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Substrate Integrated Waveguide Slot Antenna for V-Band Applications

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ABSTRACT

In this paper, a low-profile broadband substrate-integrated waveguide (SIW) slot antennafor V-Band applications is proposed. The size of antennais 13*9*0.381 mm3 and printed in a RT/Duroid 5880 substrate with a dielectric constant of2.2. The proposed antenna consists of modified Venus-shaped slot etched on the top ofsubstrate. It is designed and simulated using Ansys HFSS tool for the frequency of operation60 GHz. Parametric study is also performed on various parameters to improve theperformance the antenna. It is observed that they are in good agreement with the theoreticalequations. The simulated results show the reflection coefficient S11= –25 dB, impedancebandwidth = 1.7 GHz (ranging from 59.3 GHz to 61.0 GHz), VSWR = 1.05, gain =7.88 dBi atthe resonant frequency. Therefore, a good matching characteristic along with good level ofradiation efficiency levels and stable radiation pattern makes the antenna suitable for V-bandapplications.

KEYWORDS: SIW,Venus-shaped slot, HFSS, reflection coefficient, VSWR.

1. INTRODUCTION

The rapid broadening of wireless communication takes place in modern scenarios due to demand in cellular communication, DTH etc., The demand for communication is quickly increasing in every individual life so in order to arrange quick access to the users by improving the bandwidth (i.e., data rate). The only prospect to improve the bandwidth is to improve the latest using frequencies, especially millimeter frequencies rather than microwaves (because of high frequency).For high frequencies especially in millimeter waves the coplanar waveguides and microstrips based antennas are inappropriate. Different types of transmission lines like post-wall waveguide and laminated waveguide are used in order to perform conditions of the high frequency application. Additionally replaced name as a substrate integrated waveguide and it is convenient for milli-meter wave frequency application that is for high-frequency application. 60GHz frequency range is a type of unlicensed frequency in the millimeter wave band and mostly preferred for narrow beam, high data rate and short-range applications and for less interference. It is used for applying the SIW antennas because of using the fabrication process as SoS. In contrast to other SIW based antennas the characteristic of SIW based slot antennas are cost effective, small sized, high bandwidth, moderate fabrication, maximum gain. SIW based slot antennas meet the conditions of broadband and miniaturization.

Some of the literature studies were discussed as follows: Bakhtafrooz and Borji1 are the first scientists who introduced antenna for millimeter wireless applications and shapes consisting of stack of layers, which were of 4

× 4 and 6 × 6 arrays, respectively. Y Zhang, proposed a miniature dual-band SIW slotted array fabricated on one single layer of substrate for millimeter-wave 5G applications. His design not only shows manufacturing simplicity, but it also provides sufficient impedance bandwidths (26.6–28.3 GHz and 36.8–38.9 GHz) and high realized gain (10.9 dBi and 12.1 dBi for the lower and higher frequency bands, respectively).Bakhtafrooz A proposed a novel slot array antenna with two layers of substrate integrated waveguides (SIW) is presented for millimeter-wave wireless applications. Unlike conventional SIW-based slot arrays, in this structure a feed waveguide is placed underneath the main substrate layer containing the slot array and is coupled to the branches of the array via slanted slot, this results in a considerable reduction in size and eliminates unwanted radiations from the feed network. Experimental results for two slot arrays with 4 × 4 and 6 × 6 elements operating at 60 GHz are presented showing 14.8 dB and 18.5 dB gain, respectively.Yan L proposed a SIW slot array antenna has been presented, which is integrated on a single substrate. Having small size, and low loss, the new structure is well suited for the design of low-cost planar array antennas at microwave and millimeter-wave frequencies. The measured return loss is less than -10dB within a bandwidth of 600MHz, Antenna directivity is 15.7dB.

2. ANTENNA GEOMETRY AND DESIGN

The proposed antenna is designed using HFSS (high frequency structure simulator) software and presented in the below figures.

