Bulletin of Electrical Engineering and Informatics
Vol. 8, No. 2, June 2019, pp. 644~652
ISSN: 2302-9285, DOI: 10.11591/eei.v8i2.1522

Design and parametric evaluation of UWB antenna for array arrangement

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Article Info

Article history:

Received Jan 9, 2019
Revised Feb 24, 2019
Accepted Mar 17, 2019

Keywords:

AVA
BAVA
CSTMWS
SLL
UWB
VNA
VSWR

ABSTRACT

This paper has introduced the concept of UWB antenna in array arrangements. The four elements of Balance Antipodal Vivaldi Antenna (BAVA) has been used for planar and H-plane array configuration in this research. Each single element of BAVA Antenna is printed on the glass-reinforced epoxy laminate material (FR4) along an overall thickness of 1.57mm and ε_r=4.3 respectively. The optimized measurement of each particular element is 60.75mm x 66mm approximatel. Further the parametric evaluation of four BAVA elements in different planes has been observed in this paper. The placement of array elements has almost coverd entire UWB frequency range and appropriate reflection coefficient which is better than -10dB has been established in both combinations. According to simulation results, the array elements in planar arrangement presenting a suitable reflection and works well at 3.2GHz frequency while the arrangement in H-plane the array elements works well at 7GHz of frequency. In planar arrangement, the operating frequency of antenna elements is shifting as results of the distance among inter elements which increase in wavelength. In H-plane arrangement an antenna elements generate additional gain up to 10.2 dB with good radiation patterns as compared to the planar plane. The CSTMWS simulation software has been used for antenna structural design and parametric verification.

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1. INTRODUCTION

In an array system the use of ultra-wide band has become an ultimate choice of several scholars [1-3] Currently, these types of systems are playing a vibrant role in different radar and imaging applications [4, 5]. In modern research about medical sciences the use of compact array system which gives high resolution and precise results are generally required for the detection of different stages of cancer [6-8]. The special high gain antennas with compact in structure are commonly used in designing scheme of these kinds of systems and it gives a good impact especially in medical sciences. It shows a valuable contribution in further applications such as satellite communication system and technology [9].

Initially the concept of Antipodal Vivaldi antenna has been discussed by Gazit [10]. A high amount of gain and better directivity with low side lobe level has achieved under UWB frequency range from the use of AVA in many application [11-14]. For further betterment and improvement in term of performance parameters an equal slits line has introduced at the both edge of an antenna called Balance antipodal Vivaldi antenna [15, 16]. Now BAVA has been considered as a suitable alternative in many applications.

In this research an elliptical shaped structure with equal slits line for the formation of BAVA array configuration is introduced. The comparison analysis of two types of planes which are planar plane and H-plane in a capacity of reflection coefficient, voltage standing wave ratio, gain or directivity and side lobe level has been discussed in this paper [17].

2. SINGLE ELEMENT DESIGN AND CONFIGURATION

The design concept of antipodal Vivaldi antenna on simulation software has two exponentially tapered slot confined by inner and outer edges using a substrate material of FR4 which has a low cost in nature. The material has a dielectric constant value ε_r=4.3, requiring a total thickness of h=1.57mm and dielectric loss value which is δ=0.02 respectively. The representation of basic geometrical structure of AVA is shown in Figure 1.

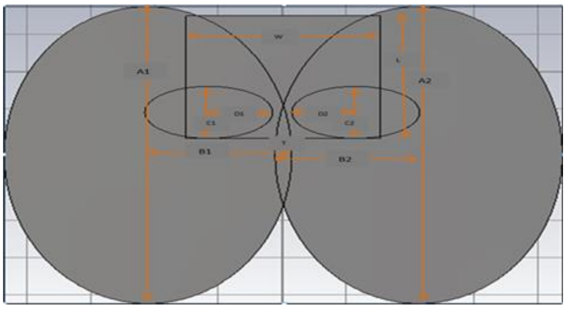

Figure 1. Geometry of the antipodal Vivaldi antenna [17]

This design of an antenna is depending upon two main parts such as a feed lines and radiation flares of an antenna [18-20]. An elliptical curve structure is used for the formation of BAVA and this type of structure provides respectable broadband characteristics because of smooth transition [21] and it is developing an excellent connection among the two parts of an antenna. Hypothetically, the effective parameters of an antenna can be calculated by the following [22].

$$\mathrm{fmin} = \frac{\mathrm{c}}{2\mathrm{W}\sqrt{\varepsilon_{\mathrm{eff}}}} \tag{1}$$

The upper limit of an antenna which is considers being infinity. The representation of lower limit depends upon the following factors which are width and effective dielectric constant ($\varepsilon_{\mathrm{eff}}$) values of an antenna respectively.

