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Via's based parametric Analysis of SIW Antenna for Multiband Performance

Akhileswari.Sirigineedi
Department of ECE
Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology
Chennai, India
akhileswari0311@gmail.com

S. Bhoopalan
Department of E.C.E
Muthayammal Engineering College
Rasipuram, India
bhoopalanjp@gmail.com

Muddineni Raveendra
Department of Electronic Engineering
National Ilan University
Yilan City - 260, Taiwan
muddineniravi962@gmail.com

U. Saravanakumar, SMIEEE
Department of E.C.E
Muthayammal Engineering College
Rasipuram, India
saran.usk@gmail.com

T. Suresh Babu
Department of E.C.E
Muthayammal Engineering College
Rasipuram, India
tsureshbabume@gmail.com

***Abstract*—Substrate integrated waveguide antenna is proposed with considerable bandwidth and return loss, which is used for multi-band application is described in this paper. A general patch antenna is converted to a substrate integrated antenna by placing an array of cylindrical vias densely on the patch. The main objective of designing this antenna is to be analyzed the effect of vias when its dimensions are scaled at multi resonance operational performance of the antenna. A parametric analysis design has been proposed to obtain high bandwidth without losing its gain properties. And also, the effect of the transmitted power improvements technique has been discussed in this paper.**

Keywords—Substrate integrated waveguide (SIW), Multiband, via's, patch antennas,

I. INTRODUCTION

"In the early era, miniaturized antennas are playing a vital role in communication" [1,2] as they are having very low profiles such as easy fabrication [3], small size [3,4] but high performance, and better usage, miniaturized SIW (substrate Integrated Waveguide) antenna is one of them. It has a low profile but gives acceptable and better return loss gain and bandwidth [5]. An antenna with dimensions (60mm,60mm,1.6mm) substrate, (38mm,29.4mm) patch is realized here, cylindrical via with a radius of 1mm are made on the patch.

This is multiband SIW as the name says can be used in different bands and used for multi-purposes. These SIWs have the high-power transmitting capacity [6] and cheap so that it is becoming more popular. The radius of the vias is changed and checked in the analysis it is observed that by increasing the radius of the vias, the resonating frequency obtained is better so the proposed SIW antenna has the vias with a radius of 1mm. The microstrip line is used as a feeding line (which plays a major role in antennas) because it offers less return loss without a complex process in changing its dimensions and simple to fabricate. In the field of antennas, it's highly difficult to obtain better performance by changing a single parameter [7.8.9].

In this paper, the key factor of the changing multi-band performance is the radius of the vias. This single parameter can vary the number of resonating bands as well return loss performances. Slot antennas are famous for making antennas to resonate at some frequency and by optimizing some techniques to bring its resonance frequency into desired frequency such as microstrip antennas [10,11] and siw antennas and planar inverted F antennas. The Substrate material can be used to such FR4, RT duriod [12], ceramic, etc. when frequency increases the loss of the dielectric material will become more to avoid this problem Rogers RT/duroid 5880 (TM) is the best option to use whose loss tangent is 0.0009.

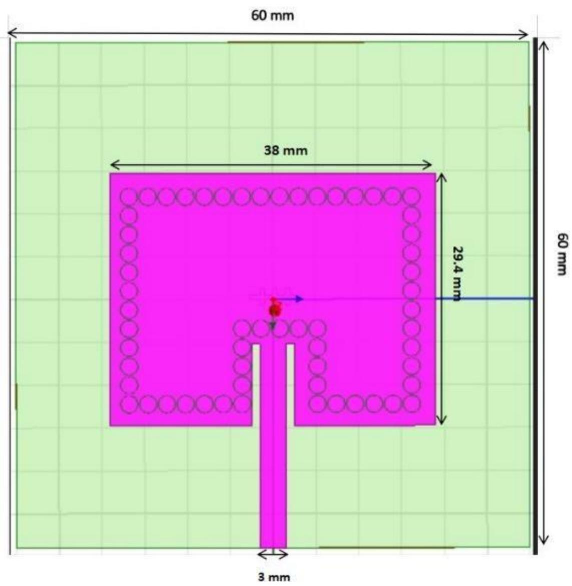


Fig .1 Proposed antenna model

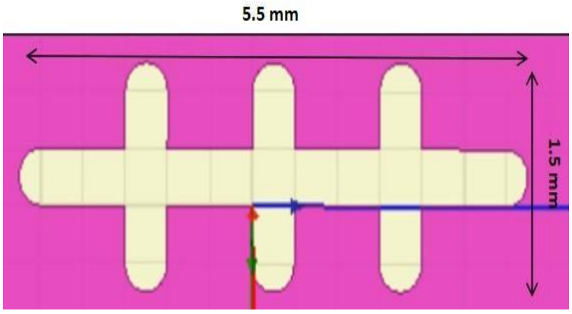


Fig-2: Dimensional view of a slot on the patch surface

II. ANTENNA DESIGN:

Width calculation:

