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A Wide Bandwidth Antipodal Vivaldi Antenna Array for 5G mm Wave Applications at 28 GHz

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Abstract – **A novel antipodal Vivaldi antenna (AVA) array is proposed for 5G mm Wave applications. The proposed AVA array consists of 1x4 antenna elements and with dimensions 55.3x26.6x0.79mm³. The antenna is designed using Rogers RT/duroid 5880 material having dielectric constant 2.2 and presented material have low dielectric losses and is suitable for high frequencies. Rhombus parasitic patches, triangular corrugations at edges, and air vias are used in antenna feed line design for improvement of gain, bandwidth, and low radiation losses. The proposed antenna is operating from 25 GHz- 32 GHz frequency range and antenna is resonating at 28.56 GHz. Gain is varying from 9.45 to 14.88 dBi and 95% radiation efficiency is obtained in specified frequency band. At resonant frequency 28.56 GHz front to back ratio (FBR) is 34.47dB is obtained. The proposed antenna is designed using ansys HFSS tool.**

Keywords – **AVA, corrugations, parasitic patches, air via, FBR (Front to back ratio)**.

I. INTRODUCTION

In fifth generation (5G) frequency range2 (24.25 GHz-71.0 GHz) communication systems to reduce propagation losses, there is need of wide bandwidth and high gain antennas [1]. In recent times printed Vivaldi antennas are also frequently used in 5G applications [2]. Antipodal Vivaldi antennas (AVA) are suitable to provide wide bandwidth and high gain because of the tapered curve. Different methods like arrays, corrugations, parasitic patches, metamaterials and SIWs are also added to AVA antenna to obtain wide bandwidth and high gain [3]. These Vivaldi antennas are firstly designed by P.J Gibson in year 1979 [4], Later E. Gazit modified Vivaldi antenna to antipodal Vivaldi antenna (AVA) in the year 1988 [5].

SIW is used in microstrip transition structure of AVA 1x4 array to obtain better bandwidth and return loss for X-band applications [6]. To change the frequency response of antenna, corrugations are added to the antipodal Vivaldi 1x4 antenna array for 5G communication applications [7]. Coupling reduced antenna is introduced with 1x8 AVA elements, and here return loss is also enhanced for 5G mm Wave applications [8]. An isotropic Meta surface cells are added in between left and right arms of AVA to enhance gain for future 5G mm Wave applications [9]. To improve antenna, gain and better frequency response dielectric lens and corrugations are used in AVA antenna design for 5G devices [10]. To reduce side lobe level and for gain improvement pencil type slots are introduced to AVA array for 5G mobile communication [11]. Corrugated edges and triangular metal directors are applied to AVA array to improve gain [12]. A wide bandwidth AVA 1x8 array is proposed for 5G mm-wave applications [14]. A 1x4 highly compact AVA array for 5G mm-wave applications here corrugations inserted to antenna to get better FBR (Front To Back Ratio) [15]. To improve the directional characteristics of AVA, parasitic patches are introduced for UWB imaging applications [16]. A 1x4 AVA antenna proposed with parasitic patches and corrugations to improve gain and bandwidth [17].

The proposed AVA array consists of four elements. Various methods are applied to obtained bandwidth, return loss, FBR and gain. Antenna design analysis is explained in section II. Results and discussions are seen in section III. In section IV conclusion is given.

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II. ANTENNA GEOMETRY

The proposed antipodal Vivaldi antenna consists of left and right arms asymmetrically. One arm is on front side and another one is back side on the antenna. The left arm consists microstrip feed line and it maintains the 50Ω characteristic impedance. Antipodal Vivaldi antenna is designed using exponential tapered curve is expressed as [12]

