Bandwidth improvement of a rear end slot antenna on a Substrate Integrated Waveguide cavity

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Abstract – ***A technique for enhancing the bandwidth of the planar slot antenna on the substrate integrated waveguide cavity has been discussed in this paper. Planar slot antennas are extensively used in research because of its simple profile and moderate gian. Inspite of employing a planar rectangular slot which results in a narrow bandwidth, a broadband slot can be used to improve the bandwidth. This slot antenna is been placed at the rear end of the substrate integrated waveguide and excited by 50Ω grounded coplanar waveguide to provide good isolation. The substrate integrated waveguide adopts the mm wave technology and it facilitates the feeding element and the antenna to be built on the same substrate. The return loss is obtained as -30 dB and -22 dB at 10GHz and impedance bandwidth of 1.98% and 9.9 % for the rectangular slot and the broadband slot respectively. Further the performance is analysed by varying the height of the substrate, the length and width of the slot. The benefits of the antenna include simple profile, low weight, easy fabrication and integration with planar circuits.***

Keywords — substrate integrated waveguide, slot antenna, broadband, return loss, bandwidth, simple profile and easy fabrication

1. INTRODUCTION

For many decades, slot antennas are highly famous among researchers and industrialists for its simple structure, good isolation from feed network and ease of integration with other planar circuits [1]. They are used for a frequency range of 300MHz to 25 GHz. The slot is a cut on a metal conductor having length in terms of λ. The slot antenna is a complementary of dipole antenna having similar field characteristics except the change in E and H field components. The radiation pattern of a slot is bidirectional. Since slot antenna gives out bidirectional radiation, a metallic reflector or a cavity is placed at a distance of λ/4 on the rear side of the slot to increase the performance in single direction (i.e.) unidirectional pattern. The integration of non-planar metallic cavity at the rear end of the slot makes the system heavier and bulky [2-3].

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The introduction of substrate Integrated waveguide (SIW) helps in integrating planar and non-planar structures over a single substrate with the help of metallic vias which connect the upper and lower plate that forms the side walls of the waveguide. The SIW technology is proposed by cassivi to construct a cavity in a planar substrate [4]. This structure is similar to laminated waveguide [5] or post wall waveguide [6]. Later the SIW cavity has replaced the metallic cavity which is proposed by Luo et al [7]. Researchers have concentrated on size reduction of the metallic cavity by ferrite or dielectric loading in the cavity. In paper [8], with the use of suitable metallic structure the reduction of size has nearly come to half. Further in [9], a Multilayer Printed Circuit Board (PCB) is realized to construct a simple profile cavity backed slot antenna using SIW structure having slot etched at the ground plane and feeding is done through stripline at the middle. The antenna designed on SIW is considered as open ended waveguide radiator [10] and waveguide slotted antenna [11]. Yet all these techniques resulted in a bandwidth of only 2.16% which needs to be improved for real time applications. In [12], a rectangular slot of higher length is used to increase the bandwidth which yields to 6.3%. In this paper, a broadband slot antenna has been designed on SIW to increase the bandwidth and possess moderate gain. The designed slot antenna gives good radiation behavior, simple profile, low cost with ease of fabrication combines the merit of planar slot antennas and cavity backed antennas which can be made through single layer PCB process.

2. DESIGN PROCEDURE

The geometry of rear end planar slot antenna is given in Fig 1. It is constructed with four rows of metallic vias arranged linearly. For proper radiation and low leakage, certain rules to be followed as given in eqn (1,2).

$$d/d_2 > 0.5 \quad (1)$$

$$d/\lambda < 0.1 \quad (2)$$

By choosing the conditions [5], the behavior of SIW will be equivalent to metallic cavity. The slot can be etched out at the lower plane to have better isolation from the feeding network. The feeding is given by 50Ω grounded coplanar waveguide to excite SIW. The grounded coplanar waveguide is used as feeding element over the top surface for excitation of the slot on the ground plane. The top and bottom plate is interconnected by metallic vias which forms the structure of substrate integrated waveguide.

