International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Design Of Wideband Siw Cavity Backed Antenna Using a Modified Rectangular Slot and Metallic Vias

Yarra Kiran Kumar, Vema Naveen, Poleboina Bivilla Rani, Popuri David Raju
UG student, Dept of E.C.E
RVRJC College of Engineering
Guntur, Andhra Pradesh, India

Abstract——In this era of fifth generation (5g), communication technologies are mainly expected to meet higher data transmission rates and larger bandwidths. Among the available implementation technologies, the Substrate Integrated Waveguide (SIW) plays a key role. In this paper, our main aim is to enhance the bandwidth of the cavity backed slot antenna. Additionally, fulfilling the requirements of gain, directivity, size reduction and cost. SIW techniques are widely used in 5g, iot applications, satellite communications and many other. A slotted SIW antenna is designed in the x band (8Ghz-12Ghz). The simulation will be performed using ANSYS HFSS (high frequency structure simulator) software. The designed antenna consist of metallic vias and a modified rectangular slot in order to achieve the wideband application. The reflection coefficient graphs are observed at different modes in the proposed antenna.

keywords:- bandwidth, simulation, coefficient graphs,cavity
backed

I. INTRODUCTION

A new generation of high-frequency antennas called "substrate integrated waveguide – SIW" was proposed and demonstrated many years ago.Substrate integrated waveguide is a technique in which some metalized holes and two metal plates are located altogether of the substrate layer and those metalized holes are not in contact with each other.The waveguide can be easily fabricated with low-cost mass-production, where the post walls consists of via fences.SIW arrangement retains most of the advantages associated with high gain light weight, low power losses, high power capacity etc. The main approach is using a cavity backed slotted antenna.Because the cavity-backed antenna structure overcomes potential problems

.

such as heat dissipation and unwanted surface wave modes. However SIW cavity-backed slot antennas usually suffer from narrow bandwidths, due to the high quality factor and single resonance response. we aim at increasing the bandwidth of the antenna. A cavity-backed substrate integrated waveguide (SIW) antenna is a type of antenna that consists of a radiating element placed on top of a SIW cavity.The cavitybacked SIW antenna can be designed to operate at various frequency bands.It is also relatively easy to fabricate and can be integrated with other components, such as filters, amplifiers, and mixers.The design of cavity-backed SIW antennas can be optimized using electromagnetic simulation software i.e., ANSYS HFSS(high frequency structure simulator).The optimization process involves selecting the appropriate cavity dimensions, dielectric material, and radiating element parameters to achieve the desired performance characteristics.

II. DESIGN THEORY

A. Substrate details

The substrate material used in the proposed antenna is Rogers RT Duroid 5800.The RT/duroid 5800 material has a dielectric constant (Dk) of 2.2 and a dissipation factor (Df) of 0.0009 at 10 GHz.The thicknesses is ranging from 0.0015mm to 0.25mm.Although it is commonly known for its excellent dimensional stability. The thickness of the substrate in the proposed antenna is 1 mm .It is a high-performance material that offers unique electrical and mechanical properties for high-frequency circuit applications.

B. Geometry

The Top plane and bottom plane of the antenna are taken as perfect electric conductors.A 50 ohm microstrip line is used to feed the antenna.The dimensional parameters of the antenna is show in table 1.In order to avoid the energy leakage from the via gaps, the diameter d and the spacing of the sidewall shorting vias s are chosen to be d = 1 mm and s = 1.5 mm, respectively, which satisfy the conditions of s/d less than or equal to 2 and d/0 less than or equal to 0.1

1) resonant frequency:

$$fr(TEmnp') = \frac{1}{2\sqrt{\epsilon_r \mu_o \epsilon_o}} \sqrt{(\frac{m}{L_eff})^2 + (\frac{n}{_eff})^2 + (\frac{p'}{h})^2} \quad (1)$$