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

The AVA geometrical structure consists of four elliptical curves. The two big curves are vertically mounted with two other curves which are placed horizontal. For the transformation of BAVA, some modification such as slits lines with equal in dimension placed at the edges side of an AVA antenna. It provides good radiation and smooth transition among the radiation flares shown is Figure 2.

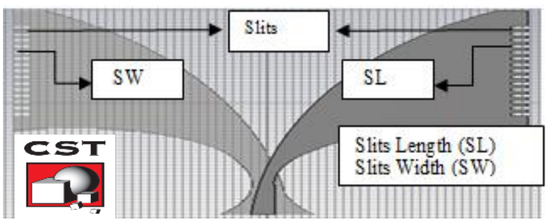

Figure 2. Balanced antipodal Vivaldi antenna (BAVA) [17]

The BAVA is working an UWB frequency range and feed line has a fixed width which achieved a characteristic impedance Z_o=50Ω. The CST computer simulation software has been used for derived the results [23, 24]. Theoretically, following equations such as (3) and (4) will be considered for impedance calculation [25]. The optimized measurements of BAVA are declared in Table 1.

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

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

Table 1. Optimized dimensions for the UWB Antenna [17]

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
SL	1mm
SW	2mm
h	1.5mm
t	0.035mm

2.1. Reflection coefficient

The simulation and experimental results of single element of BAVA antenna represents the reflection coefficient (S_{11}) under UWB frequency range as shown in Figure 3 and Figure 4. It is perceived that given antenna almost cover UWB defined frequency range and maximum reflection coefficient (S_{11}) simulation based which is around -55.45 dB and -41.5dB experiment based at certain frequency which is suitable for imaging and others application.

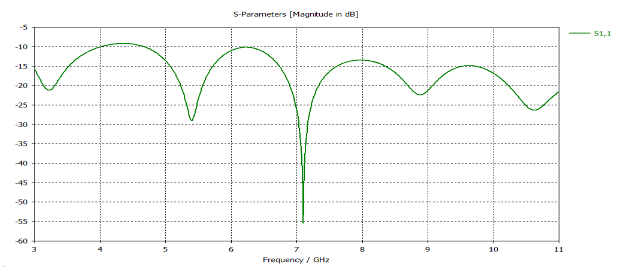

Figure 3. Simulation based variation of reflection coefficient (S_{11}) with frequency for UWB single BAVA

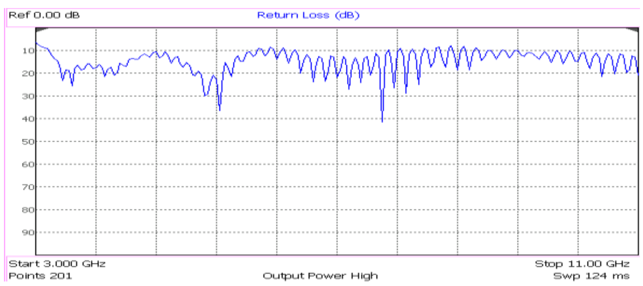

Figure 4. Experimental based variation of reflection coefficient (S_{11}) with frequency for UWB single BAVA

2.2. Radiation patterns

The BAVA radiation patterns represent a good combination of gain and side lobe level, half power bandwidth and angular width at different range of UWB frequency. The maximum gain has been given which is around 10.1 dB at 7 GHz of frequency. It can be showed in Figure 5.

