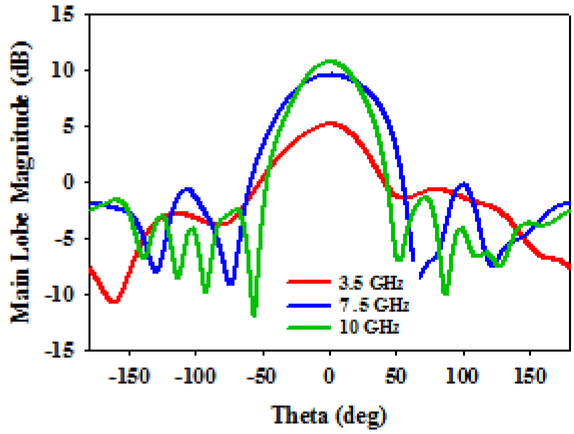
(b)

Figure 2. (a) Reflection Coefficient (S_{11}) and (b) Realized Gain of Proposed Antenna.

Figure 2 (b) illustrate the simulation result of the variation of realized gain with frequency. A high realized gain of 3.86 dB to 10.70 dB is achieved by the proposed antenna throughout the operating frequency bandwidth with the highest realized gain at 10 GHz. Similarly, Figure 3 shows the E-Plane and H-Plane radiation pattern of the antenna.



(a)



(b)

Figure 3. Radiation Pattern of Proposed Antenna at 3.5 GHz, 7 GHz and 10 GHz (a) E-Plane and (b) H-Plane

A high directive and symmetric beam is achieved especially at high frequencies which proved the suitability of the antenna

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

for the proposed application as shown in Figure 3. Table 2 gives the numerical values of the simulated radiation pattern parameters.

TABLE 2. Radiation Pattern Parameter Values

Frequency	Parameter	E-Plane	H-Plane
3.5 GHz	Main Lobe Magnitude (dB)	5.15	5.15
	HPBW (deg)	68.9	142.1
	Side Lobe Level (dB)	-5.8	-3.6
7 GHz	Main Lobe Magnitude (dB)	9.57	9.57
	HPBW (deg)	75	38.6
	Side Lobe Level (dB)	-9.8	-11.4
10 GHz	Main Lobe Magnitude (dB)	10.8	10.8
	HPBW (deg)	50.6	31.7
	Side Lobe Level (dB)	-12.1	-4.6

To further study the behavior of the designed antenna structures, surface current distribution at 3.5 GHz and 7 GHz are illustrated in Figure 4. It can be observed from the figure that the radiating current flows uniformly along the inner taper profile of the radiating arm of the antenna. This indicates that the antenna has uniform surface current distribution with high amplitude.

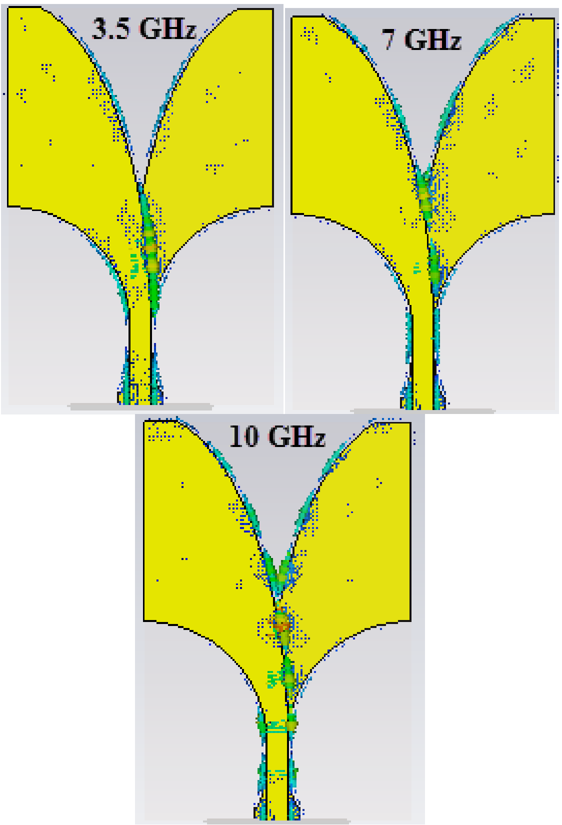


Figure 4. Surface Current Distribution of Proposed AVA at 3.5GHz, 7 GHz and 10 GHz