Where, m,n,p’ are number of half wave sinusoidal cycles, fr = Resonant Frequency, ϵ_r = *RelativePermittivityorDielectricConstant.*

2) Effective Length or Width: An effective Length or width of the proposed antenna is given as

$$WeffforLeff = WorL - \frac{d*d}{0.95*p'} \quad (2)$$

TABLE I

DIMENSIONAL PARAMETERS FOR THE PROPOSED ANTENNA

Parameters	length(mm)
W	18.8
L	33
W(slot)	1.5
L(slot)	17.7
L4	5.8
L3	5.7
L2	10.7
L1	10.8
S2	1.35
S1	1.2
s	1.5
d	1.0
gm	1.6
lm	2.5
Wf	3.1
Er	2.2
h	1.0

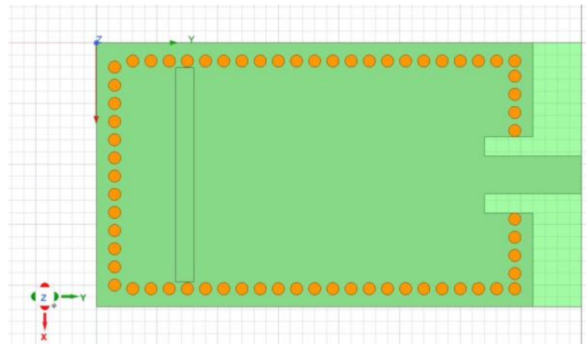


Fig. 1. SIW ANTENNA WITH SLOT

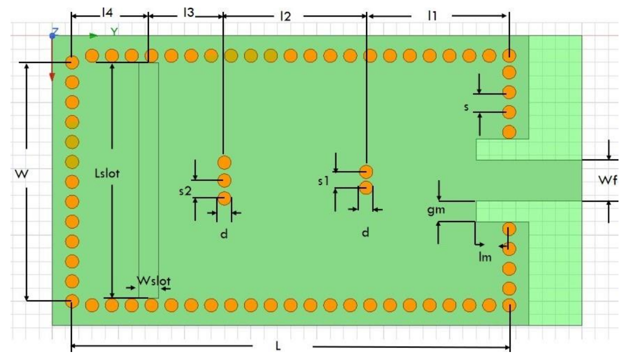


Fig. 2. SIW VIA LOADED ANTENNA

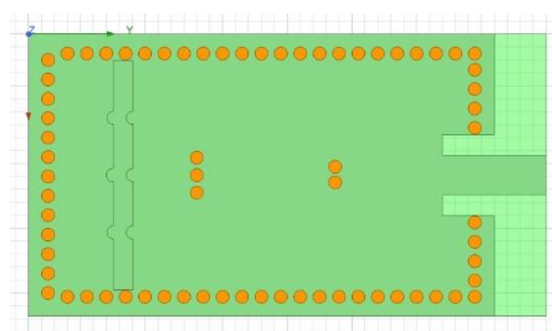


Fig. 3. MODIFIED SIW ANTENNA

Resonant frequency is the frequency at which an antenna resonates and exhibits its maximum efficiency in transmitting or receiving electromagnetic waves.It is determined by its physical dimensions and the electrical properties of the surrounding

Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

environment.Effective length is a measure of the electrical length of an antenna, which takes into account the frequency and the physical length of the antenna. From fig 1 , SIW antenna is configured with a slot of desired parameters. similarly, from fig 2 it is observed that vias are loaded in addition to the slot from the previous fig.