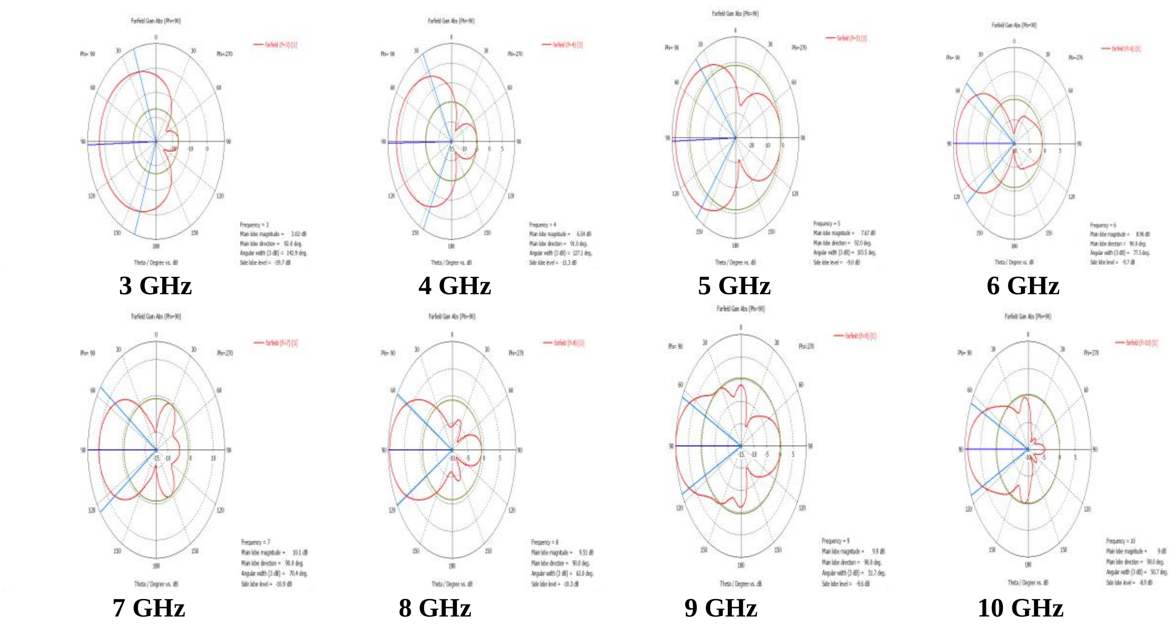

Figure 5. Polar radiation patterns of UWB single BAVA

2.3. Voltage standing wave ratio

The depicted Figure 6 based on simulation result and Figure 7 based on experimental result which represent voltage standing wave ratio of a BAVA. It is operating under UWB frequency and the magnitude of VSWR should be less than 2. It means that the reflection effect which generated from the BAVA can be minimized. The graph of VSWR has shown a good arrangement of ratio which is about 1 and it is better for imaging system.

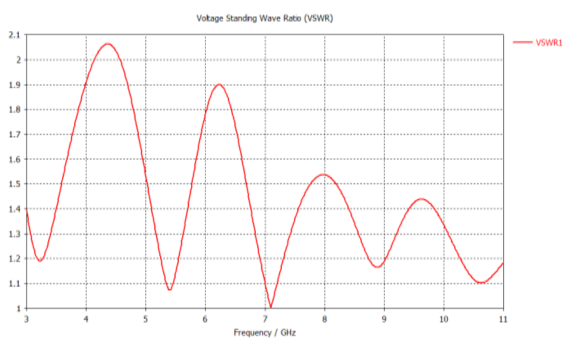

Figure 6. Simulation based VSWR of single element of BAVA

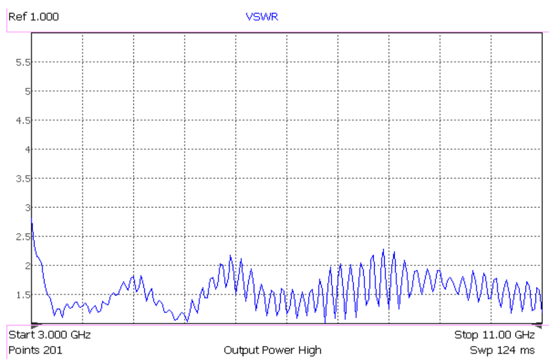

Figure 7. Experimental based VSWR of single element of BAVA

3. FOUR ELEMENTS ARRAY DESIGN IN PLANAR ARRANGEMENT

Four elements of BAVA array in planar arrangement is introduced in this research. In several imaging applications the requirement of antenna cascading because of demand in stability for good reflection results so the antenna array in planar plane is introduced as presented in Figure 8.