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \text{ mm --------------------- (1)}$$

$$W = \frac{3\times10^8}{2(2.5\times10^9)\sqrt{\frac{2.2+1}{2}}} \text{ mm}$$

$$W = 0.04743 \text{ mm}$$

$$W = 47.43mm$$

Calculation of the Effective Dielectric Constant

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \text{ ------------(2)}$$

$$\varepsilon_{eff} = \left(\frac{2.2+1}{2}\right) + \left(\frac{2.2-1}{2}\right) / \sqrt{\left(1+12\,\frac{1.6}{47.43}\right)}$$

$$\varepsilon_{eff} = \left(\frac{3.2}{2}\right) + \left(\frac{1.2}{2}\right)(0.84370)$$

$$\varepsilon_{eff} = 1.6 + (0.6 \times 0.84370)$$

$$\varepsilon_{eff} = 2.10622$$

Calculation of effective length:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \; mm \text{ ----------(3)}$$

$$L_{eff} = \frac{3\times10^8}{2\times2.5\times10^9\times\sqrt{2.10622}} \text{ mm}$$

$$L_{eff} = \frac{3}{50\sqrt{2.10622}} \text{ mm}$$

$$L_{eff} = 41.342\ mm$$

Calculation of length extension:

$$\Delta L = 0.412h\,\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \text{ mm------------- (4)}$$

$$\Delta L = \frac{0.412\times1.6(2.10622+0.3)(29.90775)}{(2.10622-0.258)(30.4437)}\ mm$$

$$\Delta L = \frac{47.4390}{56.26} \text{ mm}$$

$$\Delta L = 0.8432 \text{ mm}$$

Calculation of actual length of the patch

$$L = L_{eff} - 2\Delta L \quad \text{mm--------------------------(5)}$$

$$L = 41.342 - 2(0.8432) \text{ mm}$$

$$L = 39.6556 \text{ mm}$$

Initially, the ground has been considered with dimensions (60mm x 60mm) and a substrate of Rogers RT/duroid 5880 (tm) material with dimensions (60mm x 60mm x 1.6mm) is built upon the ground, and a patch is made on the substrate of dimensions (38mm x 29.4mm) and an array of cylindrical via's of radius (0.1mm) are made on the patch and a uniform structure is shaped on the patch with dimensions (5.5mm x 1.5mm), the theoretical length is calculation is shown in equation(5). Gradually radius of the vias is increased from 0.1mm to 1mm and found the best results at 1mm.

The theoretical values of the patch dimensions such as length, effective length, and width have been derived in equations (5) and (1) respectively, and then dimensions have been reduced to a minimum to let Antenna resonate at multiple resonating bands by making slots on the patch surface. Rogers RT/duroid 5880 (TM) material is used as the dielectric substrate. Effective dielectric constant is calculated from equation (2). And the length and width of the antennas calculated from equation (1 & 5).

III RESULTS AND DISCUSSION

The introduced antenna is examined using HFSS (high-frequency structural simulations) software. "The return loss by this antenna is less than (-10dB) which is actually referred to as the good return loss" [14]. The proposed antenna is resonating at the following frequencies 2.4 GHZ, 3.8 GHz, 3.8 GHz, 4.6GHz, 5.2GHz, 5.4GHz, 7.6GHz, 8.4GHz, 8.6GHz, 9.4GHz, 9.6GHz, 9.7GHz. the bandwidth of this antenna is ranging from (200-300MHz) and above at some resonating frequencies mentioned in Table.1.

Considering VSWR, The VSWR plot is shown in Fig 4, the VSWR value is near 1.311 which is considered the best as already known (VSWR =1) is the ideal case. figure 3 is the S11 plot, the resonating frequencies and return loss are shown with a comparison with different plots of an antenna at the different radius of via's. The plotted E- plane and H-plane over 360 degrees is represented in Fig 5, Fig 6, Fig 7. E-plane and H-planes are corresponding to 0 degrees (black colour plot) and 90 degrees (red colour plot) respectively.

