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Research paper

Micro strip FED SIW venus shaped slot antenna for millimeter wireless communication applications

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Abstract

SIW is an excellent technology for millimeter frequency range of applications. In this paper, introduced SIW Venus shaped slot antenna for 60 GHz frequency applications, it is useful for millimeter wireless communication applications. The proposed structure is intended with help of Rogers substrate ε_(r) = 2.2 and thickness of substrate is 0.381mm. Computer simulation technology (CST) studio suite is used for designing of proposed structure and obtained impedance bandwidth of 4.49 GHz with a resonant frequency of 60 GHz, their reflection coefficient is -27.576 dB. The simulation results like VSWR, gain, radiation pattern and efficiencies are observed for above proposed antenna. Finally introduces the RLC lumped equivalent circuit model for proposed antenna, that can be developed with the help of MATLAB, it generated reflection coefficient and VSWR results and it is perfectly matched with proposed antenna reflection coefficient and VSWR results.

Keywords: *Matrix Laboratory (MATLAB); Millimeter Waves (MMW); Substrate Integrated Waveguide (SIW); System on Substrate (SOS); Wireless LAN (WLAN.*

1. Introduction

The growth of millimeter wavelength waves are rapidly growing in communications and paying attention due to a growth of academia and industry applications [1]. The Mmw (Millimeter waves) technologies are 60GHz (Millimeter wireless communication networks) [2-3], 79GHz (Automotive radar systems)[4] and 94 GHz (millimeter wave imaging) are fixed unlicensed frequencies in millimeter waves. In last decades, the investigation is going on for broadband and high gain antenna for implementing those applications.

The 60GHz is one of the unlicensed frequency band in millimeter wave frequency range and used for millimeter wireless communication. This band occupies the 57-64 GHz frequency range; assign by federal communication commission (FCC) used to connect the unlicensed devices and used for broadband (high data rate) and short range applications.

SIW is one category of transmission line used for high frequency range of applications like millimeter and centimeter wave applications, also called as laminated waveguide and post wall waveguide [5]. SIW is mainly derived from SICs and generalized diagram of SIW is shown in Fig. 1. The shape is common like a waveguide, fabricated by using two rows of periodic via's or hole is inserted between top and bottom of ground planes through substrate [6-7]. Compare to existing transmission lines like microstrip as well as a waveguide, it has moderate weight and more power handling and less interference. The planar technology is used for fabricating SIW that is a system on substrate (SoS), it is the main advantage of SIW. Due to planar technology is used in SIW, it can also use as a passive components, active components and antennas.

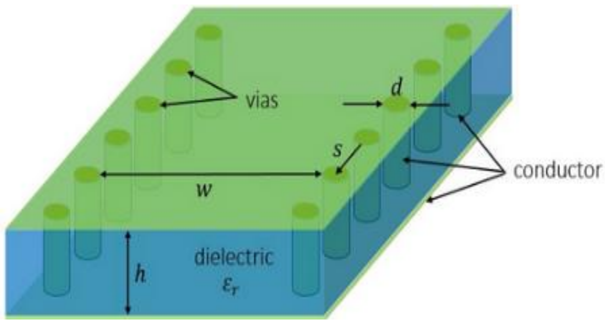

Fig. 1: Schematic Representation of SIW.

The SIW width is also depended on d as well as s, as given in equation 1 [8-9]

$$Ar = a_s - (d^2/0.95s) \quad (1)$$

Equation 2 is used to reduce the losses in SIW.

$$D \leq \lambda_g \text{ and } s \leq 2d \quad (2)$$

The structure of this paper as follows. Sec.2 describes about proposed antenna design, sec3. gives the overview of simulation results discussion, Sec.4 describes the Equivalent circuit model and finally sec.5 describes the conclusion followed by references.

2. Antenna design

The Fig. 2, represents the proposed antenna structure in that Fig. 2a, represents the top view of the proposed structure and Fig. 2b, represent the bottom view of and Fig. 2c, represents the side view of the proposed antenna. The proposed antenna is designed by using rogers substrate material with $\varepsilon_r = 2.2$ and thickness of 0.381mm. In the above figure yellow colour represent the copper and white colour represents the substrate material and green colour represents via that is coated by copper. The venus shaped slot is etched in top view of an antenna that can be represented in Fig. 2a. The microstrip feed with an input impedance of 50ohms is connected to the SIW antenna. Fig. 2c, shows the definition of SIW that is inserted holes between top and bottom ground planes through substrate. The parameters used for representing proposed structure are represented in Table.1. The L1 and L2 are the lengths of the microstrip and tapering microstrip and chosen the values are quarter guided wavelength for perfect matching. The D and S are very important parameters for designing of proposed antenna and their values are 0.3mm and 0.6mm. The dimensions of proposed structure is 4 x 9.034 x 0.381mm^3.

