Horn Shaped SIW Antenna for 5G Applications

[1]N Krishna Jyothi , [2]Chilupuri Anusha

[1,2]Assistant Professors,
[1,2]Departmrnt of Electronics and Communication Engineering
[1,2]G. Narayanamma Institute of Technology and Science, Hyderabad, India

Abstract: Substrate Integrated Waveguide (SIW) is the promising technology for mm wave frequency band due to low loss, high Q, compact size and low cost. It also allows the integration of all the components on the same substrate. Over the last decade the demand for high data rates has increased exponentially due to rapid growth in telecommunication sector. To overcome the need of high data rates 5Gwireless systems are introduced as next-generation cellular systems. These systems take advantage of mm wave frequency band due to larger bandwidth and increased channel capacity. At these frequencies, 24GHz is particularly in focus due to high transmission rate through atmospheric barriers, which makes it appropriate for high data rates and high-resolution imaging applications. This work consists of planar SIW horn shape antenna design for mm wave frequency band. The proposed antenna is designed at a frequency of 24 GHz with a substrate of ROGERS RT/DUROID 5870 and its thickness is 1.6 mm. The proposed antenna improves the performance characteristics like Gain, Impedance matching and Radiation efficiency makes it suitable for numerous 5G wireless systems. This antenna can be used in wireless communications, particularly in the area of, 5G RF front end and 5G Applications MIMO.

***Index Terms*—SIW horn shape; Gain; Impedance matching; Radiation efficiency**

INTRODUCTION

Horn antennas have been widely used at microwave and milli-meter frequencies as feeder of the reflector antenna systems. The size of horns made with metallic waveguides are massive, so horn structures using low profile are selected in planar form which is practically applicable in communication systems [1]. The planar horn antennas are compatible with microwave and milli-meter wave circuits and provide convenient way in many applications. The rectangular shaped horn antennas [2] are mostly used in a number of applications because horn antennas provide exceptional radiation properties like symmetry patterns, high gain, easy fabrication, and more bandwidth but their implementation in planar form seems to be difficult due to the bulky geometry and especially the 3D horn sizes. These difficulties can be overcome by SIW technology [3]. To improve the radiation efficiency and directivity of the beam, the wave guide should be provided with an extended aperture to make the abrupt discontinuity of the wave into a gradual transformation. So that all the energy in the forward direction gets radiated. This can be termed as Flaring. Now, this can be done using a horn antenna. The horn antenna has a distinctive shape and is unlike many other forms of antenna and is used at microwave frequencies [4].

The horn antenna can be considered to be a waveguide that has been widened out in the form of a horn. As a result, it finds many applications in areas where waveguides are used [5]. Shaped like a horn and this antenna forms a smooth transition between the waveguide and free space whilst also directing the radio waves in a beam [6].

The horn antenna may be considered as an RF transformer or impedance match between the waveguide feeder and free space which has an impedance of 377 ohms [7]. By having a tapered or having a flared end to the waveguide the horn antenna [8] is formed and this enables the impedance to be matched. Although the waveguide will radiate without a horn antenna, this provides a far more efficient match. In addition to the improved match provided by the horn antenna, it also helps suppress signals travelling via unwanted modes in the waveguide from being radiated [9] [10].

The designed horn shaped SIW antenna is utilized for 5G applications. The proposed antenna represents the horn antenna using SIW Technology for 24GHz applications, with improved gain. This has resulted in high bandwidth, low return loss, which made the antenna suitable for 5G applications. SIW Horn antenna is the integration of rectangular waveguide and horn antenna. Due to compact structure, fabrication easiness and more reliability SIW configurations are applied in this design. It shows that the horn antenna is created with the use of metallic vias (It connects top and bottom plane of the structure). It gives the benefits of non-planar features and other features also namely, small size, low cost, light weight, easy to manufacture using PCB technique and other planar processing technologies, and also being easily connected to coplanar waveguide utilizing a wideband and uniplanar transition. SIW horn shaped antenna is shown in Fig. 1.

I. ANTENNA STRUCTURE AND DESIGN

The horn shaped SIW antenna is developed in this work has a width (W) = 24.5mm and length (L) = 35.5mm. The Fig. 1 presents the geometrical structure of SIW based horn shaped antenna here.

