SIW fed Balanced Antipodal Vivaldi Antenna for Millimeter Wave Application

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***Abstract*—SIW fed Balanced Antipodal Vivaldi antenna is a highly directional antenna designed for its application in high-density millimeter wave frequencies. Vivaldi antenna is a wideband antenna, we design a balanced antipodal Vivaldi antenna. It gives high directivity and fewer radiation losses for a particular frequency range. The BAVA with SIW tapered microstrip fed uses tapered microstrip fed because it is used in the measurement and connection purpose. Antenna designed is considered to be good if the S11-parameter (return loss) for that is less than -10dB. The simulation results for the final design is showing appreciable results with a return loss of less than -10dB.**

***Index Terms*—Antenna, Balanced Antipodal Vivaldi Antenna, Substrate Integrated Waveguide, Tapered Microstrip.**

I. INTRODUCTION

The BAVA antenna is based on a traditional balanced antipodal Vivaldi architecture and requires piling substrate layers to compensate for the dielectric load between the central and exterior layers of metallization. [1]. The BAVA structure is designed by sandwiching the layers of substrate and copper the middle layer of copper is the main signal transmission (director) and the upper and lower copper layer act as the ground.The transition of SIW tapered microstrip to BAVA the lower copper plate of BAVA act as ground connected to upper copper layer through the two via located at the corner and opposite to each other.The tapered microstrip fed design is for the purpose of SMA connector connection [2].

II. SIW TAPERED MICROSTRIP

As a type of efficient optimized transmission lines compatible with planar technology, SIW has been proposed, to provide incomparable self-consistent shielding and high-quality factor efficiency. These leakage effects could also be used positively for the planning of antennas by deliberately introducing perturbations in these guides in order that they radiate during a controlled fashion [3]. SIW tapered microstrip is used for connection and transmission.The transformation can be broken down into two sections, the line of the tapered microstrip and the phase between the rectangular waveguide and the microstrip [4]. A good match must be given over the entire SIW bandwidth by the combination of these two sections. The SIW bandwidth is specified between $1.25f_c$ and $1.9f_c$, as for the traditional rectangular waveguide [4].

A. Design and specification

In order to achieve the desired measurements, the SIW measurements must be carefully chosen. In this case, metallic posts are replaced by the two simple ideal conductor walls, cylindrical vias must be as near as possible to tend to a dielectric filled rectangular waveguide [5]. The cut-off frequency in case of a rectangular waveguide is given by (1)
consider a TE_{10} mode for the SIW. The a_s is the distance between the pitch form the center of the via and a is the width of SIW and d is the diameter of via [6].

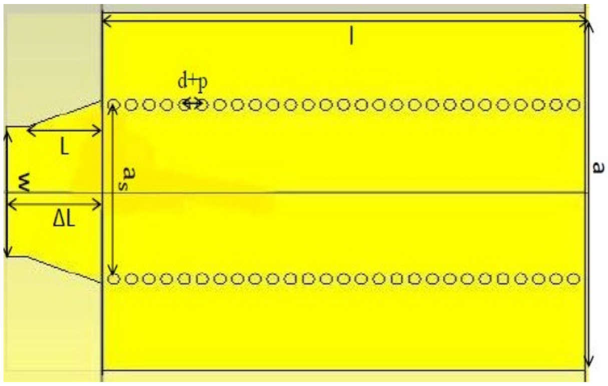


Fig. 1: SIW tapered microstrip design.

$$f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \tag{1}$$

$$a_s = a_d + \frac{d^2}{0.955p} \tag{2}$$

where,

$$a_d = \frac{a}{\sqrt{\epsilon_r}} \tag{3}$$

a_d is an intermediate parameter, diameter of a via and distance between the via (pitch) are interrelated to each other.

$$d < \frac{\lambda_g}{5} \tag{4}$$

$$p \leqslant 2d \tag{5}$$

Guided wavelength helps in determining the via diameter and pitch. λ_g have a direct relation with operating frequency and the width of SIW.

$$\lambda_g = \frac{2\pi}{\sqrt{\left(\frac{2\pi f_c}{c}\right)^2 + \left(\frac{\pi}{a}\right)^2}} \tag{6}$$

The total length of the SIW is based upon the number of via and simulation results for the different-different number of via. Let n be the number of via, then we can define the length of SIW form (7).
where,

$$l \leq (n * d + 1) * p \tag{7}$$

Tapered microstrip width can be calculated from (8),(9) [7], the transition of tapered microstrip with SIW with width equal to a_s is to be done.