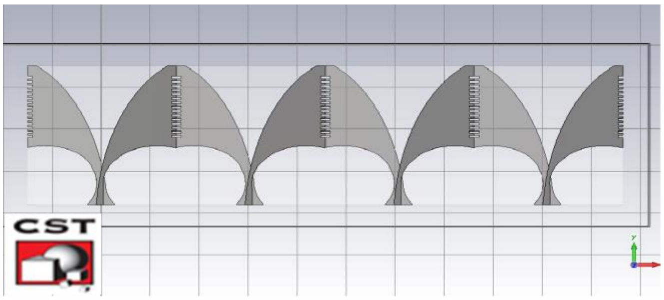

Figure 8. Four element of BAVA array in planar plane arrangement [17]

3.1. Reflection coefficient

The S_{11} parameter of four elements of BAVA array in planar plane arrangement is presented as shown in Figure 9. It covers whole UWB frequency and giving a satisfactory reflection coefficient on all ports as represent in Table 2.

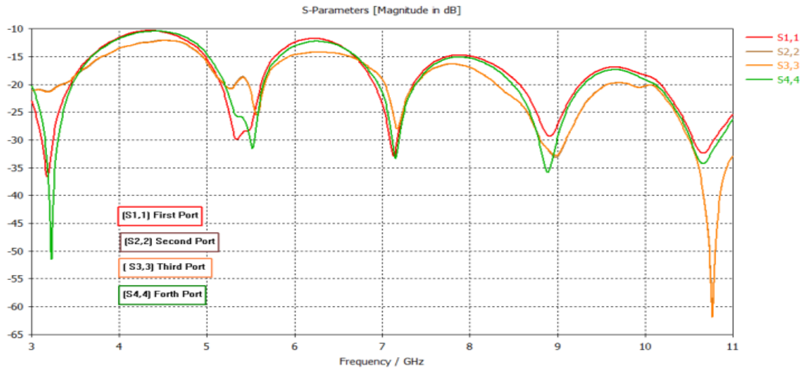

Figure 9.Variation of reflection coefficient (S_{11}) with frequency for 4-element BAVA array in planar plane arrangement

Table 2. S-Parameter of 4-element of BAVA array in planar plane

S-Parameter (dB) Four Elements in Planar plane Configuration			
1-Port	2-Port	3-Port	4-port
-36.65	-60.89	-61.90	-51.27

3.2. Radiation patterns

The representation of 4-elements of planar BAVA in term of gain is presented in Table 3. It gives a good combination of gain at 7 GHz to 8 GHz frequency range at all ports.

Table 3. Gain of 4-element of BAVA array in planar plane

Gain (dB) Four Elements in Planar plane Configuration					
S.No.	Frequency	1Port	2Port	3Port	4Port
1	3 GHz	3.54	4.09	4.18	2.96
2	4 GHz	6.41	6.26	6.28	6.11
3	5 GHz	7.74	7.50	7.34	7.08
4	6 GHz	8.45	7.54	7.60	8.18
5	7 GHz	9.13	7.64	7.61	8.63
6	8 GHz	9.17	8.76	7.76	8.98
7	9 GHz	8.82	7.55	7.53	8.65
8	10 GHz	8.29	7.39	7.46	8.07

3.3. Voltage standing wave ratio

The VSWR of 4-element of BAVA array in planar plane arrangement is offered in Figure 10. It is operating under UWB frequency range and giving reasonable magnitude on all ports as depicted in Table 4 respectively.