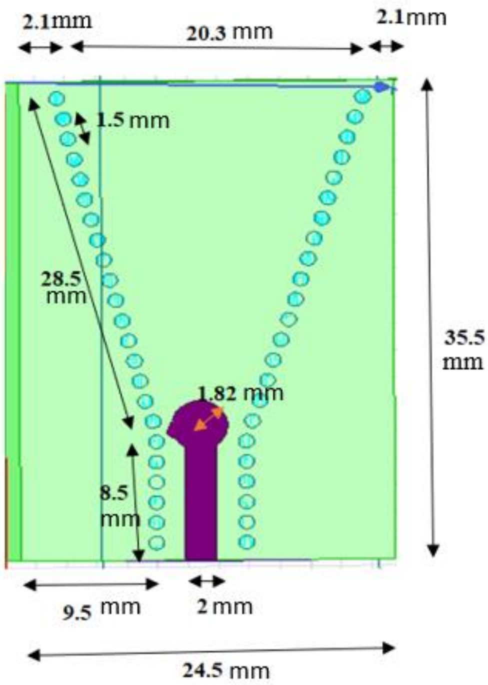

Figure 1: Proposed SIW horn shaped SIW antenna

This antenna composed of vias in the shape of horn and line feed. The horn shaped SIW antenna is printed on Rogers RT/Duroid 5870(tm) with thickness of 1.6mm and εr of 2.33 and this substrate has low loss tangent gives useful performance characteristics at IOT frequencies. Based on the required application, the frequency, substrate material and the height of the antenna is preferred. The dimensions of vias and spacing between vias are determined by following equation.

$$a_d = \frac{a}{\sqrt{\epsilon_R}} \quad (1)$$

$$a_s = a_d + \frac{d^2}{0.95\mathrm{p}} \quad (2)$$

The Table 1 summarizes the parameters of the horn shaped SIW antenna design.

TABLE 1. Dimensions of proposed horn shaped SIW antenna

Parameters	Notation	Dimension (mm)
Width of the substrate	W sub	24.5
Length of the substrate	L sub	35.5
Thickness of substrate	tsub	1.6
Width of the feed line	WF	2
Length of the feed line	LF1	8.5
Length of ground	LG	35.5
Width of ground	WG	24.5
Diameter of via	D	1.0
Height of via	H	1.6
Spacing between two vias	P	1.5
Radius of circular patch	R	1.82

II. SIMULATION RESULTS AND DISCUSSIONS

The results of horn shaped SIW antenna obtained by simulation are discussed here. It is observed that return loss is less than -10dB at few resonant frequencies leading to wider bandwidth. The VSWR value is less than 2 for all resonant frequencies. The return loss for horn shaped SIW antenna are presented in Figure 2. From the graph, it resonates at six different frequencies from 23.2GHz to 27.5GHz frequency to ensure wideband matching for 5G applications. The VSWR at 24.5GHz is 1.07 represented in Figure 3. The gain and directivity of this antenna are 6.9dB and 7.0dB respectively indicated below in Fig. 4 and Fig. 5.