III. ANTENNA WITH SLOT

An SIW antenna with rectangular slot usually involves the use of a planar transmission line integrated into a dielectric substrate.This aperture allows the electromagnetic wave to radiate and the slot serves as the radiating element.The SIW antenna with loaded vias and slot combines the benefits of

A. Reflection Coefficient

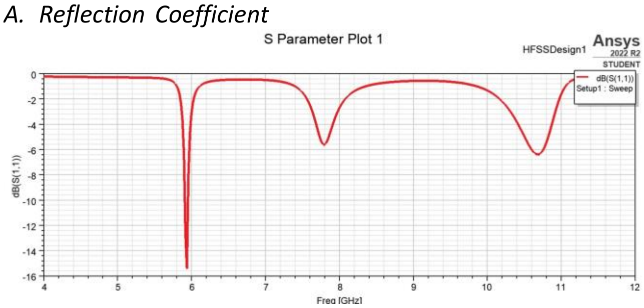


Fig. 4. Reflection coefficient(s-parameters)

6 Ghz

B. Input Resistance

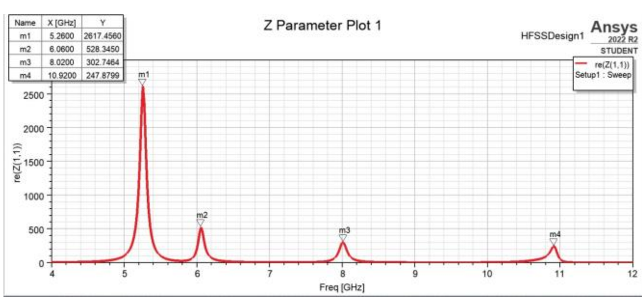
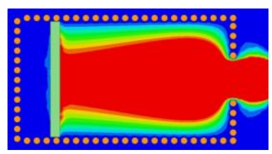


Fig. 5. Input Resistance(z-Parameters)

both integration of different layers and radiating patch(vias are small holes drilled through the substrate that connect the different layers of the SIW structure).Likewise, the modified SIW antenna also has both slot along with loaded vias.Hence, it provides miniaturization and integration of the antenna.

The reflection coefficient and the input resistance graphs are plotted as shown in the above graphs.By measuring the S11 parameter, we can determine the amount of energy reflected back towards the source.This is also known as ”return loss” or ”input reflection coefficient”.Accordingly,by the input



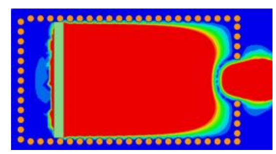


Fig. 6. at 5.3 Ghz

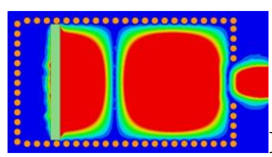
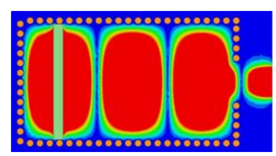


Fig. 7. at



resistance plot ,the input impedance of the device is determined. Both these parameters can be used to analyse information to optimize the impedance matching for maximum power transfer.

C. Electric field distributions

The electric field is a vector field that describes the strength and direction of the electric force experienced by a charged particle in the presence of other charged particles or currents.These field plots are simulated in HFSS i.e., by taking the input resistance plot as reference all these field distributions are taken into consideration.Initially as there are no radiating slots on the cavity it will not radiate Electromagnetic waves into free space.The transverse electric modes are observed at different frequencies at modes TE110 ,TE120 ,TE130.

From the below figures , when a radiating slot is placed the electric fields are perturbed. Fig.6 and 7 shows TE110 at 5.3 and 6 Ghz. Fig.8 shows TE120 at 8.GHz. Fig.9 shows TE130 is observed at 10.9GHz.From the results we cannot find the antenna suitable for operation as the frequencies are spread

Fig. 8. at 8 Ghz Fig. 9. at 10.9 Ghz

out and dont involve in providing any Bandwidth for efficient operation.

Consequently, from fig.2 an SIW antenna is being loaded with vias. The use of vias can also improve the radiation efficiency of the antenna by reducing the surface waves that propagate on the substrate. This is achieved by creating a conductive path between the copper-filled SIW structure and the ground plane of the substrate. This conductive path allows the antenna to radiate more efficiently, which can improve the antenna's gain and bandwidth. When an antenna with the same rectangular slot is loaded with vias,there is only a significant change in its bandwidth. With the introduction of shorting vias, We observed a fruitful operation band with a minimum return loss of -10dB in that band.. It is further widened by the modification of the rectangular slot.

