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Design and Optimization of Ultra-Wideband Antipodal Vivaldi Antenna for Radar and Microwave Imaging Application

F. A. SHAIKH, S. KHAN, Z. ZAHARUDIN, A.H.M ZHIRUL ALAM, M. BIN YAACOB, Z. SHAHID, F. DIYANA, B.T. A. RAHMAN, KIRAYU BT. BADRON

Department of Electrical and Computer Engineering, International Islamic University Malaysia

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Abstract: The functional characteristics and parametric study of Ultra-Wideband Antipodal Vivaldi Antenna along with end-fire radiation pattern via UWB frequency range for radar as well as microwave imaging application has presented in this paper. The comparative study of different kind of AVA according to their structure and dimension has been proposed. Although the basic design concept of conventional antipodal Vivaldi antenna has reported and initially designed for a broad impedance bandwidth performances. Furthermore, the modification of AVA by incorporates the corrugations edges on both side of basic AVA structure. As a result, high gain has achieved with improved directivity and observed a flat gain especially at low frequency. The modified design structure almost covered entire UWB bandwidth. The propose antenna structure and optimization method is conceded out by simulation software named CST. The validations of antenna performance parameters like return loss, input impedance and directivity through simulation software. Prototypes of both like conventional and proposed modified antennas have fabricated and verified intended for its return loss as well as directional pattern.

Keywords: Microwave Imaging; UWB; AVA; CAVA; MAVA and CST

1. INTRODUCTION

Wireless communication adapted an imaginative approach for the transportation of Ultra-wideband pulses. Generally, UWB are used for transmit and receive pulses for the development of communication system. In time domain, the behaviour of UWB waveform pulses has more compressed as compared to frequency domain among sinusoidal partners (Reed *et al.,* 2002).The spectrum series of ultra-wideband (3.1GHz to 10.6GHz) has nominated in February 2002 by Federal communications Commission (FCC). This initial registration UWB frequency series has declared free for local consumer (FCC 2002). A Vivaldi antenna is most significant contender of UWB range and used in numerous imaging application as well as satellite communication. P. Gibson primarily investigated it in 1979, (Gibson *et al.,* 1979).

According to structure configuration of Vivaldi antenna, it has classified into three major types like TSVA (Tapered Slot Vivaldi Antenna), AVA (Antipodal Vivaldi Antenna) and BAVA (Balanced Antipodal Vivaldi Antenna). (Ba *et al.,* 2014). It has been observed that AVA has an excellent ability to propose reasonable return loss, (Moosazadeh *et al.,* 2015), large-scale interference with respect to UWB band, better directional radiation pattern and well-maintained surface current across whole UWB frequency range. (So *et al.,* 2016).The fundamental structure of UWB Vivaldi antenna carries a feed line. Generally, this feed line is a strip line otherwise micro strip. Usually, it has a radiating structure and some geometrical shape of Vivaldi antenna contain different kinds of radiating structure (Chu *et al.,* 2015) but it has provided limited coverage and not able to satisfy whole ultra-wide bandwidth. The most viable approach is exponential tapered slot curves that can offer better results and good broadband. (Pandey *et al.,* 2015). In many applications, the configuration of UWB AVA contains a variety of uniqueness like plain design, high gain and excellent bandwidth. (Moosazadeh *et al.,* 2016).

In this article, the comparison of conventional with modified antipodal Vivaldi antenna has introduced. The several parameters like return loss, radiation pattern and side-lobe level has discussed in this paper. Some modification is required in conventional geometrical shape to design modified version of an antipodal antenna. The elliptical slot curves has placed at the end of both edges of an antenna in order to achieved better directive gain and reflection as compared to conventional antenna (Moosazadeh *et al.,* 2017).

The structural formation of this define paper as follow. In Section 2, the discussion about the basic geometrical design of an antenna and composition. In section 3, presented the specification of an antenna and

++Corresponding author:Faraz Ahmed Shaikh, email:farshaikh@uit.edu farshaikh@uit.edu; cnar32.sheroz@gmail.com
Department of Electrical and Computer Engineering, International Islamic University Malaysia

related parameters that derived through simulation software. Ultimately, Section 4 describes the outcomes and establishes a conclusion. Section 5, the acknowledgement representation.

2. ANTENNA DESIGN AND CONFIGURATION

The geometrical structural design of AVA is present in **(Fig. 1)** A low-cost material named FR4 substrate is used for construction an antenna with a thickness of h=1.6mm, dielectric constant ε_r=4.4 and the value of dielectric loss tangent δ=0.02. (Shaikh *et al.*, 2017) The projected antenna contained two major parts: feed line and radiation flares.

The elliptical curve is used for the formation of conventional antipodal Vivaldi antenna. (Shaikh *et al.*, 2018) The structure outline of flares has elliptical in shape in order to achieved good broadband features due to the smooth transition between the feeding line and radiation flares. (Abbosh *et al.*, 2008).