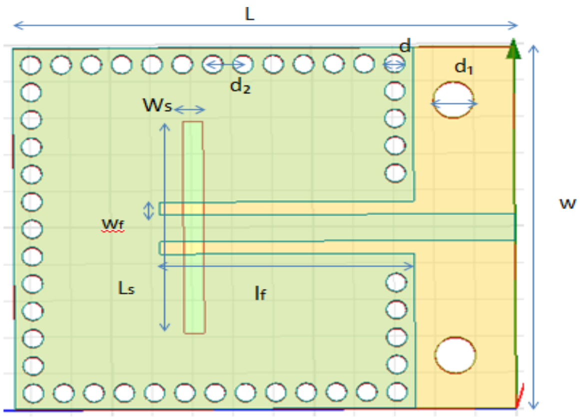

Fig. 1. Geometry of rear end rectangular planar slot antenna on SIW

The geometric parameters of the antenna are referred from the paper [7] as given in Table 1. The return loss of the antenna is given in fig 2 as -30 dB at 10 GHz and it is a narrow band antenna. This shows that the antenna can be suitable for an application where more isolation is needed for other frequencies except 10GHz.

Table 1 Geometrical parameters of the antenna in fig 1

PARAMETER	**NOTATION**	**UNIT (in mm)**
Size	l x h x w	19.8 x 23.8 x 0.5
Diameter of vias	d	1
Diameter of big vias	d_1	2
Centre to centre of vias	d_2	1.5
Width of slot	w_S	1
Length of slot	L_S	11.2
Length of feed	L_f	11.5
Width of feed	W_f	0.9

To increase the bandwidth of the slot antenna, the planar rectangular structure is replaced by a broadband slot as shown in fig 2.

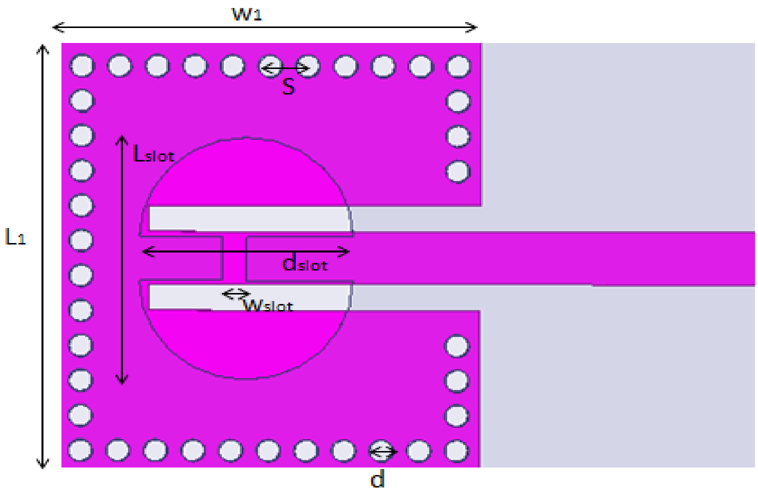

Fig. 2. Geometry of rear end broadband planar slot antenna on SIW

The broadband slot antenna is etched on the bottom layer of SIW structure and the 50 ohm grounded co-planar waveguide is etched out on the top layer. The SIW is formed by rows of metallic vias inserted into a dielectric filled rectangular waveguide. To avoid leakage losses between metallised vias eqn (1) and (2) has to be maintained. The geometry of fig 2 is given in Table 2.