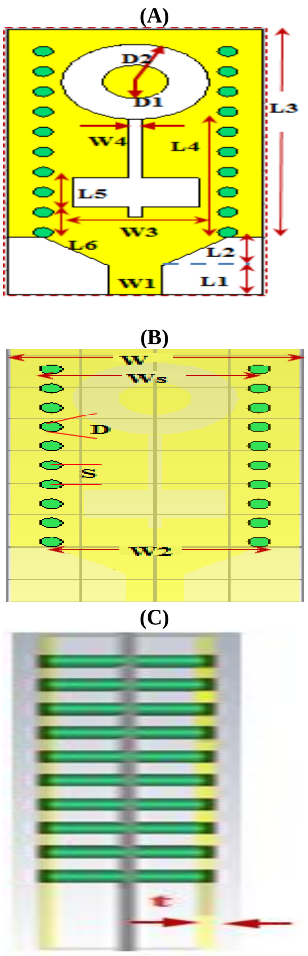

Fig. 2: Proposed Antenna Design A). Top Inspection B). Bottom Inspection C). Side Inspection

The slot width is chosen based on equation. 3

$$(\lambda/4) \leq W_3 \leq (\lambda/2) \quad (3)$$

Length also satisfies by the equation. 4

$$L_5 \leq W_3 \quad (4)$$

Table 1: Dimensions Used for Design

Parameters	Dimensions(mm)	Parameters	Dimensions(mm)
D	0.3	L4	3.52
h	0.381	L5	0.9
L1=L2	0.85	L6	0.9
L3	6.2	S	0.6
W1	0.8	T	0.035
W2	2.8	D2	2.25
W	3.9	D1	0.5
W3	1.92	Ws	2.81
W4	0.2		

3. Simulation results

The S_{11} of proposed antenna strucuture is represented in Fig. 3, this sturcture will produces the impedance bandwidth of 4.94 GHz (range from 59 to 63.494 GHz) with a resonant frequency of 60GHz , their reflection coefficient values are -28.87 dB. This proposed antenna is fitting for millimeter wireless communications (60GHz).

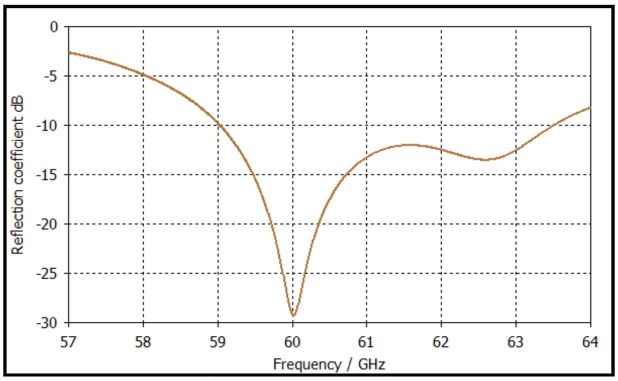

Fig. 3: Frequency vs S11.

The Fig. 4, represents the frequency versus VSWR of proposed antenna in between 57-64 GHz frequency band. This also provides bandwidth of 4.498 GHz with respect to VSWR with a reflection coefficient of 60GHz with a VSWR value of 1.0719. The 2:1 VSWR bandwidth is perfectly matched with the impedance bandwidth with -10dB reference line.

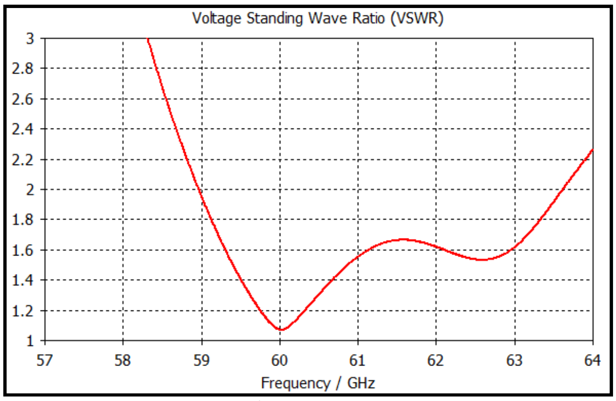

Fig. 4: VSWR.