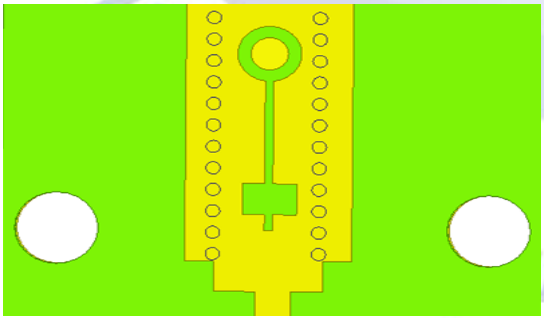

Fig-1: SIW slot antenna.

Above figure shows the geometry of the antenna, fabricated on a 0.821mm thick RT Duriod substrate with permittivity and Dielectric loss tangent of 2.2 and 0.0009, respectively. The dimension of the antenna is 13 mm × 9 mm × 0.381 mm.

The proposed antenna is composed of rectangular patch with Venus slot and highlighted metallic cylindrical vias as shown in the figure. The rectangular patch is made up of copper materials with dimensions of 4mm x 7.3mm.

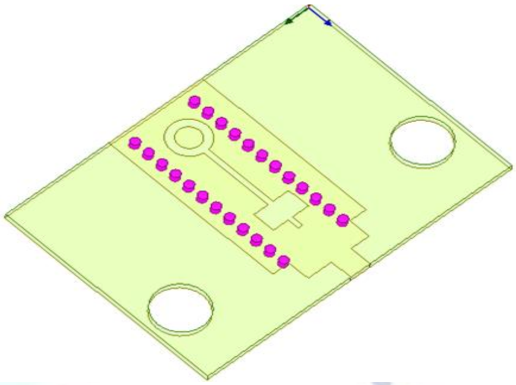

Fig-2: SIW slot antenna.

The highlighted metallic cylinders (metal via's) have radius of 0.17mm and height of 0.381mm. The copper materials is used for the creation of the metal via's. The distance between the two consecutive metallic vias is 0.6mm and the distance between two adjacent vias is 2.54mm.

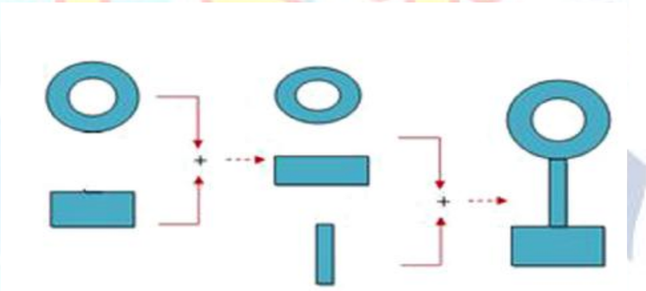

Fig-3:The geometry of the VENUS SLOT.

The Venus-shaped slot is etched on the top side of the substrate. The Venus slot is a combination of concentric circles, a horizontal rectangle anda vertical rectangle. The concentric circles consist of outer circle with a radius (R1) of o.77mm and inner circle with radius(R2) of 0.45mm. The dimensions of the horizontal rectangle and vertical rectangle is 1.5mm x 0.87mm and 0.2mm x 4.2mm.

By following the above figure, the unification of concentric circles and the rectangles are done by using the HFFS unite function and subtraction of the slot the from the top side of the antenna is done by using the HFFS subtract function.

DESIGN EQUATIONS OF SIW:

For TE10 mode,

$$f_c = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m\pi}{w_{eff}}\right)^2 + \left(\frac{n\pi}{h}\right)^2}$$

Where f_c is the desired frequency and c is the velocity of the light. h is the thickness of the substrate and m=1, n=0.

$$f_c = \frac{c}{2 * w_{eff} * \sqrt{\varepsilon_r}}$$

ε_r is the dielectric constant and (Weff) Equivalent waveguide width.