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12\left(\frac{h}{w}\right)}} \tag{8}$$

where, ϵ_e is the effective permittivity and ϵ_r is the relative permittivity of the substrate.

$$w = \frac{c}{2f_c\sqrt{\frac{\epsilon_r+1}{2}}} \tag{9}$$

$$\Delta L = \frac{c}{2f\sqrt{\epsilon_e} - 0.824h\left(\frac{(\epsilon_e+0.3)\left(\frac{w}{h}+0.264\right)}{(\epsilon_e-0.258)\left(\frac{w}{h}+0.8\right)}\right)} \tag{10}$$

where, w is the width and ΔL is the total width of the tapered microstrip. The length l can be calculated with the number of simulation results.

TABLE I: SIW TAPERED MICROSTRIP PARAMETER

Parameter	***Value***
a	5.405mm
a_s	2.648mm
a_d	$\leqslant$2.606mm
d	<1.19mm
p	$\leqslant$2.38mm
ϵ_e	3.183
w	1.4718mm
ΔL	1.296mm

III. BAVA

The Vivaldi antenna is a special tapered slot antenna with a planar arrangement that is easy to merge to create a compact structure with elements that transmit and elements that receive. [8]. The BAVA design is used to remove the problems with Co-planar and Antipodal Vivaldi antenna design. BAVA is having the three metal layer sandwich between substrate with extra outer substrate layer. Upper and lower metal layer act as a ground and middle layer act as a director for the antenna as in 'Fig. 2'.

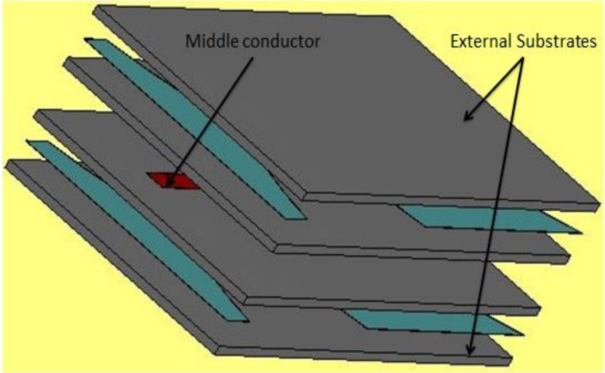


Fig. 2: Exploded view of the BAVA construction.

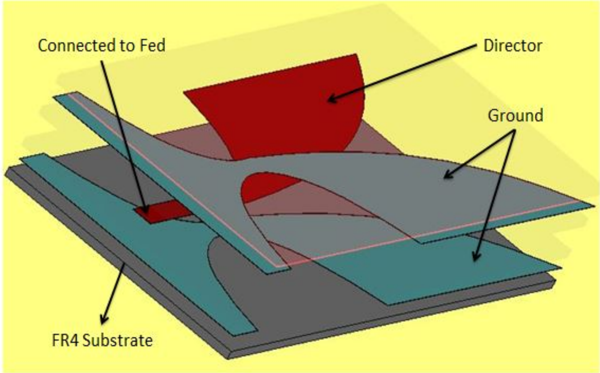


Fig. 3: BAVA design conductors arrangement.

A. Design and specification

BAVA is designed with various exponential curves and linear curves extruding them. Various parameter of the curve can be calculated with the simulation. These exponential curves can be considered as an arc of the big loop antenna. To have a consistent magnetic field through out the antenna. Height of substrate is 0.08 mm to be considered through out the design.

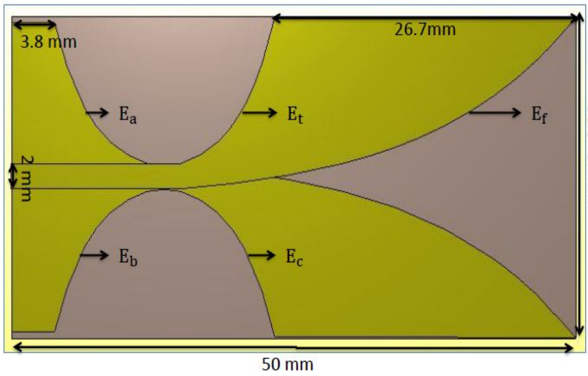


Fig. 4: BAVA design parameters, use to generate the copper layer.

