Design of Hexagonal shaped HMSIW based IOI shape slot antenna for sub-6GHz applications

V SHIVA PRASAD NAYAK[1], MANJUNATHACHARI K[2]

[1]*Assistant Professor,* [2]*Professor*

[1,2] *Dept. of EECE, GITAM (Deemed to be) University, Hyderabad, India.*

svadthya@gitam.edu and mkamsali@gitam.edu

Abstract.

The rapid advances in 5G technology have moved the focus toward compact and efficient antennas for sub-6 GHz applications, which are essential for modern miniaturized devices. The proposed antenna is hexagonal with two rectangles, a circular slot on top of the layer excited by the microstrip line. This design aids integration and enhances performance in the sub-6 GHz frequency range. The critical parameters of the antenna, like resonance frequency, bandwidth, VSWR, radiation pattern, and gain, have been detailed using CST Studio Suite software. It will be helpful for sub-6 GHz 5G applications. Resonating at 3.55 GHz, the antenna presents a 80 MHz bandwidth around a -10 dB reference line and keeps a VSWR of 2:1. From simulation results, it is found that the developed antenna has a good radiation pattern and gain, making it very promising for effective deployment in modern 5G communication systems.

Keywords: **Slot antenna, Hexagonal, Substrate Integrated Waveguide, Sub-6GHz.**

1. INTRODUCTION

Now, 5G is effectively transmitted with a good capacity and connects many devices at relatively low power. 5G is the wireless technology that has proliferated in recent days for the use of device-to-device technology [2], data-driven wireless communication applications, and Industrial Revolution 4.0. Advanced technology applications, such as smart cities, virtual reality, and driverless vehicles, will benefit from advanced communication techniques with the modernization of the Internet of Things using 5G. The operation bands range from 3.3 to 3.7 GHz in India, 3.4 to 3.8 GHz in France, and 3.4 to 3.8 GHz is Spain; all are a part of sub-6 GHz bands. Such frequency bands have become highly popular due to the associated advancements like high throughput, low latency, low power consumption, lower price, and reduced operating distance

The primarily preferred transmission line for high-frequency functions is the substrate-integrated waveguide (SIW) [4]. Other names of SIW are bonded waveguide and post-barrier waveguide, and it is single form of substrate-integrated circuits (SICs) [5-6] for stamped deuce rows of vias linked in the top-to-bottom level through the substrate and also realized for passive, active mechanisms and antenna because of using of system-on-substrate (SOS) technology used to progress. Now, an essential parameter for SIW is the diameter of a hole. The spacing of vias can be represented as in eq.1 and the width of SIW as derived from eq.2 [6].

$$d \leq \frac{\lambda_g}{5} \quad \text{and} \quad s \leq 2d \tag{1}$$

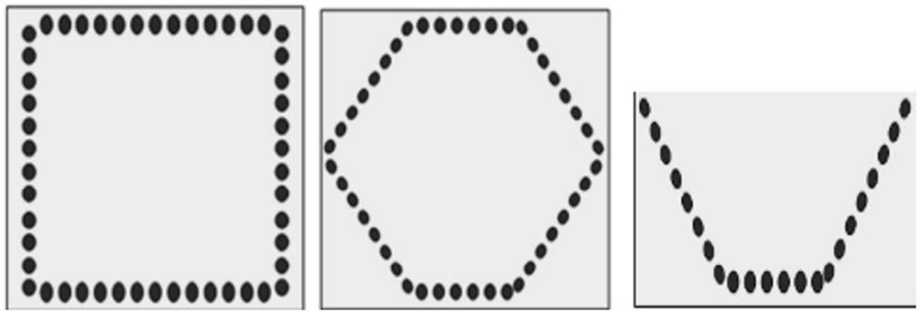
$$a_R = a_S - \frac{d^2}{0.95s} \tag{2}$$