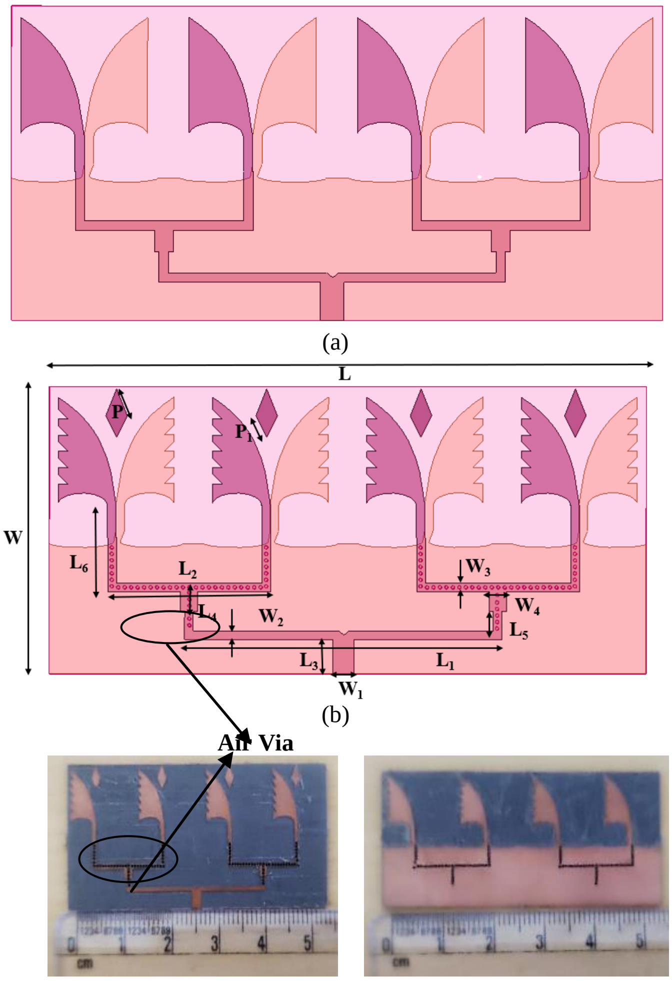
$$y_1 = a_1 e^{a_2 x} + a_3 \quad (1)$$

$$y_2 = b_1 e^{b_2 x} + b_3 \,. \quad (2)$$

Here a_1, a_2, a_3, b_1, b_2, and b_3 are constants and these may be positive or negative values depending on Cartesian co-ordinate system. The proposed AVA array antenna consists of 1x4 antenna elements and it has dimensions 55.3x26.6x0.79mm³ as shown in fig 1(b). Antenna designed on Rogers RT/duroid 5880 material having 2.2 dielectric constant and 0.0009 dielectric loss tangent.

Improved gain, FBR and bandwidth are observed by adding triangular corrugations and rhombus parasitic patches to AVA array. By using SIWs in microstrip feed structure better return loss is obtained.

The proposed antenna dimensions are L=55.3mm, W=26.6mm L_1=29.4mm, L_2=15.1mm, L_3=3.2mm, L_4=1.8mm, L_5=2.4mm, L_6=8mm, W_1=2mm, W_2=0.2mm, W_3=0.8mm, W_4=1.6mm, P=2.5mm, P_1=2mm, d=10.8mm and SIW (substrate integrated waveguide) or Via's are inserted feed line structure with radius r=0.16mm and h=0.79mm. SIW is in cylindrical shape and spacing between SIWs is 0.6mm. The proposed AVA 1x4 array is fabricated on rogers Rt/duroid 5880 material using pcb semi automatic machine and it is shown in Fig.1(c). Here SIW (substrate integrated waveguide) or cylindrical vias are made by hand using needle.



(c)
Fig. 1. Presented AVA 1x4 Array: (a) AVA array, (b) AVA with corrugations, parasitic patches and air via, (c) Fabricated model front view and back view

III. Results and Discussions

A. Simulation and Measured Results of Proposed Antenna

The proposed antenna is designed using ansys HFSS tool and simulation and measured results are presented below.

From Fig. 2 observe the S_{11} or reflection coefficient of proposed antenna. Here without triangular corrugations and rhombus parasitic patches bandwidth (26.9-29.6 GHz) of proposed AVA antenna is reduced and without SIWs (Substrate integrated waveguides) return loss is -24.97dB at resonant frequency 28.56 GHz, by adding SIWs in micro strip feed line structure return loss is improved to -37.32dB at resonant frequency. Similarly, can observe the measured return loss is -10 dB below from 25 GHz to 32 GHz and it can see in Fig.3

By adding triangular corrugations to AVA array antenna Front to Back Ratio (FBR) will increase and that can be observed in Fig.4. FBR should be high for long range.