In theory, the defined upper frequency limit of Vivaldi antenna is infinity and lower frequency limit generally rely on the width of an antenna and secondly the value of effective dielectric constant (ε_{eff}) as calculated here in (1) and (2) from (Wang *et al.*,. 2007).

$$fmin = \frac{c}{2W\sqrt{\varepsilon_{eff}}} \quad (1)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \quad (2)$$

W_f represent the width of feeding line and using the characteristic impedance Z_o = 50Ω respectively. It can derive by the subsequent equations (D.M. Pozar, 2005).

$$z_o = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(\frac{8h}{w} + \frac{w}{4h}\right) \quad for \left(\frac{w}{h}\right) < 1 \quad (3)$$

$$z_o = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{w}{h} + 1.393 + \frac{2}{3}\ln\left(\frac{w}{h} + 1.444\right)\right]} \quad for \left(\frac{w}{h}\right) \geq 1 \quad (4)$$

The above mentioned specification has used for the UWB antenna design including impedance Z_o = 50 **Ω**. Some modification like placement of elliptical curve at the end of edges of an antenna, used for the construction of the modified version of antipodal Vivaldi antenna (MAVA).The most advantageous dimensions are represent in **(Table 1)** and simulated via software (CST Microwave Studio, 2015) depicted in **(Fig..2(a) and 2(b)** respectively.

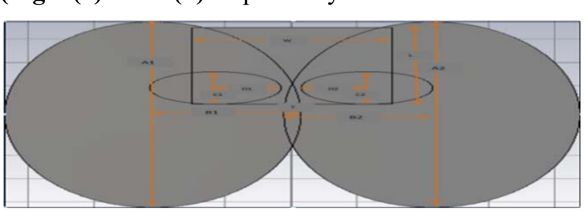


Fig..1: Geometrical Structure of AVA

Table 1: Dimensions of UWB Antenna

Parameter	Dimension
W	60.75mm
L	66mm
A1	80mm
B1	22.5mm
A2	80mm
B2	22.5mm
C1	14mm
D1	10mm
C2	14mm
D2	10mm
T(feed width)	2.85mm
EL	3mm
EW	1.5mm
h	1.5mm
t	0.035mm

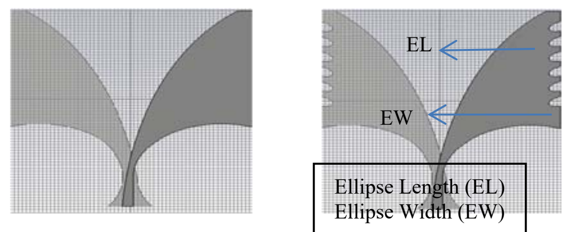


Fig..2 (2a) Conventional Antipodal Vivaldi Antenna (2b) Modify Antipodal Vivaldi Antenna

3. SIMULATION ANALYSIS AND DISCUSSION

A. *Reflection Coefficient*

The deviation of reflection coefficient (S11) of both antennas like CAVA and MAVA with UWB frequency range as present in **(Fig.3(a) and Fig.3(b)** respectively. It has observed that it covers complete UWB frequency range around 3GHz to 11GHz and the reflection coefficient (S11) are below -10dB, which is good for radar imaging system and satellite communication.

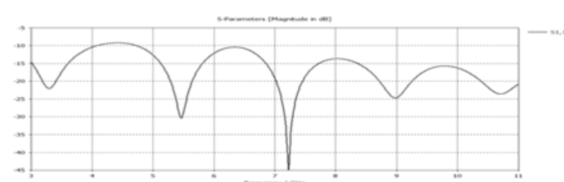


Fig.3 (a): Reflection Coefficient (S_{11}) of Conventional Antipodal Vivaldi Antenna (CAVA)

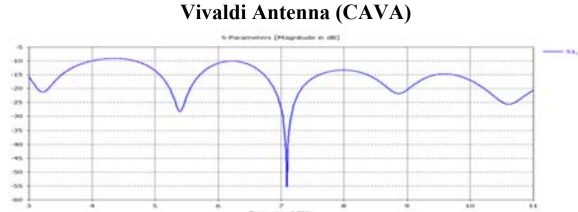


Fig.3 (b): Reflection Coefficient (S_{11}) of Modified Antipodal Vivaldi Antenna (MAVA)

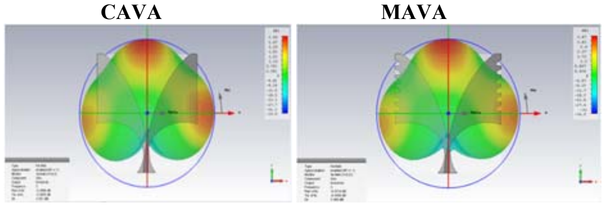
B. 3D Radiation Patterns

The 3D radiation patterns of both CAVA and MAVA have been presented in **(Fig..1).** It has been observed that in both cases the directivity of an antenna changes with respect to frequency as mentioned in **(Table. 2).** The simulation software CST has been used to derive the results. As we noticed that the MAVA has achieved a reasonable amount of directivity at 6.5 GHz and 9.5 GHz as compared to CAVA. The high gain can achieved at UWB frequency range through MAVA.