The relationship between the diameter (d) and the width of the waveguide (aR) is not delineated in the preceding equation [6]; at times, this oversight may yield erroneous values, thus a more appropriate formulation is presented as follows.

$$\mathrm{a_{siw}} = \mathrm{a_R} + 1.08 \times \frac{d^2}{\mathrm{s}} - 0.1 \times \frac{d^2}{\mathrm{a_{siw}}} \tag{3}$$

This antenna will be integrated into SIW technology as SIW slot antennas, subsequently transitioning to cavity-backed antennas to enhance bandwidth, reduce size, and achieve moderate gain [4]. This manuscript elucidates the Half Mode hexagonal-shaped SIW loaded with an octagonal slot [2], specifically designed for sub-6 GHz fifth generation applications. Section 2 provides a comprehensive overview of the proposed design, Section 3 complete with design equations and a detailed presentation of results in terms of S11, gain, radiation pattern, surface current, etc [3]. Section 4 offers a succinct conclusion, supplemented by references.

2. DESIGN ANALYSIS



a. SIW b. Hexagonal shaped SIW c. HMSIW

Figure 2.11. Evaluation of HMSIW

Figure 2.1. illustrates the progression of the HMSIW, using an FR-4 substrate characterized by a substrate width thickness of 1.6 mm, relative permittivity of 4.3, and a copper width thickness of 35 µm. Figure 2.1.a. depicts the rectangular-shaped substrate integrated waveguide (SIW) cavity, which has been transformed into a hexagonal-shaped SIW cavity as presented in Figure 2.1.b. In Figure 2.1.b, the cavity is bisected into two halves to facilitate the realization of a half-mode SIW for size reduction, as demonstrated in Figure 2.1.c. Figure 2.2. delineates the parameter argument of the antenna, with a one circular and two rectangular slots situated on the upper of the antenna. Table 1 enumerates the dimensions of the parameters utilized in this design.

The length of HMSIW is $$L = {}^{L_{SIW}}/_{2} \quad (4)$$

Rectangular slot width is $${}^{\lambda}/_{4} \leq W \leq {}^{\lambda}/_{2} \quad (5)$$

Rectangular slot length is $$L \leq W \quad (6)$$

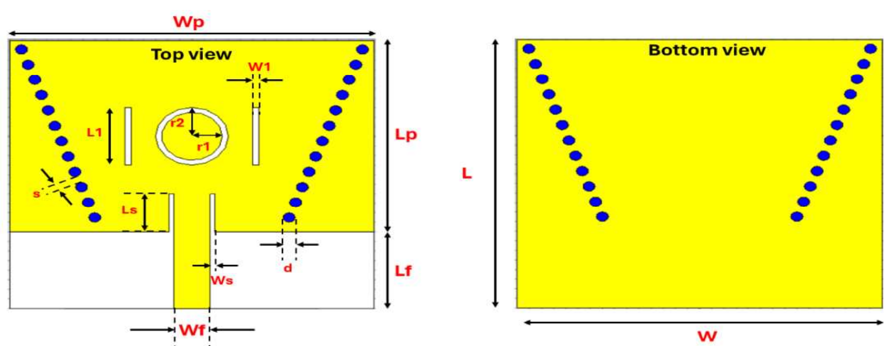


Figure 2.2. Parameter representation of the design

Table 1: Optimized Parameters (in mm)

Parameter	Value	Parameter	Value	Parameter	Value
L	36	W	30	W_1	0.5
r1 /r2	2.5/3	Lf	8	Wf	3
s/d	1.5/1	Lp	20	Wp	30
L_1	6	Ls	4	Ws	0.4