Table 2 Geometrical parameters of the antenna in fig 2

PARAMETER	**NOTATION**	**UNIT (in mm)**
Size	l x h x w	19.8 x 30 x 0.8
Diameter of vias	d	1
Centre to centre of vias	S	1.6
Diameter of slot	d_{slot}	8
Width of slot	w_{Slot}	1
Length of slot	L_{Slot}	12

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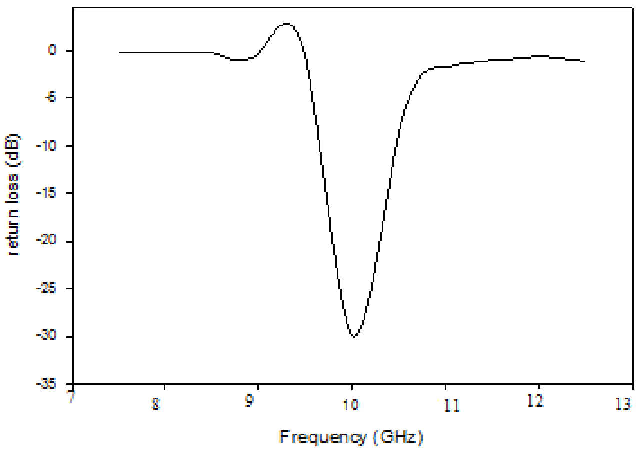
3. ANTENNA PERFORMANCE

(a) Performance of planar rectangular slot antenna:

The antennas has been simulated on Rogers/RTDuroid 5880 substrate having the permittivity of 2.2 and loss tangent 0.001 and copper is chosen as the metal on the upper and the lower plate. The substrate height is less than λ/50 which makes the size of the cavity smaller than the conventional cavity. The metallic vias is also formed by copper. It is simulated for continuous frequency of 7 to 12 GHz and return loss is been found to be -30 dB at 10GHz as given in fig 3. The antenna is simulated by varying the height of the substrate and length of the slot, the return loss characteristics is been noted which is shown in fig 4 and fig 5. It is shown that as the height of substrate increases, the bandwidth also increases slightly. It is clear that the cavity depth is directly related to impedance bandwidth from Fig 4. The bandwidth is nearly measured to be 200 MHz. The slot has higher effect on the resonant frequency. By increasing the slot length, the resonant frequency is decreased to lower region as shown in Fig 5. It is inferred from the result that resonant frequency is inversely proportional to the slot length. It is good to keep slot length as half of wavelength for better radiation efficiency. It is possible to vary width of the slot to improve impedance bandwidth. As the width of the slot increases, the bandwidth increases to a little extent and when the width is decreased the bandwidth is decreased and hence the width is directly proportional to the bandwidth as shown in fig 6.



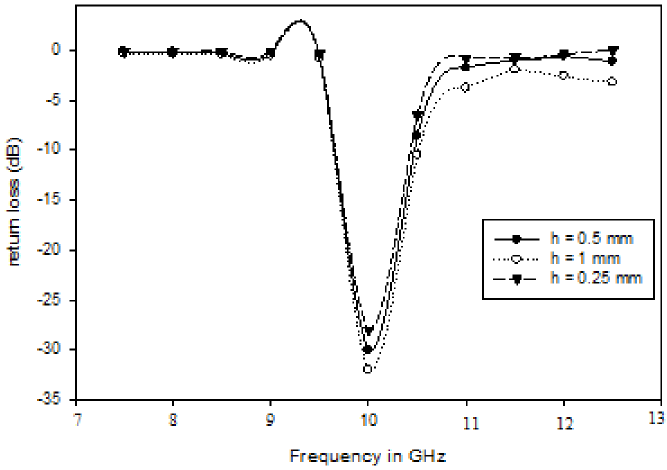


Fig. 4. Return loss of the rectangular slot antenna by varying height of the substrate