IV. MODIFIED ANTENNA WITH SHORTING VIAS

A. Working Principle

When no slot is placed, there will be no radiation of electromagnetic field spaces.After a slot is placed ,the electric fields get perturbed.cavity starts radiation but with some narrow bandwidth .Hence , shorting vias are introduced at the null voltage positions. These shorting vias won't disturb the electric fields because of their position. Modes at lower frequency gets shifted to higher frequencies due to the loading effect of the shorting vias. Modified slot further helped in enhancing the bandwidth to some extent.

B. Reflection Coefficient

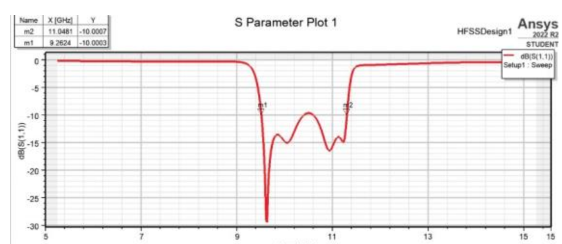


Fig. 10. Reflection coefficient(s-parameters)

From the above figure,S11 of -10dB is observed from 9.26GHz to 11.04GHz which contributed a bandwidth of 1.78Ghz . The formula for fractional bandwidth is

$$fc = \frac{fh + fl}{2} \quad (3)$$

$$B_frac = 2\frac{fh - fl}{fh + fl} \quad (4)$$

where, fc is the center frequency, Bfrac is the fractional bandwidth, fh is the highest frequency, fl is the lowest frequency. A fractional bandwidth of 17.5 percent is achieved from the above formulae.

C. Electric field distributions

In a modified SIW antenna, the electric field distribution depends on the geometry of the waveguide structure.For example, if a slot is introduced in the waveguide structure, the electric field distribution will change due to the presence of the slot. The slot can act as a radiator or a resonator, and it can also affect the impedance of the antenna.

Similarly, if the width or height of the waveguide is varied, the electric field distribution will also change. These modifications can be used to control the resonant frequency, impedance matching, and radiation pattern of the antenna.

From the fig.10 ,the reflection coefficient is observed and the peak points are marked.The electric field distributions are observed at those peak points.Normally ,when shorting Vias are placed at the null voltage positions of TE130 mode.Hence there is no effect on field distributions.

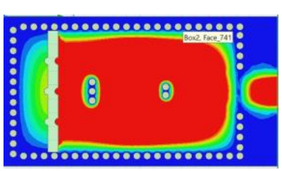


Fig. 11. at 9.3 Ghz

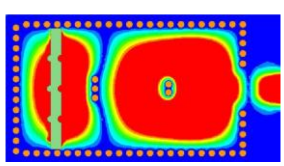


Fig. 12. at 9.7 Ghz

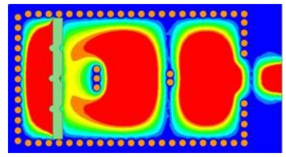


Fig. 13. at 10.6 Ghz

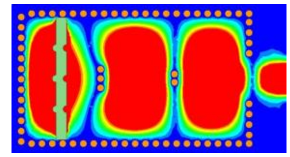


Fig. 14. at 10.9 Ghz

V. RADIATION PATTERN OF PROPOSED ANTENNA

The radiation pattern of a substrate integrated waveguide (SIW) antenna depends on its geometry, operating frequency, and other design parameters. It can be characterized by several parameters, including the directivity, gain, and polarization. By adjusting the shape and size of the waveguide structure and the location of the radiating element to achieve the desired radiation pattern. From fig.10 the radiation pattern is obtained . The start and end points are taken into consideration for observing the radiation pattern. Thus we get,the two polarizations i.e .,a) co-polarization b) cross-polarization as shown in the figures below.