$$w_{eff} = w - \frac{d^2}{0.95 * s}$$

To avoid leakage losses

$$d = \frac{\Lambda_g}{5}$$

$$s \leq 2 * d$$

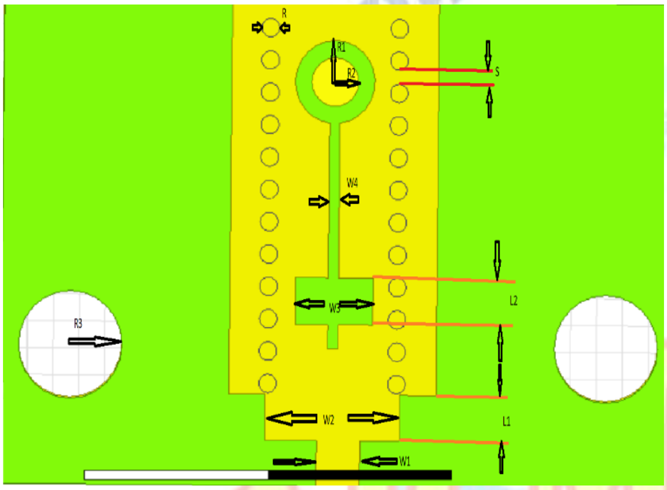

Fig-3: Parameters describing antenna geometry.

The parameters used in the design are R1 = 0.77mm, R2 = 0.45mm, W3 = 1.5mm, W4 = 0.2mm, R = 0.17mm, S = 0.6mm, W = 2.54mm, W2 = 2.6mm, W1 = 0.84mm, L2 = 0.87mm, L1 = 0.85mm, R3 = 1mm.

3. RESULTS AND DISCUSSION

PARAMETRIC ANALYSIS:

Influence of distance between rows of metallic vias(W):

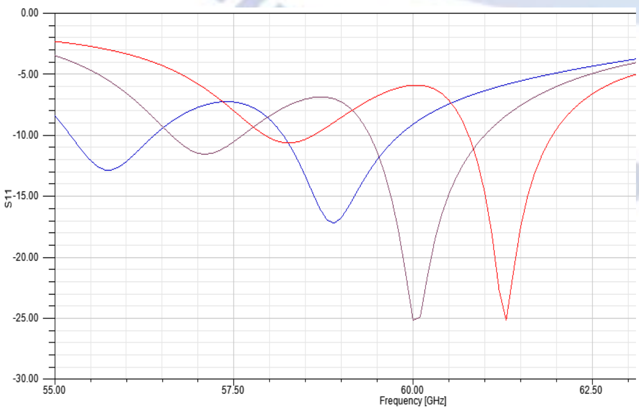

Fig-4: S11 values for different values of W.

The above figure represents the variation in the matching characteristics with change in distance between rows of metallic vias. As the distance varies from 2.44mm to 2.64mm, the upper cut-off frequency changes from 61.3GHz to 58.9GHz. As the distance increases, the operating frequency decreases which is in accordance with the theoretical formula stated above.

Influence of horizontal rectangle slot width (w3):

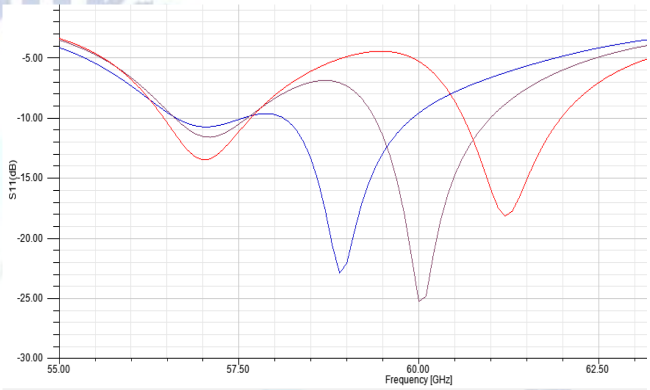

Fig-5: S11 values for different values of W3.

Though the distance between the slots has an impact on operating frequency of antenna, however the dimensions of the geometry used in the slot can also be used to tune the antenna to the desired frequency without changing the original SIW structure. The width of the rectangle changes from 1.7mm to 1.3mm, the upper cut-off frequency changes from 58.9GHz to 61.2GHz. A little effect on frequency has been noticed.