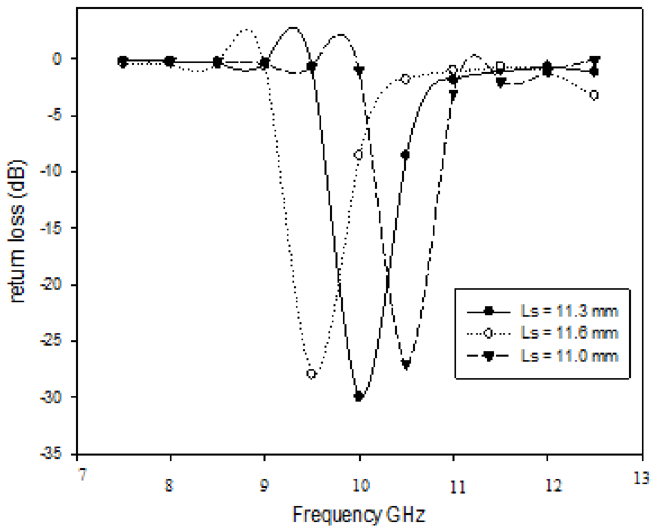


Fig. 5. Return loss of the rectangular slot antenna by varying length of the slot

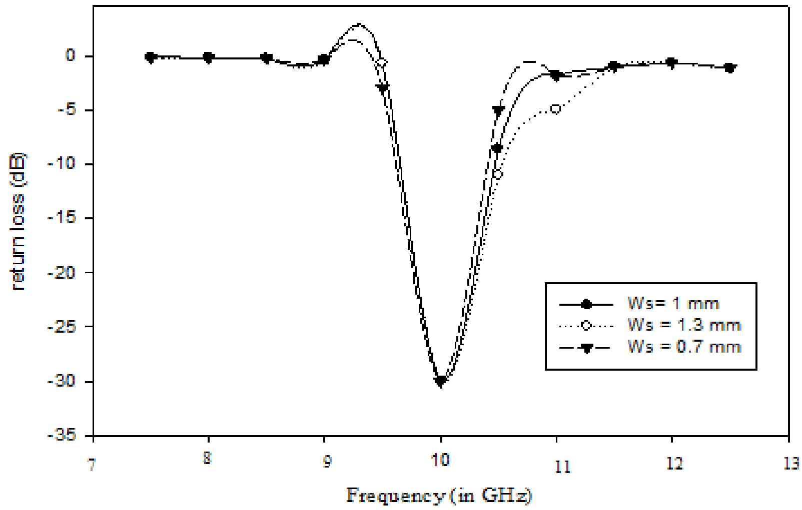


Fig. 6. Return loss of the rectangular slot antenna by varying width of the slot

(b) Performance of planar broadband slot antenna:

Rogers/RTDuroid 5880 substrate having permittivity of 2.2 and loss tangent of 0.001 is been used to simulate the broadband slot antenna. The top and bottom conductor is chosen to be copper. The height of the substrate is chosen to be 0.7mm to retain the simple profile configuration. The return loss is simulated to be -22 dB at 10 GHz and the 10 dB impedance bandwidth is found to be 1GHz (9.9%) from 10.5 to 9.5 GHz which is better than the bandwidth of rectangular slot antenna as shown in fig 7.

Fig. 7. Return loss of the broadband slot antenna

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The bandwidth and the input impedance of the broadband slot antenna firmly depend on the diameter of the slot (d_{slot}). The effect of d_{slot} on the operating bandwidth is shown in fig 8 in which the 10 dB impedance bandwidth raises with increase in d_{slot} until the impedance matching of feeding network is not disturbed. The resonant frequency is affected by the variation in the length of the slot (L_{Slot}). As the L_{Slot} increases, the resonant frequency shifts towards the lower end of the frequency as both the parameters are inversely proportional. So the resonant frequency is determined by the length of the slot as shown in fig 9.