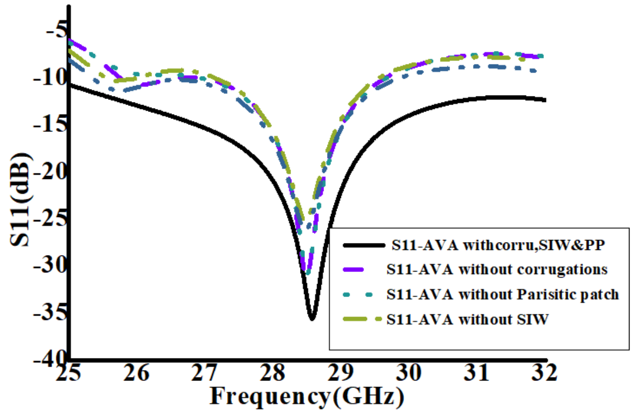


Fig. 2. S_{11} of proposed AVA array

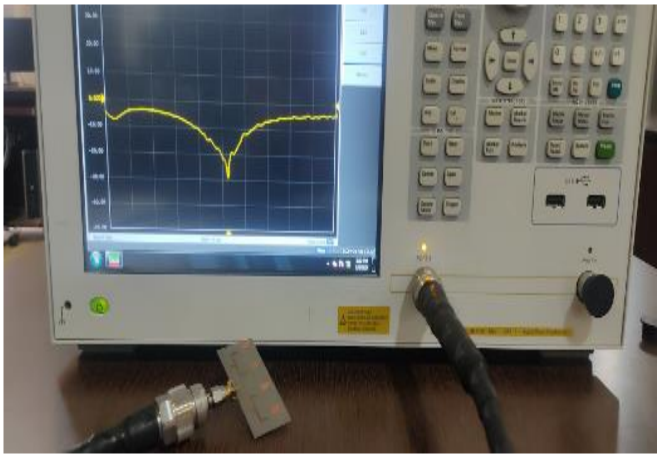


Fig. 3. Measured S_{11} of proposed AVA array

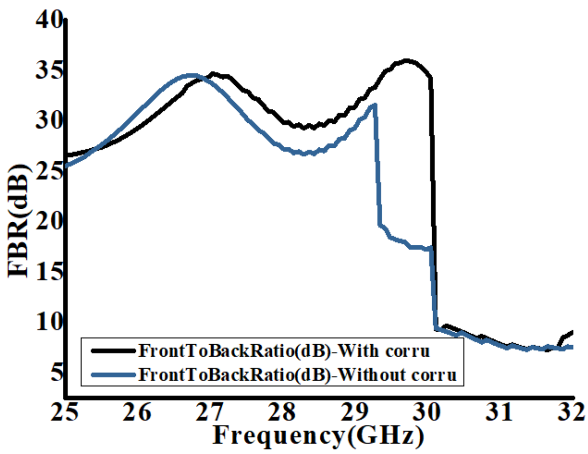


Fig. 4. Frequency (Vs) Front to Back Ratio (FBR)

directional antennas and it is described as a ratio that compares the highest azimuth gain with the gain in a direction that is 180^0 from the given azimuth. From Fig.4 observe that at resonant frequency without corrugations FBR is 32.33 dB and with corrugations the FBR value is 34.47 dB, can see that their improvement in FBR ratio.

By inserting parasitic patches directional characteristics like gain and directivity can be improved. From Fig.6 can observe gain of the antenna is increased with parasitic patches.