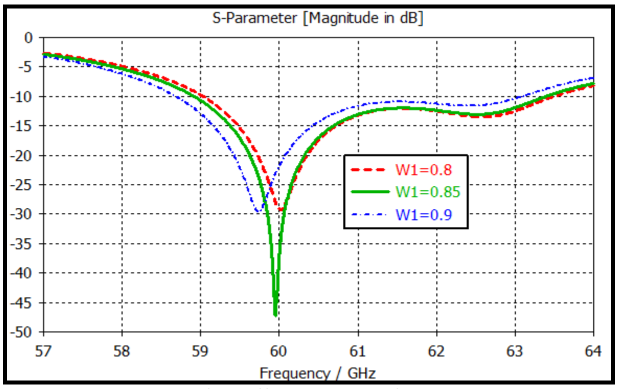

Fig. 5: S_{11} for Different Values of Feed Width.

The Fig. 5, represent the S_{11} for different values of microstrip widths in between the frequency range 57-64 GHz. From Fig. 5, we observed that while changing width will influence the resonant frequency but there is no change in bandwidth. Reflection coefficient result of proposed antenna for dissimilar values of slot widths are dissipated in Fig. 6, in between the frequency range 58.5 GHz to 63.5GHz and observed that changing width will affect the resonant frequency as well as bandwidth and also observed that increasing width of slot will decrease the bandwidth.

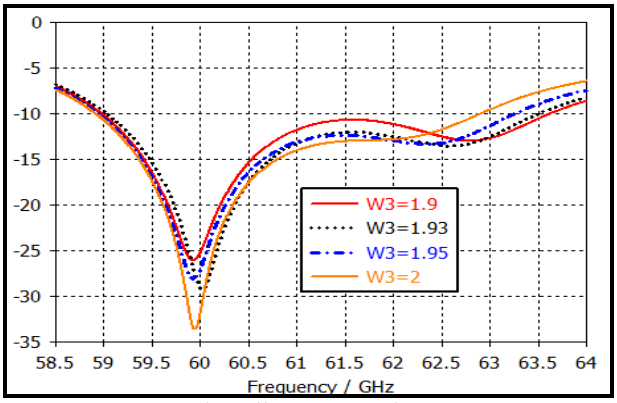

Fig. 6: S_{11} for Different Values of Slot Widths.

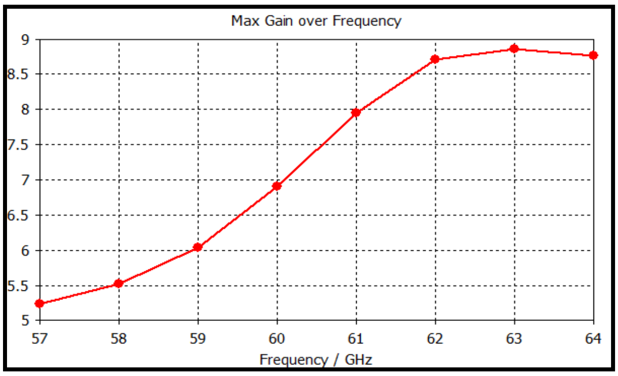

Fig. 7: Maximum Gain over Frequency (Ghz).

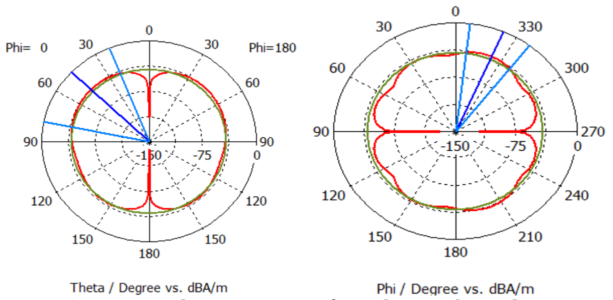

Fig. 8: 2D Radiation Pattern Left E- Plane Right H-Plane.

Maximum gain over frequency is dissipated in Fig. 7, with a frequency range of 57-64 GHz, and observed the gain values of different frequencies. The gain is 6.94 dBi at 60GHz and it is suitable for short range applications.