Influence of radius of inner circle (in slot) (R2):

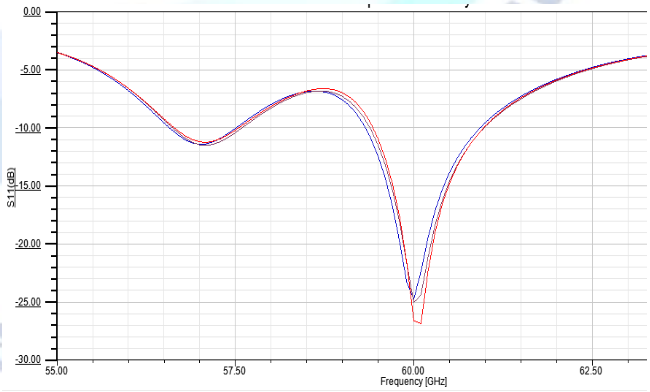

Fig-6: S11 values for different values of R2.

The above figure represents the variation of S11 characteristics with change in the radius of inner circle present in the slot. It is evident from the above figure that the operating bandwidth, frequency of antenna is not influenced by change in radius of inner circle but has little or no effect on the S11 value.

Influence of radius of outer circle (in slot) (R1):

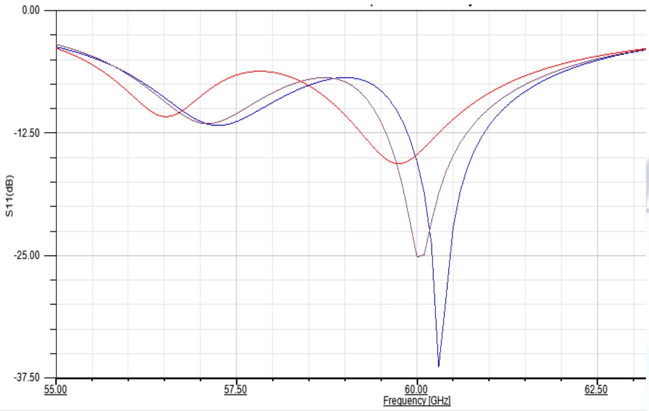

Fig-7: S11 values for different values of R1.

Unlike the influence of radius of inner circle, the change in radius of outer circle has a significant impact on the bandwidth of the antenna. As the radius of circle changes from 0.67mm to 0.87mm, the operating bandwidth changes from 1.8GHz to 1.6Hz. The effect of S11 values w.r.t radius of circle has also been noticed.

Influence of width of substrate (Ws):

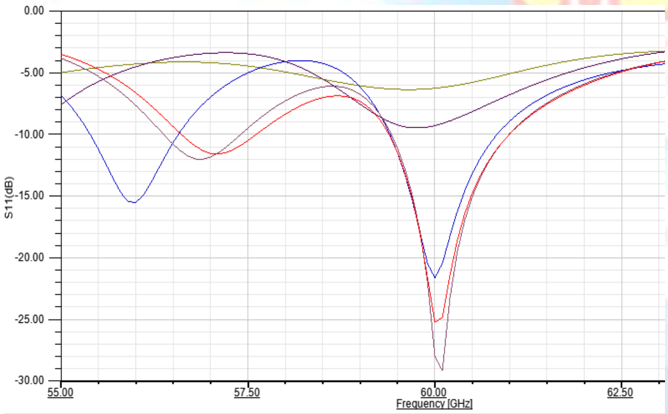

Fig-8: S11 values for different values of Ws.

The above figure represents the variation in the matching characteristics with change in the width of substrate. For the

higher values of thickness like 0.8mm,1mm correct plot is not obtained. When the thickness of substrate is in between 0.3mm to 0.5mm, the operating frequency is almost the same but there is a little effect on the S11 values.