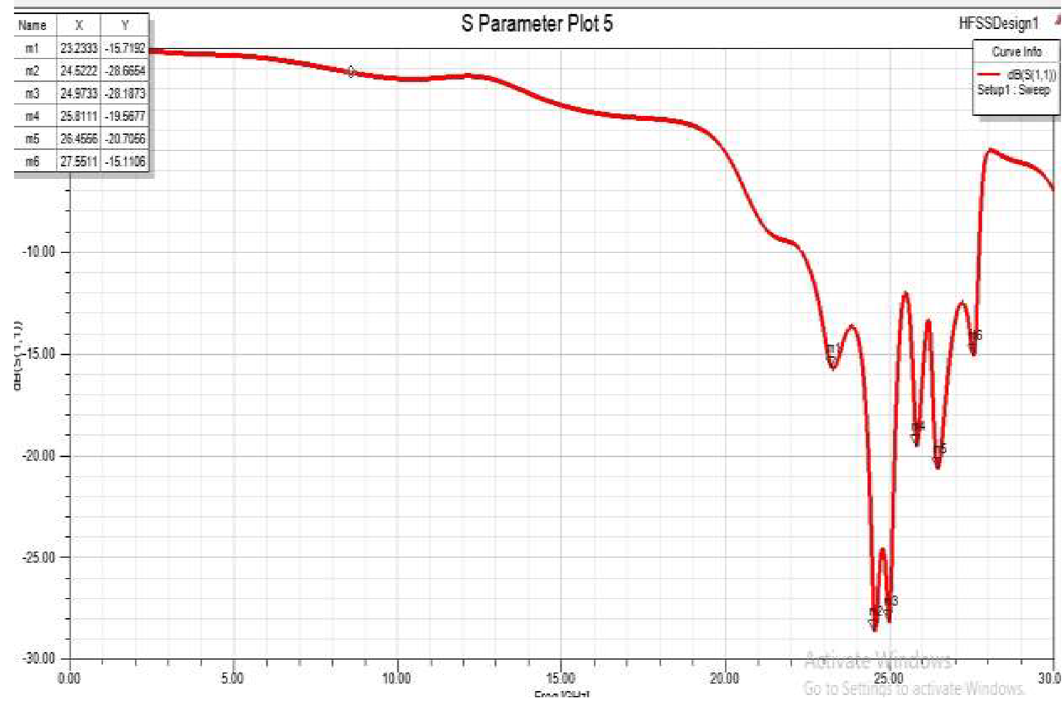

Figure 2. S11 vs Frequency plot for horn shaped SIW antenna

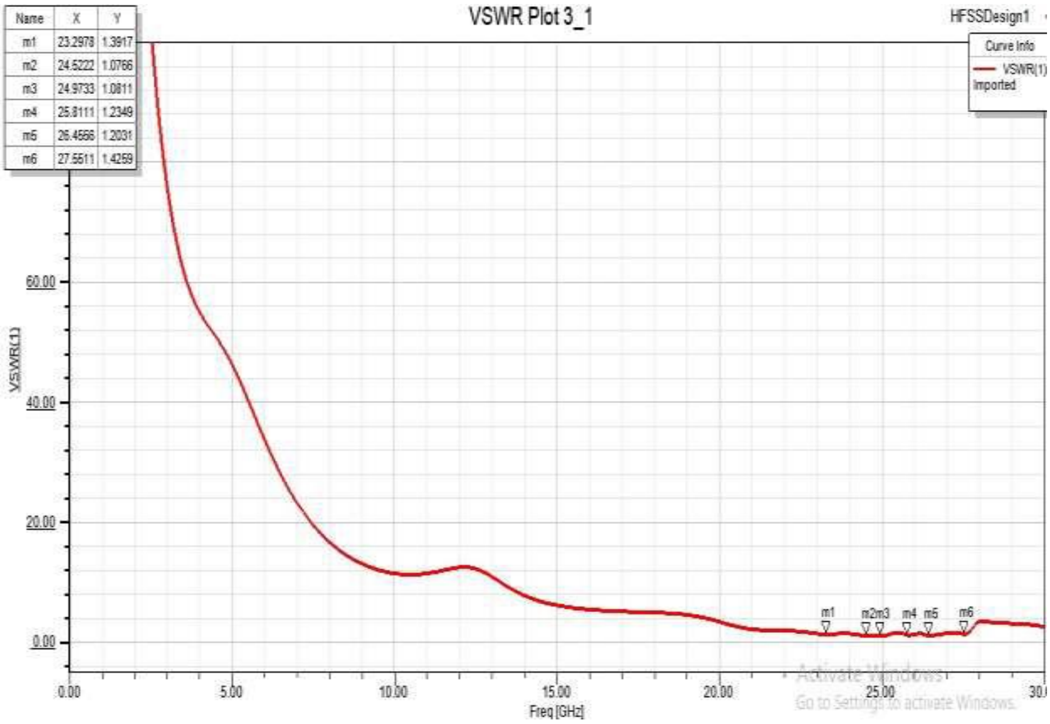

Figure 3. VSWR vs Frequency plot for horn shaped SIW antenna

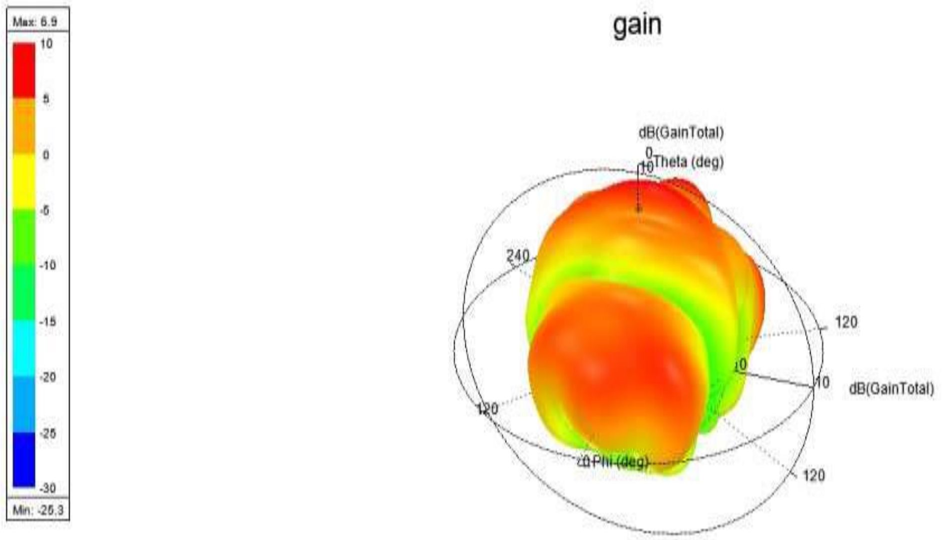

Figure 4. Gain plot for horn shaped SIW antenna

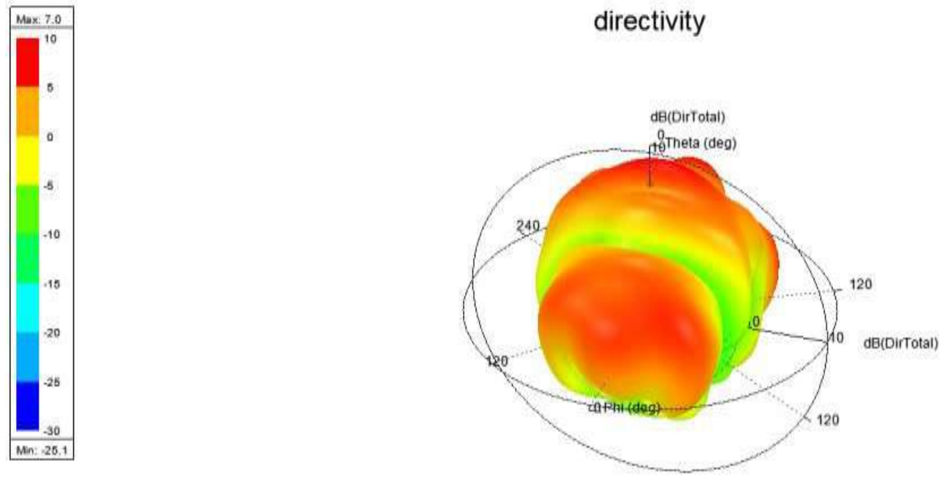

Figure 5. Directivity plot for horn shaped SIW antenna

The antenna is designed using different substrates to obtain for the better outputs. The substrates used in addition to ROGERS RT /DUROID 5870 are FR4 EPOXY, NELTEC NY9220 (IM) (tm), ARLON AD255C (tm) and ASTRA ISOLA MT77(tm). All the antennas are designed and simulated using HFSS. The antenna parameters are compared according to their results.

The comparison of the antennas with different substrates is shown in Table 2.