Fig. 8, represent the 2D radiation patterns of proposed design at 60GHz, left side indicates E-Plane and Right indicates H-Plane and also observed the direction of propagation is bidirectional in the case of E-plane as well as H-plane.

The efficiencies of proposed antenna are described in Fig. 9, with a frequency range of 57-64 GHz. The red color is belongs to total efficiency and blue color is belongs to radiation efficiency. The radiation efficiency is approximately 90% for entire frequency but total efficiency of proposed structure is fluctuated between 70% to 85%.

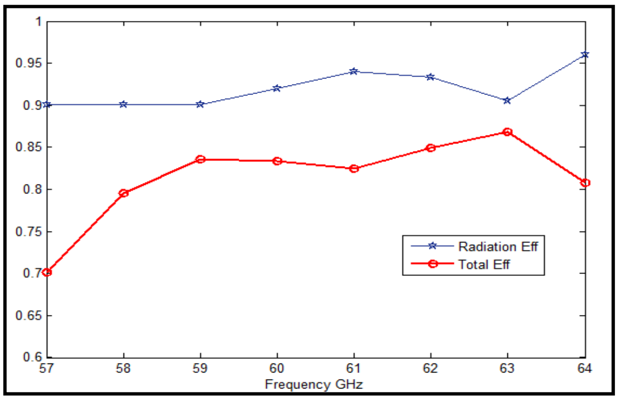

Fig. 9: Efficiencies of Proposed Antenna.

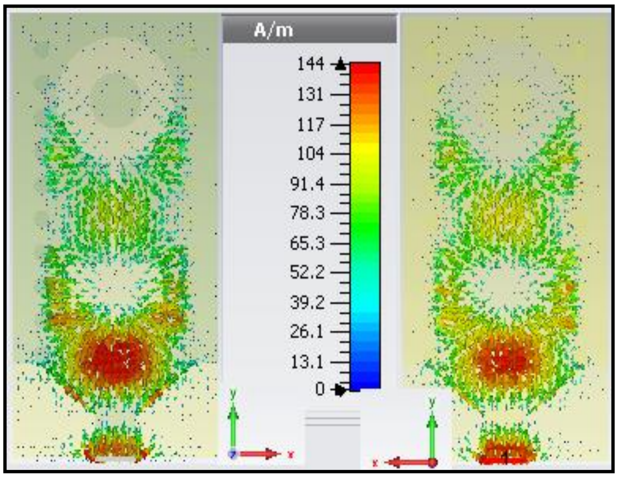

Fig. 10: Surface Current at 60 GHz.

The Fig. 10 represents the surface current of proposed antenna at 60GHz, in that left indicated for top view and right indicates for bottom view. The current flow is maximum at feed point as well as starting edge of slot also observed. There is no loss at feed point due to tapering of microstrip. The Table II describes the comparison of proposed antenna results with offered structure and observed that proposed antennas has more bandwidth, less size and moderate gain comparing with all existing structure.

Table 2: Invented Design Result Comparison with Existing Designs

S. No.	Band-width (GHz)	Gain (dBi)	Size (mm)	Resonant Frequency (GHz)	Reflection Co-efficient (dB)
Proposed	4.49	7.39	4*7.484*0.381	60	22.885
[9]	3.1	8.01	5*19.1*0.381	60, 61.66	-19.32, 24.149
[8]	3	6.04	4*5*0.381	60	30.419
[7]	1.85	4	4*4*0.381	60	-35
[2]	1.5	16.5	9.93*43.29*0.381	60	-40
[3]	0.8	7.2	4*20.7*0.381	60	-12.07

4. RLC equivalent circuit model

The proposed RLC lumped circuit modeling shown in Fig. 11. First RLC represents first resonant frequency (60GHz) and covers a frequency between 59 GHz to 61 GHz and second RLC circuit provides remaining band. The standard formulae's are used for finding R, L, C are shown in below equations.

The RLC values for a particular resonant frequency by with following equations :

$$R = 2Z_o\left[\frac{1}{|S_{11}|^2} - 1\right]\Omega \quad (5)$$

$$C = \frac{0.25 f_c}{\pi({f_o}^2 - {f_c}^2)} pF \quad (6)$$

$$L = \frac{1}{4\pi^2 {f_c}^2 C}\, nH \quad (7)$$

This circuit model is analyzed by MATLAB with help of tranfer function and finding input impedance of the above RLC ciruit for different values of frequency f.