TABLE II: BAVA CURVES PARAMETER

Curves	***Parameter***	**Value**	
		Intercept	***Tapering ratio***
E_a	-(B_1+e^{m*t})	-2.8	0.304
E_b	-(B+e^{n*t})	3	0.0756
E_c	-(A_1+e^{m*t})	-4.8	0.304
E_t	-(B+e^{m*t})	3	0.304
E_f	A+e^{n*t}	1	0.0756

The 'Table II' gives details about the curves and their parameter, value of each parameter is assigned through the simulation with each simulation it should be noted that the curves form a closed loop and also planar before extrusion.

IV. INTEGRATION OF BAVA AND SIW TAPERED MICROSTRIP

SIW as an intermediate structure between the BAVA and microstrip provide the consistent magnetic field in the BAVA. As the concern with impedance matching we are using the tapered microstip for the connection and measurement purpose. Integration will be done practically as the director and SIW upper metal will be united as one metal and act as a director. The upper metal and lower metal of the BAVA will be ground and are connected together with metal via. The integration is shown in 'Fig. 5'.

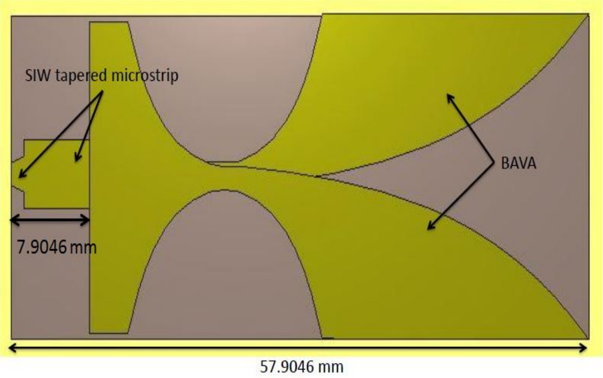


Fig. 5: BAVA SIW tapered microstrip.

A. Simulation results

Simulation using the full wave simulation tool, the range of simulation vary from (24-30) GHz as the BAVA is consider to be wideband antenna. 'Fig. 6' shows that return loss is less than -10 dB and over the wide frequency. It is observed that many dips less than -10 dB between the simulated frequency range.

Return loss is less than -11 dB at 27 GHz and less than -13.5 at 30 GHz. Via diameter and pitch of the SIW are the only parameter that effect the frequency of operation, hence return loss. Other than return loss the electric and magnetic field are also the important parameter for the antenna as the radiation will be dependent upon them.

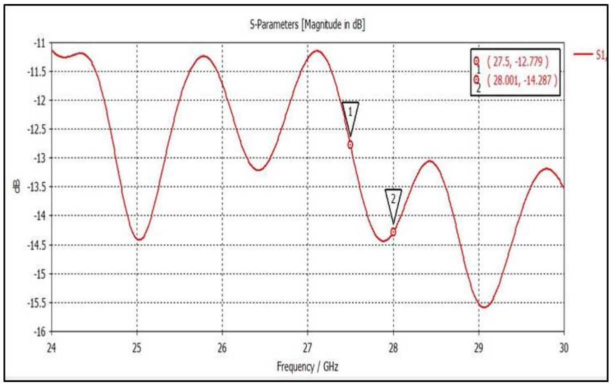


Fig. 6: return loss.

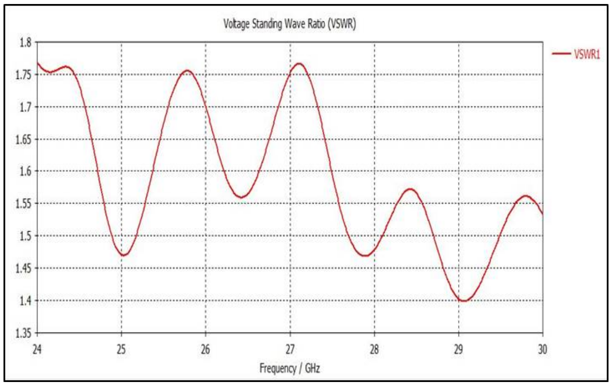
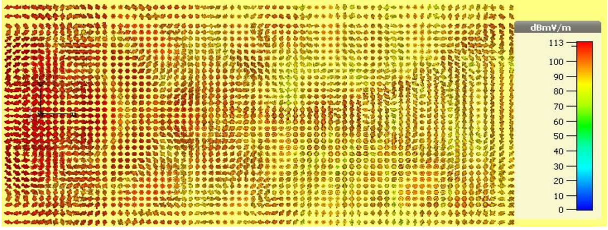