Table 2. Comparison Table for Different Substrates

Material/ Parameter	**Thickness (mm)**	**Dielectric constant**	**Resonant Frequencies (GHz)**	**Return loss (dB)**	**VSWR**
ROGERS RT /DUROID 5870	1.6	2.33	21.6222	-10.2599	1.9497
			24.3289	-45.7923	1.0205
			26.0044	-19.0939	1.2497
			26.4556	-21.8335	1.1762
			27.4867	-10.3862	1.8673
FR4 EPOXY	1.57	3.8	20.4622	-18.8823	1.2567
			24.7800	-16.1790	1.3607
			28.4533	-13.0691	1.5710
NELTEC NY9220 (IM) (tm)	0.787	2.2	24.9089	-43.1260	1.0141
			25.4899	-24.7526	1.1228
			26.3267	-19.8758	1.2258
			26.9067	-16.3075	1.3612
			28.1956	-14.9802	1.4338
ARLON AD255C (tm)	1.524	2.55	23.4267	-15.3450	1.4208
			24.7800	-24.8876	1.1206
			26.5844	-14.3519	1.4740
			27.5511	-12.5323	1.6187
ASTRA ISOLA MT77(tm)	1.52	3	22.1456	-10.4845	1.8956
			23.4899	-22.6750	1.4238
			24.8843	-10.0985	1.7895