The standard equation of reflection coefficient is

$$\gamma = \frac{Z_{in} - Z_o}{Z_{in} + Z_o} \quad (8)$$

$$VSWR = \frac{1+|\gamma|}{1-|\gamma|} \quad (9)$$

$$S11(dB) = 10 \log \gamma^2 = 20 \log \gamma \quad (10)$$

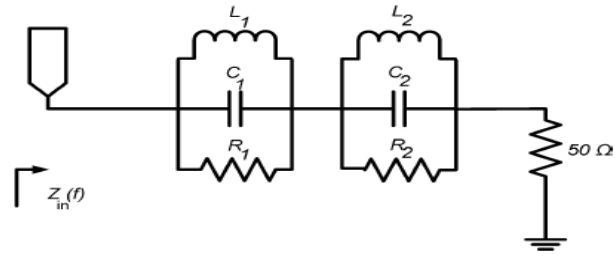

Fig. 11: RLC Lumped Circuit Model.

Table 3: Lumped Circuit Elements Values

Circuit/ Parameters	R (Ω)	L (pH)	C (pF)
1	25	1.84	3.8
2	14	2.20	2.9

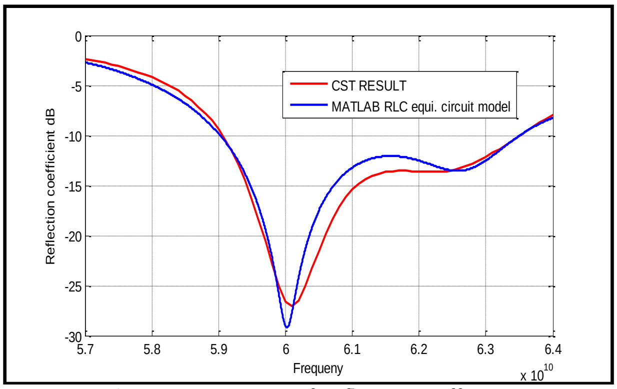

Fig. 12: Comparision Of Reflection Coefficient.

For CST result and Equivalent model

Table III represents the R, L and C values for different tuned circuits. Based on the above equations 10,11 and 12. we found the S_{11} and VSWR values for different values of frequency(f). The Fig. [12], represents the frequency(GHz) versus reflection coefficient (dB) for equivalent circuit model with MATALB and CST result. Comparing two results of the proposed parallel RLC circuit model is acceptable and matched.

The Fig. [13], represents the VSWR plots for MATLAB generated results compared with CST software. Here MATLAB generated graph is little bit less bandwidth due to effect of capacitance but match with VSWR values at resonant frequencies. So Parallel RLC circuit model is chosen for this design is acceptable.

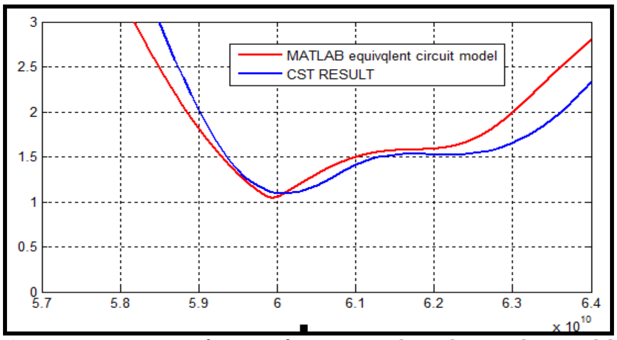

Fig. 13: Comparision Of VSWR for CST Results and Equivalent Model.

5. Conclusion

In this paper, the venus shaped SIW slot antenna was introduced for millimeter wireless communication applications. Computer simulation technology studio suite software was used to simulate the proposed structure. This structure provides 4.49 GHz bandwidth with a reflection coefficient of 60GHz. This structure occupies 64.4% band in between 57-64 GHz frequency and also developed parallel RLC equivalent circuit model with help of MATLAB obtained reflection coefficient and VSWR. The reflection coefficient and VSWR results generated by MATLAB is perfectly matched with simulation results in terms of bandwidth and resonant frequency. Based on the results generated by MATLAB the proposed equivalent models are validated. This structure is good candidate for implementing short range applications like GIFI/WLAN/Automotive application which is comes under millimetre wireless communication applications. Furthermore this is extend to another unlicenced bands in millimetre frequencies like Auromative radar and millimeter imaging applications etc,

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