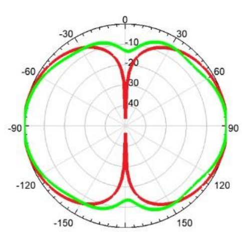


Fig. 15. co-polarization

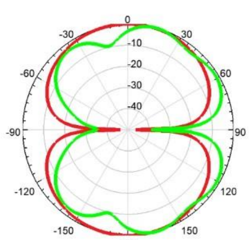


Fig. 16. cross-polarization

Co-polarization and cross-polarization refer to the relationship between the polarization of the transmitting antenna and the polarization of the received signal at the receiving antenna. Co-polarization occurs when the transmitting and receiving antennas have the same polarization. Cross-polarization occurs when the transmitting and receiving antennas have orthogonal polarization.By optimizing the polarization properties of the antennas, it is possible to maximize the co-polarization and minimize the cross-polarization, which can improve the overall performance of the system.

TABLE II COMPARISION OF OUR WORK AND OTHER REPORTED ANTENNAS

References	Year	Freq.band	FBW(percent)	Structure	h(mm)	ϵr
[9]	2008	X	1.7	Simple	0.5	2.2
[10]	2012	X	6.3	Simple	0.5	2.2
[14]	2014	X	9.4	Complex	0.787	2.2
[15]	2014	X	8	Complex	0.787	2.2
[16]	2021	X	12.1	complex	1.6	2.2
[17]	2021	X	14	complex	0.787	2.2
[19]	2014	X	11.2	complex	1.5	2.55
[21]	2013	X	10.9	complex	1.016	2.2
[22]	2022	X	14.4	Simple	1.57	2.2
This work	2023	X	17.5	Simple	1	2.2

Freq.band:Frequency band ; FBW:Fractional bandwidth

VI. CONCLUSION

In this paper, wideband SIW cavity backed Antenna using a modified rectangular slot and metallic Vias is designed for X band applications which is mainly used for radar systems ,wifi devices,sensing and aerospace applications.The advantages of these antennas are low profile and cost,compact size,high power handling capacity,easy integration and so on. A fractional bandwidth of 17.5 percent is achieved in the proposed antenna in the X band frequency. Thus,this antenna can be used as advanced version in order to reduce the complexity and increase the data tranmission rate.

REFERENCES

[1] S. Mukherjee, A. Biswas, and K. V. Srivastava, "Substrate integrated waveguide cavity-backed dumbbell-shaped slot antenna for dual frequency applications," IEEE Antennas Wireless Propag. Lett., vol. 14,pp. 1314–1317, 2015.

[2] Y. Huang, T. H. Loh, L. J. Foged, Y. Lu, S. Boyes, and H. Chattha, "Broadband antenna measurement comparisons," in Proc. 4th Eur. Conf. Antennas Propag. (EuCAP), Apr. 2010, pp. 1–5

[3] T. Zhang, W. Hong, Y. Zhang, and K. Wu, "Design and analysis of SIW cavity backed dual-band antennas with a dual-mode triangular-ring slot," IEEE Trans. Antennas Propag., vol. 62, no. 10, pp. 5007–5016, 2014.

[4] G. Q. Luo, Z. F. Hu, W. J. Li, X. H. Zhang, L. L. Sun, and J. F. Zheng,"Bandwidth-enhanced low-profile cavity-backed slot antenna by using hybrid SIW cavity modes," IEEE Trans. Antennas Propag., vol. 60,no. 4, pp. 1698–1704, Apr. 2012.

[5] Kumar, A. and S. Raghavan, "Wideband slotted substrate integrated waveguide cavity backed antenna for Ku-band application," Microwave Opt. Technol. Lett., Vol. 59, No. 7, 1613–1619, 2017.