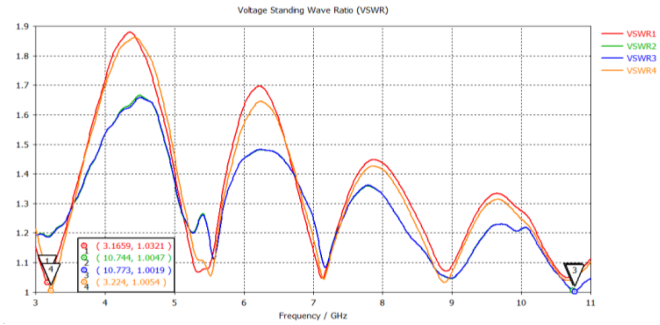

Figure 10. VSWR of 4-element of BAVA in planar plane arrangement

Table 4. VSWR of 4-element of BAVA array in planar plane

VSWR Four Elements in Planar Plane Configuration			
1-Port	2-Port	3-Port	4-port
1.032	1.004	1.001	1.005

4. FOUR ELEMENTS ARRAY DESIGN IN H-PLANE ARRANGEMENT

In H-plane arrangement the 4-elements of BAVA array is presented in this paper as shown in Figure 11. In many radar and imaging applications the requirement of high gain and stability so, the configuration in H-plane is more suitable for perceive the good results.

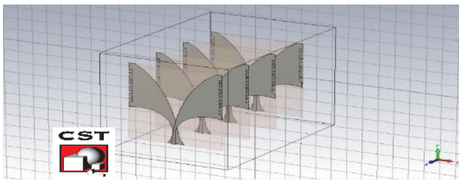

Figure 11. Four element of BAVA array in H-plane arrangement

4.1. Reflection coefficient

The reflection coefficient of 4-elements of BAVA array in H-plane arrangement is presented as shown in Figure 12. It covers almost whole UWB frequency and giving a satisfactory reflection coefficient on all ports as represent in Table 5.

Table 5. S-Parameter of 4-element of BAVA array in H-plane

S-Parameter (dB) Four Elements in H-plane Configuration			
1-Port	2-Port	3-Port	4-port
-42.17	-46.22	-42.25	-48.21

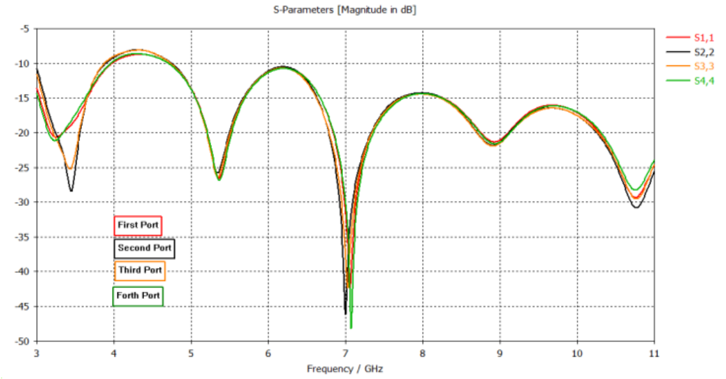

Figure 12. Variation of reflection coefficient (S_{11}) with frequency for 4-element BAVA array in H-plane arrangement

4.2. Radiation patterns

The 4-elements of BAVA array in H-plane configuration in capacity of gain are presented in Table 6. It is showing a very good combination of gain under frequency range of 7 GHz to 9 GHz at all ports.

Table 6. Gain of 4-element of BAVA array in H-plane

Gain (dB)					
Four Elements in H-plane Configuration					
S.No.	Frequency	1Port	2Port	3Port	4Port
1	3 GHz	3.86	3.08	3.14	3.93
2	4 GHz	6.53	5.67	5.82	6.68
3	5 GHz	7.48	6.95	7.06	7.73
4	6 GHz	8.82	8.53	8.55	8.87
5	7 GHz	10.20	9.06	9.33	10.30
6	8 GHz	9.4	9.21	9.33	9.52
7	9 GHz	9.76	9.45	9.45	9.83
8	10 GHz	8.94	8.71	8.78	9.26

4.3. Voltage standing wave ratio

The voltage standing wave ratio of 4-element of BAVA array in H-plane array configuration is obtained in Figure 13. It is operating under UWB frequency range and giving practical magnitude on all ports as described in Table 7.