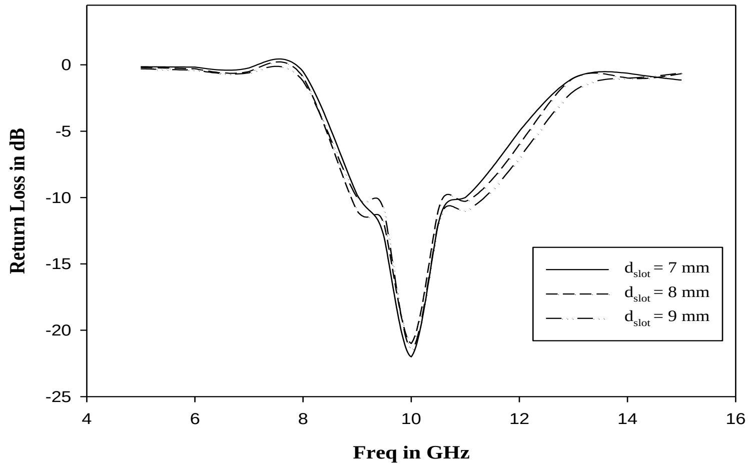

Fig . 8. Return loss of the broadband slot antenna by varying diameter of the slot

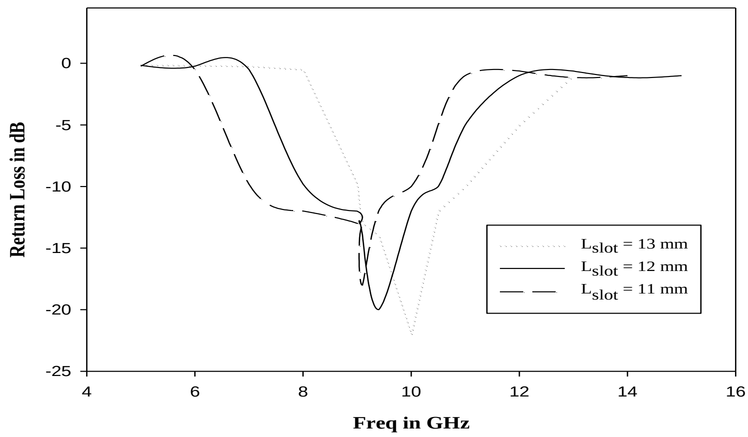

Fig . 9. Return loss of the broadband slot antenna by varying length of the slot

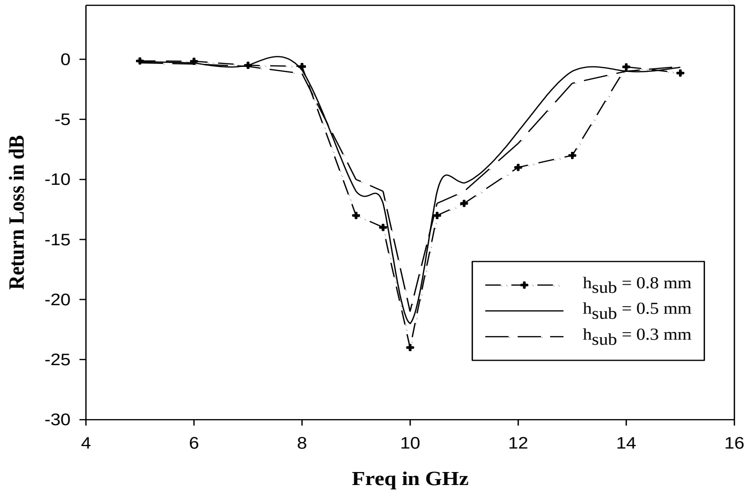

Fig . 10. Return loss of the broadband slot antenna by varying height of the substrate

It is shown in fig 10 that as the height of the substrate is reduced the bandwidth diminishes to an extent and when the height of substrate is increased the bandwidth increases unless there is no change in impedance matching. The antenna can be designed according to the specifications by altering the physical parameters.

(c) Comparison of performance:

The antenna1 and 2 are made of identical substrate, metallic plates, feeding element and other electrical characteristics. A major contrast is the shape of slot antenna as rectangular slot and broadband slot. The rectangular slot gives a bandwidth of 200 MHz whereas the broadband slot gives a enhanced bandwidth of 1GHz because of its broadband structure, The effect of variation in height of the substrate, length of the slot and diameter (width) of the slot in both the antenna is non-controversial to each other. The gain of the broadband slot antenna is found to be 3 to 3.5 dBi in the operating range whereas the gain of the rectangular slot is 4.6 to 5 dBi because of the narrow radiating property of rectangular slot. The fabrication of SIW slot antenna can be done by Printed Circuit Board (PCB) technology.