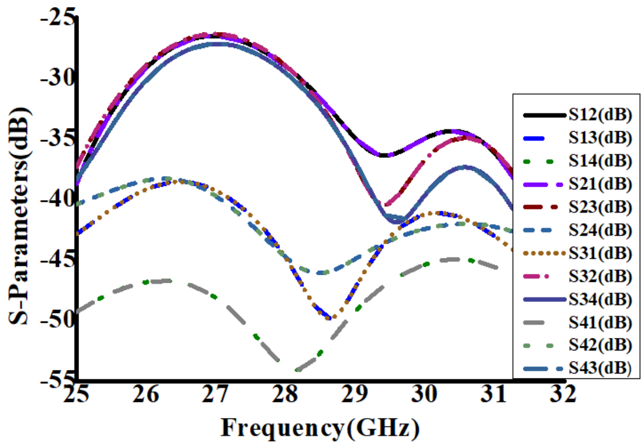


Fig.5. Isolation between antenna elements of proposed after removing 1x4 power divider antenna.

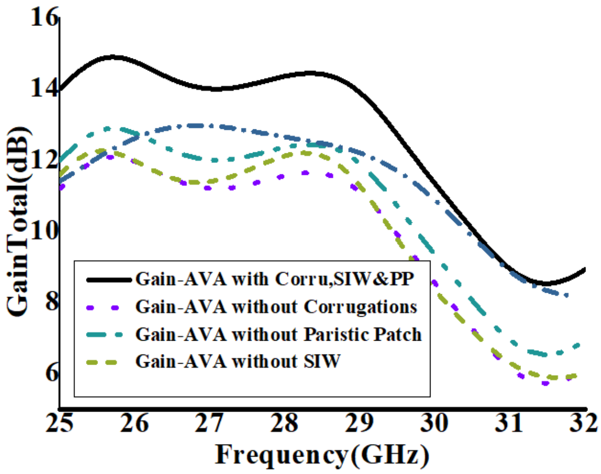
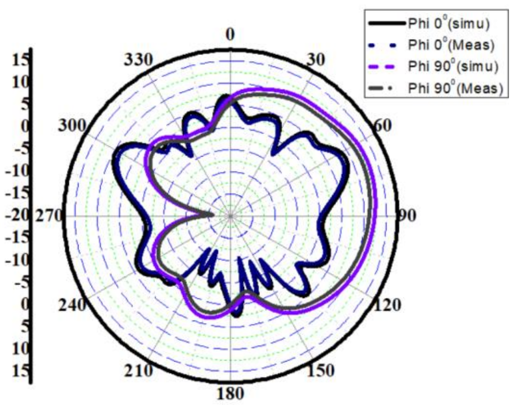


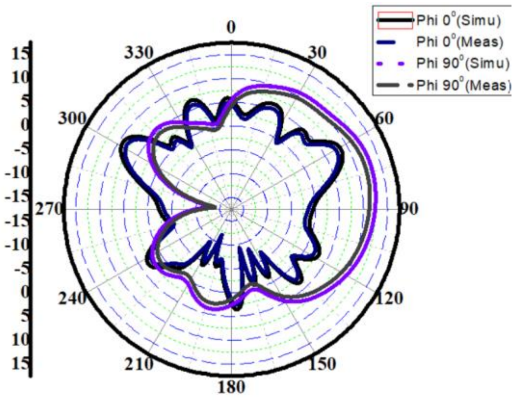
Fig.6. Gain of proposed AVA array

After removing 1x4 power divider, observe the isolation between antenna elements is below -26.08 dB for specified frequency band and is shown in Fig.5.

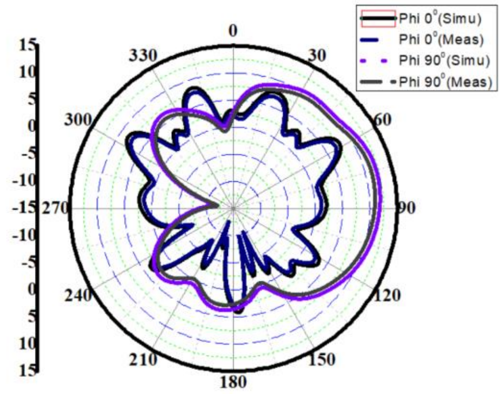
By applying different techniques like triangular corrugations, parasitic patches and SIWs to the AVA 1x4 array gain is improved and it varies from 9.45 to 14.88 dBi in specified frequency band as shown in Fig.6. Measured gain is varying from 8.43 to 12.86 dBi in mentioned frequency band.