III. Experimental Verification

Measurements have been carried out for the designed SIW Horn antenna. The performance characteristics of the antenna are measured using the Vector Network Analyzer R&S®ZVL-13 by Rohde and Schwarz. It is seen that the fabricated antenna using ROGERS RT/DUROID 5870 resonates at 18.5 GHz and 24.7 GHz frequencies and exhibits a Return Loss of -23.73 dB at 18.5 GHz and -18.48 dB at 24.7 GHz. The VSWR measured by the Network Analyzer is as shown in Figure 3. The VSWR obtained is 1.25 at 18.5 GHz and 1.36 at 24.7 GHz. Figure 2 and Figure 3 shows the S- parameter and VSWR plots of fabricated antenna. SIW based horn antenna provides better gain, wider bandwidth and multiple resonant frequencies. This type of structure is very compact and will be used in LEO-to-LEO satellite communication where more than one antenna is required for tracking to other satellite.

The fabricated antenna and the comparison between the simulated and measured return loss are shown in Fig.6 and Fig.7

Figure 6. Fabricated SIW Horn Antenna on ROGERS RT/DUROID 5870

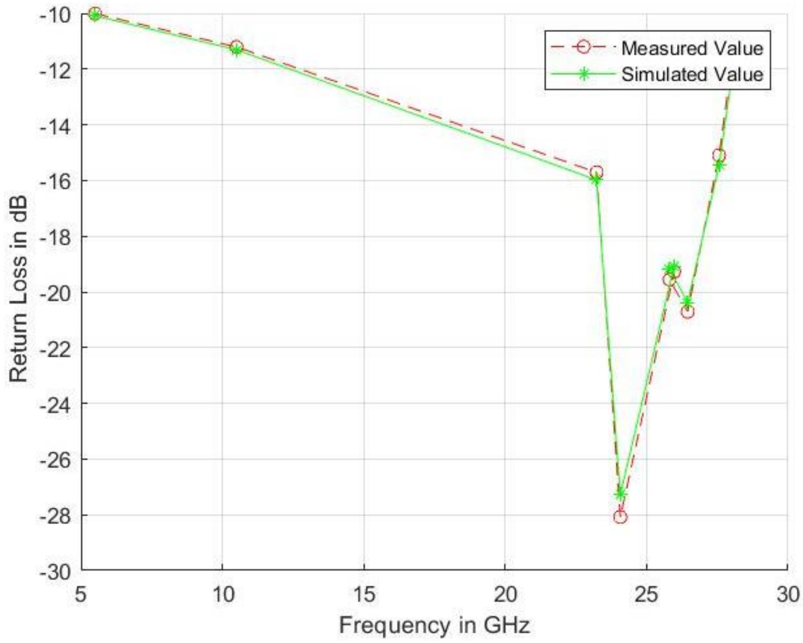

Figure 7. Measured Vs Simulated return loss of Horn Shaped SIW Antenna

IV. Conclusion

In this paper, horn shaped SIW antenna is designed and simulated using HFSS. In this antenna ROGERS RT/DURID 5870 (tm) substrate is simulated at 24GHz. The Simulated result for the plot of Return loss versus frequency has -10.3 dB and -19.0956 dB at 24.97 GHz and 25.81 GHz frequencies respectively with a bandwidth of 920 MHz, where the measured results are -23.73 dB at 18.5 GHz and -18.48 dB at 24.7 GHz frequencies. VSWR for the simulation is 1.08 and 1.23 at 24.79 GHz and 25.81 GHz frequencies respectively where-as the measured VSWR results by VNA are 1.25 at 18.5 GHz and 1.36 at 24.7 GHz frequencies. The simulated and fabricated antennas are resonated at same frequencies with a slighter change. The design of three-dimensional structure has significantly improved the gain of the SIW horn antenna. The design can also be used to get a more directive pattern for long distance communication. The structure can be further multiplied to improve the gain. Increasing user demand for the smarter and faster network which is fully secure has escalated the need for higher data rates. To provide all the users with enhanced data rates, more resource allocation is obligatory in the spectrum. In addition, the deployment of ultra-dense networks and small cells can provide network flexibility in 5G.

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