Calculation of Reflected power %:

$$Reflected\ power\ \% = (\frac{VSWR-1}{VSWR+1})^2 \times 100 \text{-------------(6)}$$

$$Reflected\ power\ \% = (\frac{1.378-1}{1.378+1})^2 \times 100$$

$$= (\frac{0.378}{2.378})^2 \times 100$$

$$= 0.02524 \times 100$$

$$Reflected\ power\% = 2.52$$

Calculation of Transmitted power :

$$Transmitted\ power = (1-|\Gamma|^2) \times 100 \text{ -----------(7)}$$

$$\Gamma = (\frac{VSWR-1}{VSWR+1}) \text{ ---------------------(8)}$$

$$\Gamma = (\frac{1.378-1}{1.378+1})$$

$$\Gamma = 0.1589$$

$$Transmitted\ power = (1-|0.1589|^2) \times 100$$

$$= (0.975) \times 100$$

$$Transmitted\ power = 97.5\ \%$$

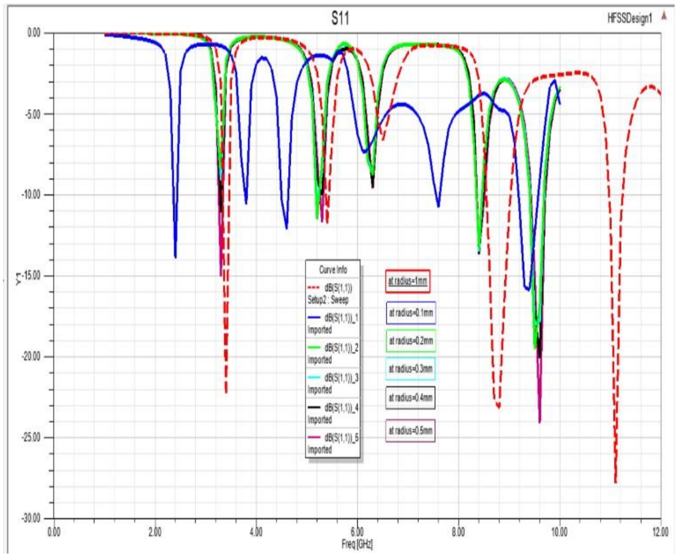


Fig.3- A plot of S11 for the proposed antenna.

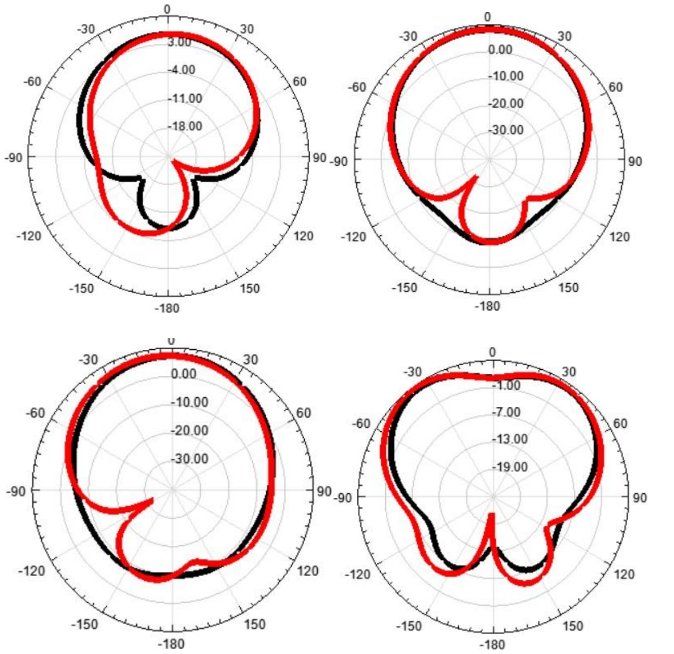


Fig.5 E-plane and H-plane at frequencies 2.4GHZ, 3.4GHz, 3.8GHz, 4.6GHz.

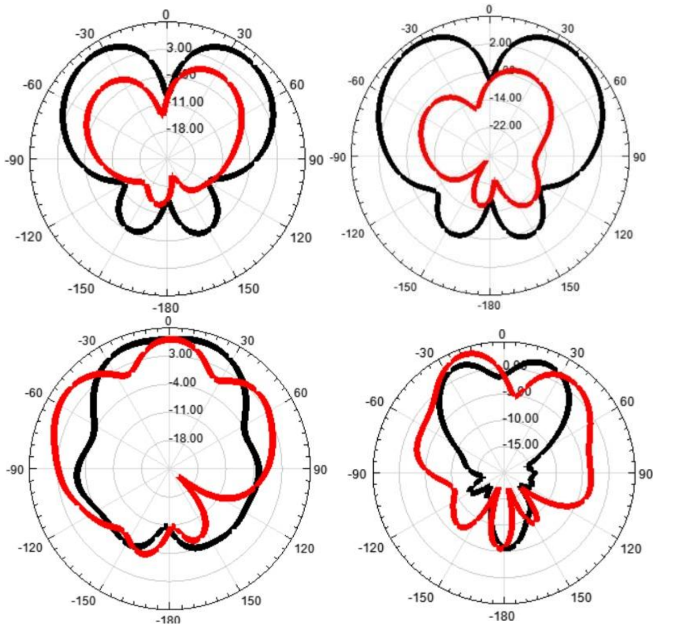
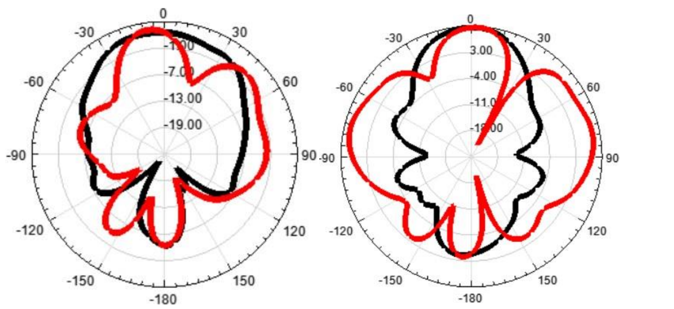