[6] Yuzhong Shi, Juhua Liu, and Yunliang Long— Wideband Triple- and Quad-Resonance Substrate Integrated Waveguide Cavity-Backed Slot Antennas With Shorting Vias

[7] Y. Cassivi, L. Perregrini, P. Arcioni, M. Bressan, K. Wu, and G. Conciauro, "Dispersion characteristics of substrate integrated rectangular waveguide," IEEE Microw. Wireless Compon. Lett., vol. 12, no. 9, pp. 333–335, Sep. 2002.

[8] C. A. Balanis, Antenna Theory-Analysis and Design. Hoboken, NJ, USA: Wiley, 2005.

[9] Luo, G. Q., Z. F. Hu, L. X. Dong, and L. L. Sun, "Planar slot antenna backed by substrate integrated waveguide cavity," IEEE Antennas Wireless Propagat. Lett., Vol. 7, 236–239, 2008.

[10] Luo, G. Q., Z. F. Hu, W. J. Li, X. H. Zhang, L. L. Sun, and J. F. Zheng, "Bandwidth enhanced low-profile cavity-backed slot antenna by using hybrid SIW cavity modes," IEEE Trans. Antennas Propag., Vol. 60, 1698–1704, 2012.

[11] N. Marcuvitz, Waveguide Handbook. New York, NY, USA: McGraw-
Hill, 1951.

[12] J. R. James, P. S. Hall, and C. Wood, Microstrip Antenna Theory and Design. Stevenage, UK: Peregrinus, 1981.

[13] Y. Yusuf and X. Gong, "Compact low-loss integration of High-Q 3D filters with highly efficient antennas," IEEE Trans. Microw. Theory Techn., vol. 59, no. 4, pp. 857–865, Apr. 2011.

[14] Mukherjee, S., A. Biswas, and K. V. Srivastava, "Broadband substrate integrated waveguide cavitybacked bow-tie slot antenna," IEEE Antennas Wireless Propagat. Lett., Vol. 13, 1152–1155, 2014.

[15] Varnoosfadetrani, M. V., J. Lu, and B. Zhu, "Matching slot role in bandwidth enhancement of SIW cavity-backed slot antenna," AsiaPacific Conf. on Antennas and Propag., 244–247, 2014

[16] Lokeshwar, B., D. Venkatasekhar, and A. Sudhakar, "Development of a low-profile broadband cavity backed bow-tie shaped slot antenna in SIW technology," Progress In Electromagnetics Research Letters, Vol. 100, 9–17, 2021.

[17] Sarani, A. V., M. H. Neshati, and M. Fazaelifar, "Development of a wideband hexagonal SIW cavity-backed slot antenna array," AEU — Int. J. Electron. Commun., Vol. 139, 153915, 2021.

[18] X.Jiang, H. Wang, and X.Zhu, "Substrate integrated wave guide filter antenna array with 45 degrees-inclined linear polarization," in Proc.IEEE 4th Asia–Pacific Conf. Antennas Propag. (APCAP), Jun. 2015,pp. 472–473.

[19] Liu, L., H. Wang, Z. Zhang, Y. Li, and Z. Feng, "Wideband substrate integrated waveguide cavitybacked spiral shaped patch antenna," Microw. Opt. Technol. Lett., Vol. 57, No. 2, 332–337, 2015.

[20] R. Lovato and X. Gong, "A third-order High-Q SIW filter/antenna with two cavities and one integrated slot antenna," in Proc. IEEE Int. Symp. Antennas Propag. (APSURSI), Jun. 2016, pp. 1219–1220.

[21] Yang, W. and J. Zhou, "Wideband low profile substrate integrated waveguide cavity backed Eshaped patch antenna," IEEE Antennas Wireless Propagat. Lett., Vol. 12, 143–146, 2013.

[22] Anil Kumar Katta, * and Praveen Babu Choppala "Development of a Low Profile Wideband SIW Cavity-Backed I-Shaped Slot Antenna",Progress In Electromagnetics Research C, Vol. 123, 227–236, 2022.