2.1. Evolution of antenna

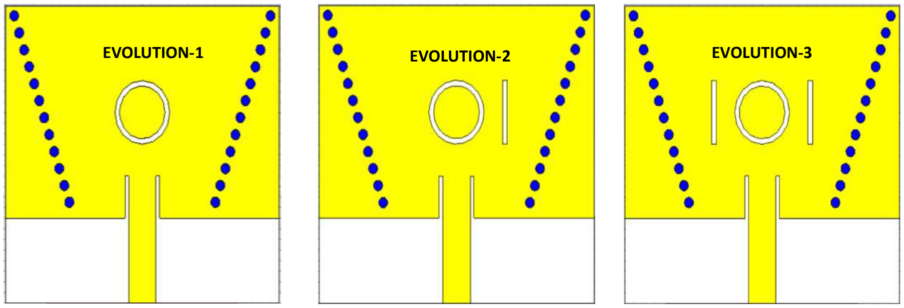


Figure 2.3. Evolution of proposed antenna

The Figure 2.3 show the complete progression of the proposed antenna design. The design of the evolution 1, S11 achieved is -24dB at fr of 3.59GHz. The evolution 2 offered S11of -27dB with fr of 3.57GHz. Finaly evolution3 is obtain operating frequency(fr) of 3.55GHz and the return loss value is of -35 dB. The comparison of Return loss(S11) vs operating frequency(fr) of evolution1, evolution2 and evolution3 has been shown in Figure 2.4.

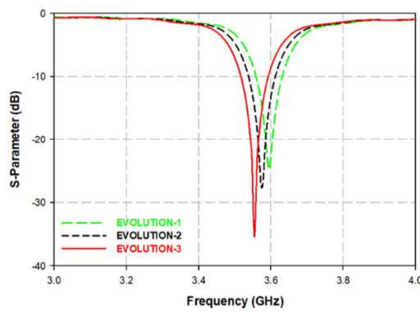


Figure 2.4. Return loss characteristics of evolution 1, evolution 2 and evolution 3

3. RESULTS AND DISCUSSION

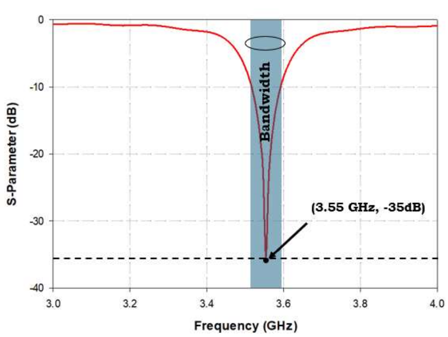


Figure 3.1. Reflection coefficient

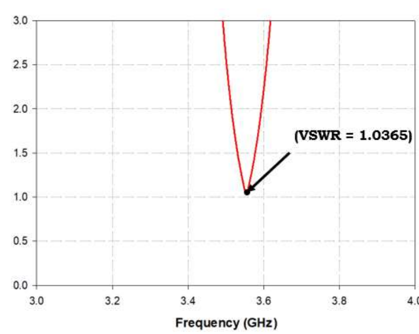


Figure 3.2. VSWR

Figure 3.1. presents the reflection coefficient of the planned antenna across the frequency spectrum ranging from 3 to 4 GHz the antenna exhibits resonance at a frequency of 3.55 GHz, yielding an S11 value of -35 dB and an operational bandwidth of 80 MHz, specifically from 3.51 GHz to 3.59 GHz, suitable for 5G applications. The voltage standing wave ratio (VSWR) corresponding to the proposed design is illustrated in Figure 3.2, indicating a VSWR value of 1.0365 at center frequency of 3.55 GHz.

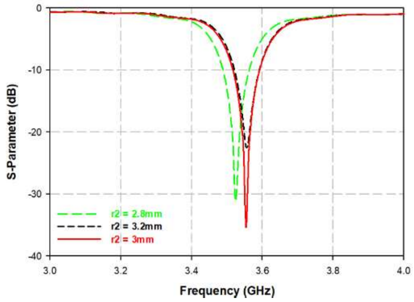


Figure 3.3. S11 for different values of r2

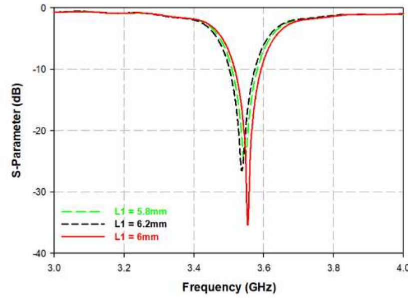


Figure 3.4. S11 for different values of L1

Figure 3.3 illustrates the reflection coefficient for different circular slot radius, specifically for values of 2.8 mm, 3.2 mm, and 3 mm. The optimal value selected among the r2 is 3 mm.