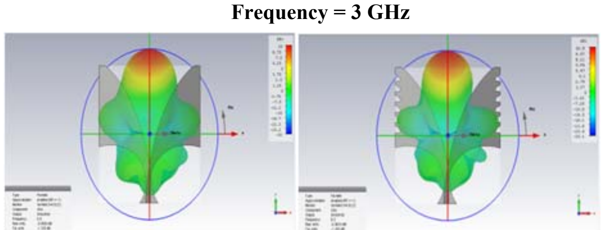
Table 2: The directivity of Conventional antenna (a) and proposed modified antenna (b)

Frequency (GHz)	Conventional (CAVA) (a)	Proposed Modified (MAVA) (b)
	Directivity (dBi)	Directivity (dBi)
3	3.05	3.47
3.5	5.25	5.76
4	6.71	7.09
4.5	7.66	7.89
5	8.26	8.32
5.5	8.88	9
6	9.54	9.88
6.5	10	10.9
7	10.4	11.1
7.5	10.6	10.9
8	10.7	10.8
8.5	10.8	10.9
9	10.9	11.5
9.5	10.6	11.6
10	10.2	10.6

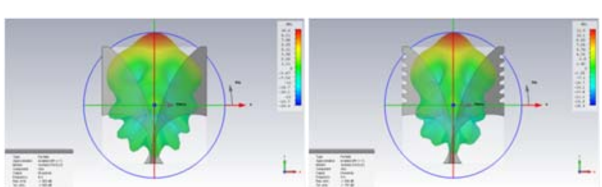
CAVA **MAVA**



Frequency = 3 GHz



Frequency = 6.5 GHz



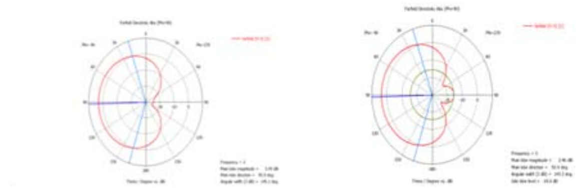
Frequency = 9.5 GHz

Fig.4: Far-field radiation patterns

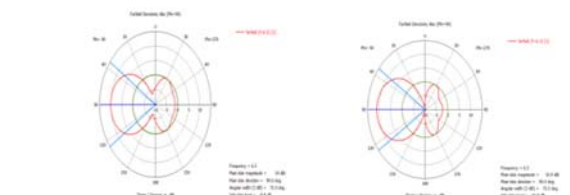
C. 3-D Polar Plots

The polar representations of both CAVA and MAVA have been presented in **(Fig. 5)**. CST simulation software is use to carry out the results under different frequency. MAVA has shown good stability in a capacity of low-side lobes by means of practical gain as compared to CAVA. Modified antenna is much appropriate of imaging application.

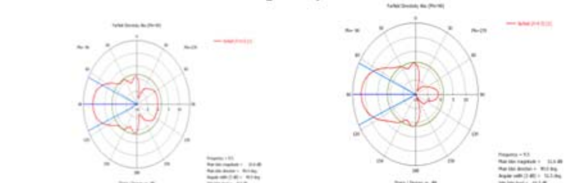
CAVA **MAVA**



Frequency = 3GHz



Frequency = 6.5 GHz



Frequency = 9.5 GHz

Fig. 5: 3-D polar plot pattern

D. Comparative Analysis of Antennas Characteristics

The comparative study of both antenna like CAVA and MAVA in term of return loss and side-lobe level are obtainable in **(Table 3).** It has been observed that a good reflection with reasonable side-lobe level achieved from MAVA at 7 GHz. Both antennas meet the official requirement of reflection should be at least -10dB but MAVA is more suitable for many imaging applications.

Table 3: Return loss (S_{11}) and Side lobe level (SLL)

Frequency (GHz)	Antenna	S_{11} (dB)	Side lobe level
3	CAVA	-14.64	-
	MAVA	-15.99	-19.0
4	CAVA	-10.48	-12.4
	MAVA	-10.07	-11.3
5	CAVA	-13.21	-9.6
	MAVA	-13.63	-8.9
6	CAVA	-11.88	-9.5
	MAVA	10.84	-9.8
7	CAVA	-44.94	-9.1
	MAVA	-55.13	-11.1
8	CAVA	-13.71	-11.3
	MAVA	-13.42	-10.2

9	CAVA	-24.66	-10.4
	MAVA	-20.38	10.0
10	CAVA	-16.32	-8.4
	MAVA	-17.12	-8.6

4. CONCLUSION

A novel structure of AVA is proposed in this article. The new design has been structured called modified antipodal Vivaldi antenna (MAVA) and tested under certain parameters. The comparison of CAVA and MAVA in term of related factors like directivity and flat gain has been discussed. It has been proved that proposed MAVA has produced more directivity at 6.5 GHz to 9.5 GHz of frequency range. In addition, it can improve antenna efficiency and gain stability over UWB frequency. The method is more efficient to enhance gain as well as directivity. So MAVA is also appropriate for microwave imaging application.

5. ACKNOWLEDGMENT

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