4. CONCLUSION

A rear ended planar rectangular and broadband slot antenna fed by grounded coplanar waveguide has been designed on a single substrate technology namely SIW. The designed slot is low profile, simple and effective when compared with conventional cavity back slot antenna. The return loss is -30 dB and -22 dB at 10GHz for rectangular slot and broadband slot respectively. The bandwidth in the broadband slot is found to be 1GHz (9.9%) whereas it is 200MHz (1.98%) for rectangular slot. The performance variation is analyzed in accordance with change in height of the cavity, length and width of the slot. It is studied from the results that return loss and impedance bandwidth can be improved by the variations in height of substrate than the changes in width of slot. Likewise the length of the slot has indirect proportionality with the resonant frequency of the slot antenna. The slot antenna can be varied parametrically in accordance with the specification of the design and application.

REFERENCES

[1] Yoshimura, Y.: 'A microstripline slot antenna (short papers)', *IEEE Transactions on Microw. Theory and Techniques*, 1972, *20*, (11), pp. 760-762

[2] A. Adams, "Flush mounted rectangular cavity slot antennas-Theory and design," in *IEEE Transactions on Antennas and Propagation*, 1967, 15, (3), pp. 342-351

[3] Vallecchi, A., and Gentili, G. B.: 'Microstrip-fed slot antennas backed by a very thin cavity', *Microw. Opt. Technol. Lett.*, 2007, 49, pp. 247–250

[4] Cassivi, Y., Perregrini, L., Wu, K.: 'Low-cost and high-Q millimeter-wave resonator using substrate integrated waveguide technique' Proc. European Microwave Conf., 32, 23 September 2002

[5] Uchimura, H., Takenoshita, T., Fujii, M.: 'Development of a laminated waveguide', *IEEE Trans. on Microw. Theory Techn.*, 1998, 46, (12), pp. 2438-2443

[6] Hirokawa, J., Ando, M.: 'Single-layer feed waveguide consisting of posts for plane TEM wave excitation in parallel plates', *IEEE Trans. Antennas Propag*., 1998, 46, (5), pp. 625-630

[7] Luo, G. Q., Hu, Z. F., Dong, L. X., et al.: 'Planar slot antenna backed by substrate integrated waveguide cavity', *IEEE Antennas Wirel. Propag. Lett*., 2008, 7, pp. 236-239

[8] Hong, W., Behdad, N., Sarabandi, K.: 'Size reduction of cavity-backed slot antennas', *IEEE Trans. on Antennas and propag.*, 2006, *54,* (5), pp. 1461-1466

[9] Locker, C., Vaupel, T., Eibert, T. F.: 'Radiation efficient unidirectional low-profile slot antenna elements for X-band application', *IEEE Trans. on Antennas and propag.*, 2005, *53,* (8), pp. 2765-2768

[10] Clenet, M., Litzenberger, J., Lee, D.: 'Laminated waveguide as radiating element for array applications', *IEEE Trans. on Antennas and propag.,* 2006, *54,* (5), pp. 1481-1487

[11] Yan, L., Hong, W., Hua, G.: 'Simulation and experiment on SIW slot array antennas', *IEEE Microw. Wirel. Compon. Lett.*, 2004, 14, (9), pp. 446-448.

IOP Conf. Series: Materials Science and Engineering **247** (2017) 012003 doi:10.1088/1757-899X/247/1/012003

[12] Luo, G. Q., Hu, Z. F., Li, W. J., *et al*.: 'Bandwidth-Enhanced Low-Profile Cavity-Backed Slot Antenna by Using Hybrid SIW Cavity Modes', *IEEE Trans. on Antennas and Propag.*, 2012, 60, (4), pp. 1698-1704