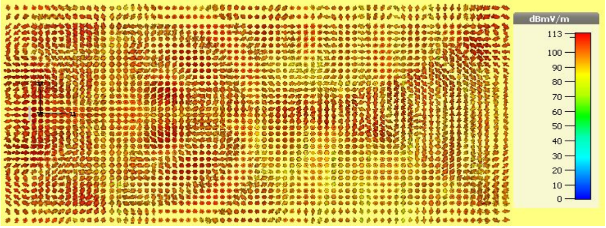
Fig. 7: VSWR.

From the simulation VSWR obtained is less than 1.5. The performance by this VSWR is appreciable and can be taken for the reference. The best VSWR getting is less that 1.4 for the frequency 29 GHz.

'Fig. 8 and 'Fig. 9 gives the electric and magnetic field

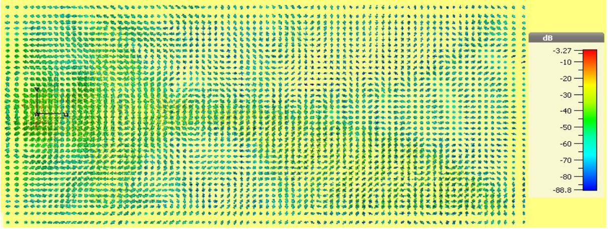


(a) 27 GHz

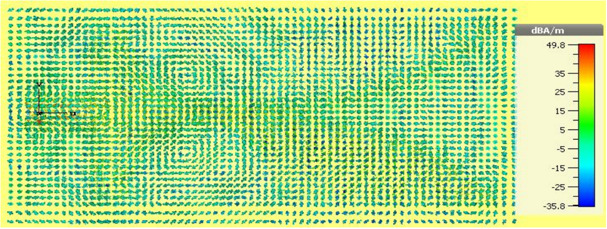


(b) 30 GHz

Fig. 8: Electric field.



(a) 27 GHz

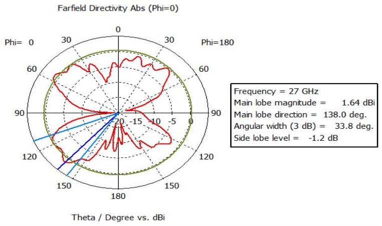


(b) 30 GHz

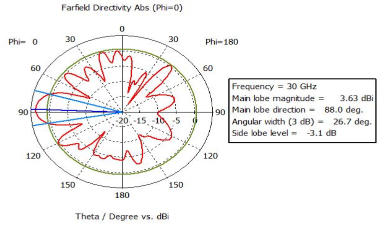
Fig. 9: Magnetic field.

distribution as the simulation for a particular two frequency we observe that electric field vary with (100-113) dBm(V/m) and magnetic field vary with (5-15) dB(A/m) these results are appreciable and can be implemented for prototype for the design and testing. The consistent magnetic field can be seen in the 'Fig. 9' because of SIW.

'Fig. 10' give the far field. From the simulated result, the (3dB) angular width BAVA antenna is 33.8 degree with side lobe level -1.2 dB for 27 GHz with main lobe magnitude of 1.64 dBi. BAVA antenna (3dB) angular width is 26.7 degree with side lobe level -3.1 dB for 30 GHz with main lobe magnitude of 3.63 dBi. As a result we can infer that 88.0 degree in polar plot for θ, the best angular width and minimum side lobe level of the BAVA antenna is 30 GHz.



(a) 27 GHz



(b) 30 GHz

Fig. 10: Far field.

CONCLUSION

The above designed BAVA antenna with SIW tapered microstrip fed is giving a appreciable result. Return loss for the BAVA is less that -10 dB and best return loss obtained is less than -15.5 dB and the directivity of 3.63 dBi with consistent magnetic field in the structure. ϕ 180 degree and θ 88.0 degree polar radiation pattern, the side lobe is minimum and more asymmetric pattern compare between two frequencies. This paper can however refer to the kind of Vivaldi antenna for the millimeter wave frequency application has the best efficiency. In addition, there is also space for BAVA performance enhancement.

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