Figure 3.4 illustrates the reflection coefficient for different rectangular slot length, specifically for values of 5.8 mm, 6.2 mm, and 6 mm. The optimal value selected among the L1 is 6 mm.

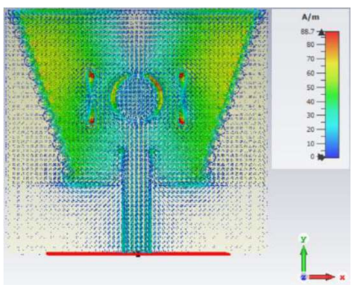


Figure 3.5. Surface current at 3.55GHz

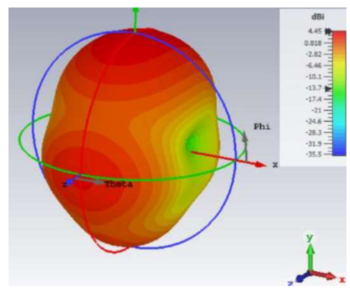


Figure 3.6. Gain at 3.55GHz

The surface current of the proposed antenna is revealed in Figure 3.5 at a resonant frequency 3.55GHz and observed that flow of current is more at circular slot as well as at rectangular slot. The Figure 3.6 shows the gain of the antenna at 3.55 GHz resonant frequency, observed that flow the current is in the direction of propagation and their value is 4.45dBi is well fitted for 5G wireless applications.

4. CONCLUSION

The half-mode hexagonal shaped SIW cavity-backed antenna was presented for sub-6GHz 5G applications and Fr-4 material used for the design. This design has loaded with one circular and two rectangular slots in top view and CST software is used for simulating the antenna for analyzing the antenna results. The antenna resonates at 3.55 GHz operating frequency with a 80 MHz occupied bandwidth ranging from 3.51 GHz to 3.59 GHz. The S_{11}, VSWR, gain values are -35dB, 1.036, 4.45 dBi at 3.55 GHz resonant frequency and observed acceptable radiation pattern for 5G Application.

5. REFERENCES

[1] NandaKumar, M. Srihari G.: Microstrip Feed Half-mode Substrate-Integrated- Waveguide loaded with SRR for dual-band Applications.Printed Antennas design and challenges, CRC press (Taylor an Fransis), 9, 125-138 (2022).

[2] Deepender, Manoj, Shrivastava, U. Verma, V.K. : A Study on 5G Technology and Its Applications in Telecommunications. International Conference on Computational Performance Evaluation (ComPE), pp.365-371, Shillong (2021).

[3] Nandakumar, M. Shanmuganantham, T. :Broad-Band H-Spaced Head Shaped Slot with SIW Based Antenna for 60GHz Wireless Communication Applications. Microwave and Optical Technology letters, 61(8), 1911-1916 (2019).

[4] Guyen Trong, N, Fumeaux, C.: Half-mode substrate-integrated waveguides and their applications for antenna technology: a review of the possibilities for antenna design. IEEE Antennas Propag Mag, 60(6), 20-31 (2018).

[5] Nandakumar, M. Shanmuganantham,T.:Broad band I shaped SIW slot antenna for V-band Applications. Applied Computational Electromagnetic Society, 34(11), 1-6 (2019).

[6] Nandakumar, M. Shanmuganantham,T.:Broad band Substrate Integrated Waveguide Venus shaped Slot Antenna for V-band Applications. Microwave and Optical Technology letters, 61(10), 2342-2347(2019).