Fig .6 E-plane and H-plane at frequencies5.2GHz, 5.4GHz, 7.6GHz, 8.4GHz.



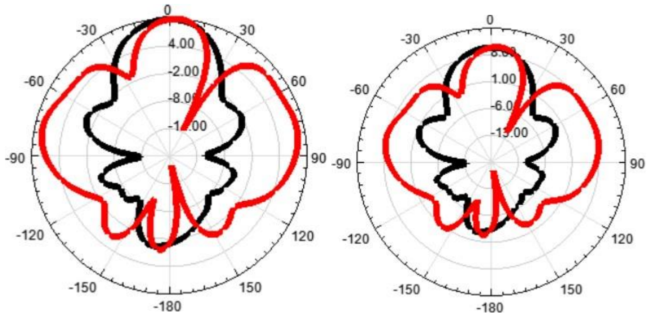


Fig. 7 E-plane and H-plane at frequencies8.6GHz, 9.4GHz, 9.6GHz, 9.7GHz.

V. CONCLUSION:

An antenna with different via radius i.e.(0.1mm, 0.2mm, 0.3mm, 0.4mm, 0.5mm, 1mm) is shown in this paper and all this research is about proposing an antenna which is used for S, C, X bands applications and all the required parameters and calculated results are investigated clearly in this paper. the number of resonance frequencies can be increased by decreasing the radius of the vias and the maximum transmitted power can be achieved by increasing the radius of the vias.

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TABLE-1, Calculated values of proposed antenna performance parameters.

S.NO	RADIUS OF THE VIA'S (mm)	RESONATING FREQUENCIES (GHz)	BANDWIDTH (MHz)	RETURN LOSS (dB)	VSWR	REFLECTED POWER (%)	TRANSMITTED POWER (%)
1	0.1mm	2.4000, 3.8000, 4.6000, 7.6000, 9.4000	77.7, 23.3, 147.7, 101.0, 380.8	-13.9348, 10.6072, -12.1258, -10.8026, -15.8461	1.577, 1.925, 1.671. 1.810, 1.385	4.97, 9.98, 6.30, 8.29, 1.29	94.99, 90.00, 93.63, 91.69, 97.39
2	0.2mm	5.2000, 8.4000, 9.5000	62.2, 108.8, 279.8,	-11.5410, -13.2979, -19.5430	1.785, 1.552, 1.236,	7.89, 4.66, 1.11	92.05, 95.32, 98.88
3	0.3mm	5.2000, 8.4000, 9.5000	36.5, 108.8, 272.0	-10.5749, -13.4741, -17.9586	1.841, 1.538, 1.290,	8.76, 4.49, 1.60	91.23, 95.51, 98.36

4	0.4mm	3.3000, 5.3000, 8.4000, 9.6000	31.1, 54.5, 139.9, 287.6	-11.0719, -10.0351, -13.6610, -20.0926	1.776, 1.920, 1.524, 1.220	7.81, 9.92, 4.30, 0.98	92.18, 90.07, 95.69, 99.01
5	0.5mm	3.3000, 5.3000, 8.4000, 9.6000	85.5, 77.7, 155.4, 287.6	-15.0180, -11.7121, -13.4152, -24.0920	1.431, 1.701, 1.543, 1.330	3.15, 6.73, 4.55, 2.00	96.85, 93.26, 95.44, 97.99
6	1mm	3.4000, 5.4000, 8.6000, 9.7000	72.5, 82.9, 196.9, 342.2	-12.4280, -12.7814, -15.9781, -25.4066	1.629, 1.596, 1.378, 1.113	5.72, 5.26, 2.52, 0.28	94.27, 94.72, 97.47, 99.71