Table 7. VSWR of 4-element of BAVA array in H-plane

VSWR Four Elements in H-plane Configuration			
1-Port	2-Port	3-Port	4-port
1.018	1.016	1.032	1.039

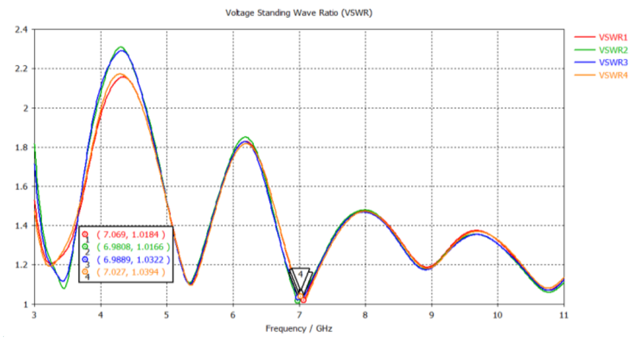

Figure 13. VSWR of 4-element of BAVA in H-plane arrangement

5. COMPARISION OF BAVA ARRAY IN PLANAR PLANE WITH H-PLANE

The comparison analysis of BAVA array in two different planes has been reported in this paper. It is confirmed that the four element array in planar plane works well under low frequency which around 3GHz to 3.5GHz with lowest return losses that is -36dB to -51dB respectively. In H-plane configuration the four elements works well under frequency range of 6.8GHz to 7.2GHz with the lowest return of -42dB to -48dB as shown in Table 8 respectively. Based on simulation results the operating frequency of 4-element of BAVA array in planar plane configuration is shifting and turn out to be lower because the change in distance called wavelength, when it is increase the frequency is become lower side. In H-plane at all ports gives better radiation which are fundamental requirement of any array system in a capacity of gain and antenna directivity under frequency range of 7GHz as compared to planar plane configuration as depicted in Table 9. The magnitude of VSWR should be less than 2 for each operating frequency of an antenna. Regarding the results of simulation, the planar configuration gives good voltage ratio around 1.03 to 1.2 at the lowest UWB frequency range that is 3GHz to 3.5GHz for all ports but in H-plane the voltage ratio increases and giving the values which are greater than 2 under specific range of frequency such as 4GHz to 4.7GHz respectively.

Table 8. S-Parameter of 4-element of BAVA array in planar plane and H-plane

	S-Parameter (dB)			
Planar Configuration	1-Port	2-Port	3-Port	4-port
	-36.65	-60.89	-61.90	-51.27
H-plane Configuration	-42.17	-46.22	-42.25	-48.21

Table 9. Gain of 4-element of BAVA array in planar plane and H-plane

Gain (dB) at Frequency=7GHz		
Planar Plane Configuration	1-Port	9.13
	2-Port	7.64
	3-Port	7.61
	4-port	8.63
H-plane Configuration	1-Port	10.2
	2-Port	9.06
	3-Port	9.33
	4-port	10.30

6. CONCLUSION

In this work UWB-BAVA antenna has been designed and developed. The parametric evolution of single element of BAVA has been carried out using CSTMWS. Further it has been investigated through experimentally via vector network analyzer (VNA). The single element of BAVA antenna has been attained the appropriate value of return loss better than -10dB and achieved satisfactory VSWR in both combinations but the value of VSWR is marginally high at frequency 4.2GHz to 4.5GHz in range. In order to minimize the reflection effect which generated by the antenna so the value of VSWR should be less than 2. Additional in this research the arrangement of four elements of BAVA in planar plane and H-plane has been introduced. The comparative study based on simulation results via CSTMWS. According to the outcomes excellent return loss has been produced in planar plane arrangement while at 7GHz of frequency high amount of gain is achieved approximately 10.20 dB in H-plane arrangement at all ports of an antenna as compared to planar plane arrangement.In the light of several parameters it has been confirmed that the design arrangements of an antenna can produce an effect on whole performane. H-plane arrangement of BAVA elements can be more appropriate for phased array antenna where the condition of stable high gain as well as planar plane arrangement can be suitable for snow radar where the requirement of high reflection. Future work of this research to counter the effects in order to decrease mutual coupling among inter elements.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance of this research which is supported by the IIUM Research Management Center (RMC) via Research Initiative Grant Scheme (RIGS) with the grant number RIGS 15-147-0147 and RIGS 16-067-0231.

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