A. SIMULATED RESULTS:

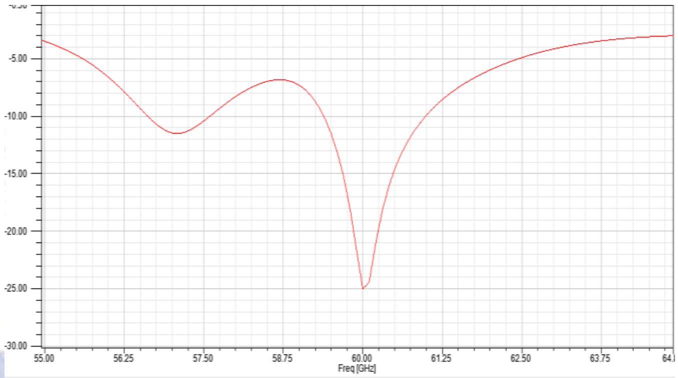

Fig-9: Reflection coefficient over frequency

The above graph represents variation of s11 with respect to frequency and it is found to be -25dB (at 60GHz) and bandwidth=1.6GHz (ranging from 59.4GHz to 61GHz)

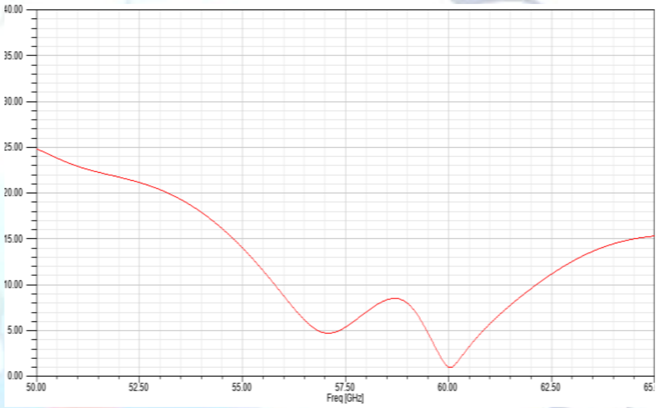

Fig-10: VSWR for the proposed design. (VSWR)voltage standing wave ratio

The VSWR over a frequency of the proposed design is demonstrated in the above figure, the vswr value is found to be 1.05 at 60GHz

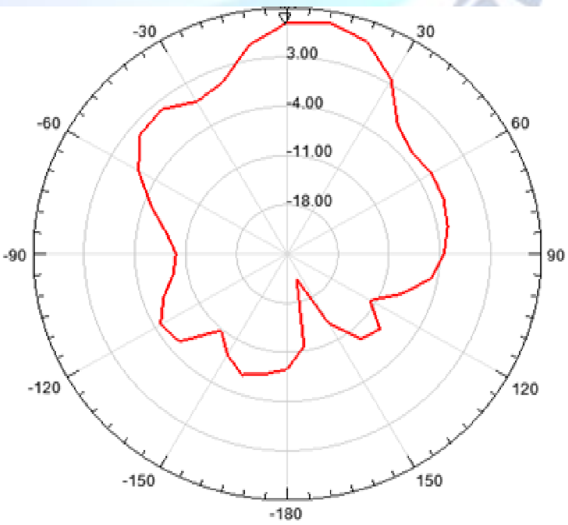

Fig-11: Radiation pattern at $\phi = 0\circ$.

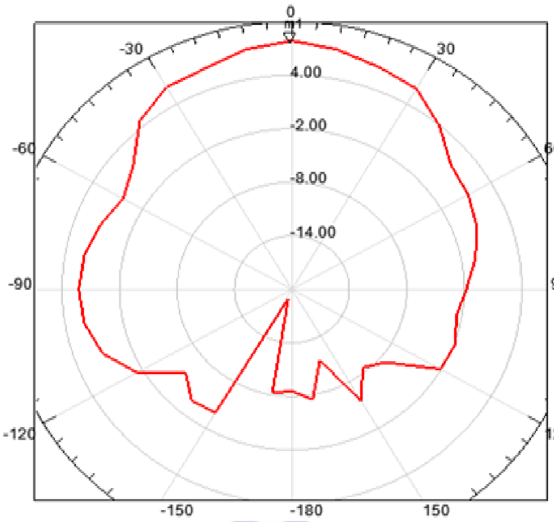

Fig-12: Radiation pattern at ϕ = 90◦.