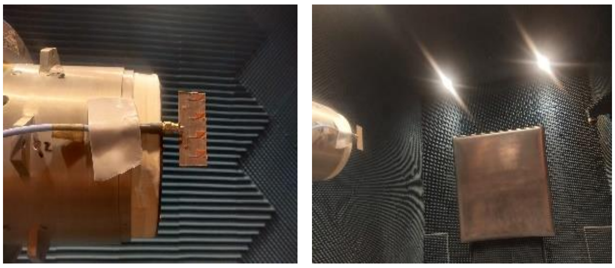
(a)



(b)



(c)



(d)

Fig.7. Radiation patterns of proposed AVA array at:
(a) 28 GHz, (b) 28.56GHz, (c) 29 GHz,
(d) by measuring using anechoic chamber

E and H plane patterns of proposed antenna are taken at 28 GHz, at resonant frequency 28.56 GHz and 29 GHz as seen in Fig .7(a) to 7(c). From Fig. 7(d) observed measured radiation patterns using anechoic chamber.

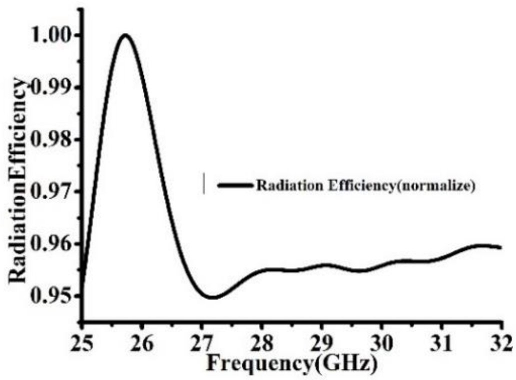


Fig.8. Radiation efficiency (vs) Frequency plot

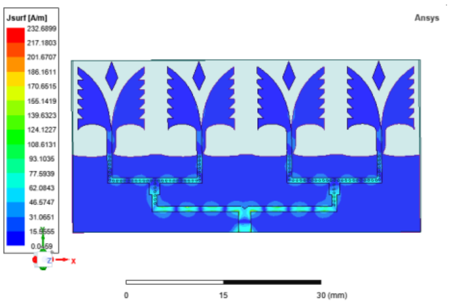


Fig.9. Surface current distribution of proposed AVA array.

Radiation efficiency is defined as the percentage of antenna’s overall output power to its total input power from its generator. From Fig.6 seen that for specified operating frequency band above 95% radiation efficiency is obtained. Surface current distribution is taken at resonant frequency at 28.56 GHz as shown in Fig.9.

Comparision table of existing antennas with proposed antenna is shown in Table 1.

TABLE 1
COMPARISION TABLE OF EXISTING ANTENNAS

Ref.No	Size(mm^3)	B.W (GHz)	Gain(dBi)	No of elements
[8]	28.823x60x 0.787	4	5.3-8.5	1x8
[11]	54.4x28.2x 0.508	2.75	12.3-12.9	1x8
[14]	21.45x52.3 5x0.787	4	13.36	1x8
[15]	24x28.8x0. 254	4.96 & 10.22	8-13.2	1x4
Proposed	55.3x26.6x 0.79	7	9.45-14.88	1x4

B.W-Bandwidth, No of ele- Number of antenna elements

IV. CONCLUSION

Antipodal vivaldi antenna (AVA) 1x4 array is presented for 5G mmWave applications. For improvement of bandwidth, returnloss and gain various techniques like triangular corrugations, rhombus parasitic patches and air vias are added to the AVA array. The proposed antenna is fabricated on rogers Rt/duroid 5880 material with dimensions 55.3x26.6x0.79mm^3. The return loss is -10 dB below from 25 GHz to 32 GHz. Gain varies from 9.45 to 14.44 dBi and above 95% of radiation efficiency is obtained in operating frequency band. Future this proposed AVA 1x4 array will arrange in MIMO to provide high efficiency, more bandwidth and better channel capacity.

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