IV. Conclusion

A compact high-gain antipodal Vivaldi antenna was investigated and proposed in this study for short range applications. A single-layered compact 60 x 45 mm^2 antipodal Vivaldi antenna was investigated to characterize its performance. The proposed antenna achieved a wide relative bandwidth of more than 118%, a high realized gain of 10.7 dB at 10 GHz and a high directive beam in both the principal planes. With simple structure and asymmetric and stable end-fired radiation pattern over its operating band, the proposed antenna has proved to be a good choice for short range applications and systems. The proposed antenna will be fabricated and measured next to validate the simulation results.

References

[1] Alhawari, A. R H., Ismail, A., Mahdi, M. A., & Abdullah, R. S. A.R., (2012). Antipodal Vivaldi antenna performance booster exploiting snug-in negative index metamaterial. *Progress in Electromagnetic Research, 27*(7), 265-279.

[2] Dastranj, A., (2015). Wideband antipodal Vivaldi antenna with enhanced radiation parameters. *IET Microwave Antennas and Propagation, 9*(15), 1755-1760.

[3] Fei, P., Jiao, Y. C., Hu, W. & Zhang, F. S., (2011). A miniaturized antipodal Vivaldi antenna with improved radiation characteristics. *IEEE Antennas and Wireless Propagation Letters, 10*(8), 127-130.

[4] Jasmine, J. A., & Anita, J. M. T. (2014). Design of Vivaldi antenna for brain cancer detection. In *Proceeding of the International Conference on Electronics and Communication Systems*, 1-4.

[5] Li, Z., Kang, X., Su, J., Guo, Q., Yang, Y., & Wang, J., (2016). A wideband end-fire conformal Vivaldi antenna array mounted on a dielectric cone. *International Journal of Antennas and Propagaton*, 2016, 1 – 11.

[6] Liu, Y., (2016). Radar cross section reduction of a microstrip antenna based on polarization conversion metamaterial," *IEEE Antennas Wireless Propagation Letters, 15*(4), 80–83.

[7] Moosazadeh, M., Kharkovsky, S., Case, J. T., & Samali, B., (2017). Miniaturized UWB antipodal Vivaldi antenna and its application for detection of void inside concrete specimens. *IEEE Antennas and Wireless Propagation Letters*,16(3), 317–1320.

[8] Namas, T., & Hasanovic, M., (2012). Ultrawideband antipodal Vivaldi antenna for road surface scanner based on inverse scattering. In *28Th Annual Review on Progress in Applied Computational Electromagnetics*, Columbus Ohio, USA. 882-887.

[9] Rajesh, N., Malathi, K., Raju, S., Abhai Kumar, V., Prasath, S. D. R., & Gulam, N. A., (2017). Design of Vivaldi antenna with wideband radar cross section reduction" *IEEE Transactions on Antennas and Propagation, 65*(4), 2102-2105.

[10] Wang, Y. W., Wang, G. M., & Zong, B. F., (2013). Directivity improvement of Vivaldi antenna using double-slot structure. *IEEE Antennas and Wireless Propagation Letters, 12*(5), 1380-1383.

[11] Zhu, F. G., & Gao, S, (2013). Compact elliptically tapered slot antenna with non-uniform corrugations for ultra-wideband applications. *Radio Engineering 22*(1), 276–280.

S. A. Adamu, Sahanunu Dahiru, and Ibrahim Abba, "Compact Antipodal Vivaldi Antenna for Short Range Communication," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 3, pp. 75-77, 2020.