The radiation pattern in the XZ plane, YZ plane is shown in the above figures, Uni directional and stable patterns were observed and well suited for wireless applications. The maximum gain obtained at 60GHz is 7.88db.

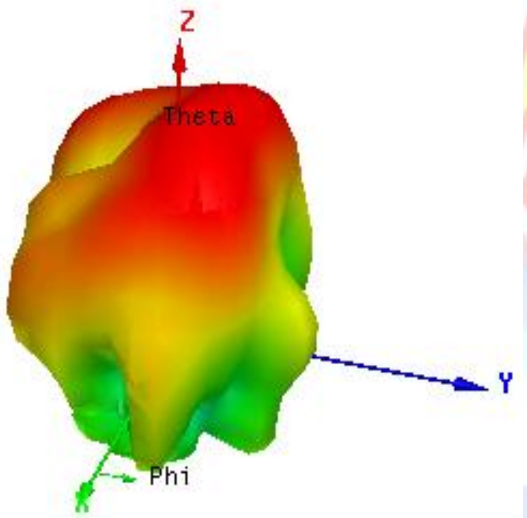

Fig-13: 3D RADIATION PATTERN

It is evident from the above figure that majority of the radiation is in a single direction as there are only small minor lobes present in the back side.

Reference	Antenna size (mm^3)	Gain (dBi)	Bandwidth (GHz)
1	25*16*0.635	6	3
2	14*16*2.6424	14.8	1.1
3	33.5*8*0.787	10	0.8
Proposed	13*9*0.381	7.88	1.6

Table-1: Comparison with existing Results.

4. CONCLUSION

A SIW slot antenna was designed. The parametric study of dimensions reveals their effect on antenna matching characteristics. The SIW structure(planar) helps the antenna to operate at higher frequencies with minimum losses as compared with the microstrip lines and waveguides. The simulated results show bandwidth of 1.6GHz ranging from 59.4GHz to 61.0GHz and s11= -25dB (at 60GHz), VSWR=1.05, gain=7.88dBi. Due to the simple structure and good efficiency, the proposed antenna can be used in many wireless applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] FAN, Z., HAINES, R. "Emerging technologies and research challenges for 5G wireless networks". IEEE Wireless Communications,2014, vol. 21, no. 2, p. 106–112.

[2] 2014, vol. 21, no. 2, p. 106–112. Nanda Kumar Mungaru, Shanmugannatham, "Broadband substrate integrated waveguide venus-shaped slot antenna for v-band applications." Microw opt Technol Lett.2019;1-6.

[3] KUMAR, A., RAGHAVAN, S. "Broadband SIW cavity-backedtriangular-ring slotted antenna for Ku-band applications". AEU:International Journal of Electronics, 2018, vol. 87, p. 60–64.

[4] SHARMA, S., KANAUJIA, B. K., KHANDELWAL, M. K. "Analysis and design of single and dual element bowtie microstrip antennaembedded with planar long wire for 5G wireless applications". Microwave and Optical Technology Letters, 2020, vol. 62, p. 1281–1290

[5] ARORA, R., RANA, S. B., ARYA, S. "Performance analysis of Wi-Fishaped SIW antennas". AEU: International Journal of Electronics,2018, vol. 94, p. 168–178.

[6] WANI, Z., ABEGAONKAR, M. P., KOUL, S. K. A "28-GHz antennafor 5G MIMO applications". Progress In Electromagnetics ResearchLetters, 2018, vol. 78, p. 73–79.

[7] AWIDA, M. H., FATHY, A. E. "Design guidelines of substrate integrated cavity backed patch antennas". IET Microwaves,Antennas & Propagation, 2012, vol. 6, no. 2, p. 151–157.