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SIW Based Slot Antenna In X-Band Using Rogers/RT duroid 5880 As Substrate

Prakash Chaurasia

Research Scholar, Department of Electronics and Communication Engineering
National Institute of Technology Agartala
Agartala, Tripura, India

Rishi Nigam

Research Scholar, Department of Electronics and Communication Engineering
National Institute of Technology Agartala
Agartala, Tripura, India

Manik Bhowmik

Assistant Professor, Department of Electronics and Communication Engineering
National Institute of Technology Agartala
Agartala, Tripura, India

Abstract

In the past few years, there has been a growing interest in SIW-based antennas because of easy design and fabrication as it is a very favourable candidate for developing high frequency microwave and mm-wave components. Substrate Integrated Waveguide (SIW) consolidate non-planar waveguide structures in planar substrate by the use of rows of metallic visa which implement the sidewall of the waveguide based circuits in planar substrates thus having planar low profile structures like MIC structures, also having high power carrying capacity and high Q-factor similar to conventional waveguides. Slot antennas are very important for high frequency application because of their low profile and compactness. In this paper we have used Rogers/RT duroid 5880 as Substrate material with dielectric constant =2.2 which is glass microfiber reinforced PTFE composites having lowest electrical loss , low moisture absorption, isotropic, uniform electrical properties over frequency and outstanding chemical resistance , are designed for exacting stripline and microstrip circuit applications. Height of substrate is h= 0.787 mm and copper is used as metal plates of antenna. The antenna has been designed and simulated using HFSS 3D simulation software. The proposed figure of 7 slot with iris structure along with two additional Via near microstrip transition antenna resonates at 11.8GHz. Return loss (s11) at 11.8 GHz is -17.74 dB, Bandwidth 342.7 MHz which is about 2.9 % of centre frequency, voltage standing wave ratio (VSWR) 1.29 and Gain 4.29 dB. The structure has excellent radiation characteristics which make it useful for X band in RADAR application, terrestrial communication and networking, space communication.

Keywords: Substrate Integrated Waveguide (SIW), Slot Antenna, Microwave Integrated circuit (MIC) .

Introduction

The development of advanced applications for millimeter waves have attain interest for researcher in wireless systems. Recently substrate integrated waveguide (SIW) technology has emerged as an attractive alternative for microwave circuits since it incorporates non-planar waveguide circuits in planar configuration [1]. Earlier the first generation of microwave guiding structures were Conventional metallic waveguides had the advantage of having high power carrying capacity , low loss at microwave frequency and high Q-factor, but also had the disadvantages of being bulky and voluminous and non - planar in nature. The second generation of microwave guiding elements was the strip like or slot-like planar printed transmission lines used in MIC having planar low profile structures, low power carrying capacity and low Q-factor .To bridge the gap between MIC structures and conventional waveguides, SIW were developed which are planar low profile structure like MIC structures , also have high power carrying capacity and high Q-factor similar to conventional waveguides[2]. SIWs are integrated waveguide-like structures fabricated by using two rows of metallic vias embedded in a dielectric substrate that electrically connect top and bottom layer of parallel metal plates.

The proposed antenna present directional radiation characteristics with high gain while maintaining its low profile planar configuration. SIW has propagation characteristics very similar to that of conventional rectangular waveguide but only difference is that, it only supports TEn0 modes (n=1,2,3…) and the dominant mode is TE10 mode [3].The proposed antenna having microstrip transition in order to provide means to excite and measure these structures. The structure consists of a microstrip line section that connects a 50 Ω microstrip line and the integrated SIW. Lastly, a new wideband microstrip to- SIW transition is introduced in year 2014 by Zamzam Kordiboroujeni [4]. It features two additional vias, which have the same diameter as the SIW vias and are placed symmetrically at both sides of the microstrip taper.

In this paper study of figure of 7 like slot antenna is presented . The proposed antenna exhibits 342.7 MHz Bandwidth with with a moderate gain and directional radiation pattern. The placement of two additional via near transition improves Return Loss and thus shows a significant improvement over available microstrip-to-SIW transitions.

Methods

Rectangular SIW is necessary to explain design technique of SIW. Width and height are important parameters of rectangular SIW because cutoff frequency is dependent on SIW width and height . TE10 mode is dominant mode in rectangular waveguide. Below Fig. 1 shows final model of SIW Antenna with their parameters.

The dimension of SIW parameters must be chosen carefully to avoid unwanted leakage of power or radiation losses. **'S'** is the longitudinal spacing or spacing between the centers of two successive via hole . **'d'** is the diameter of via hole. **'W'** is the SIW width or transverse spacing. **'L'**is the longitudinal length of SIW structure. **'Ls'** is microstrip line length and **'Ws'** is microstrip line width. These all are the basic parameters of SIW.

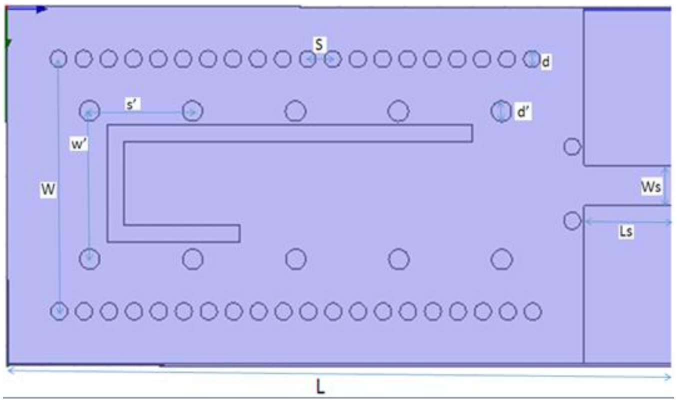

Figure 1: Parameters SIW Slot Antenna

In our proposed basic SIW structure we have merged iris like structure having two periodic rows of copper cylindrical having diameter **d'** which is greater than the diameter of via hole and also having **w'** is transverse spacing and **s'** is longitudinal spacing .Then we have added the design of figure of 7 slot like structure in between iris structure and at last we added two via near transition to improve overall result of our final SIW structure in terms of Return Loss , VSWR and Gain total.

If the diameter of via hole is **'d'** and spacing between the centers of two successive via hole is **'S'** then [5],

$$S \leq 2d$$

The cut-off frequency of any rectangular waveguide is given by [6],

$$f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

Where c is the velocity of light and „a" & „b" are broader and shorter dimensions of the waveguide respectively (m=0,1,2…& n=0,1,2,…). For any rectangular waveguide with only TEn0 modes, the cut-off frequency is given by

$$f_c = \frac{mc}{2a}$$

For dominant TE10 mode,

$$f_c = \frac{c}{2a} = \frac{1}{2a\sqrt{\mu\epsilon}} \qquad \left(\text{Since } c = \frac{1}{\sqrt{\mu\epsilon}}\right)$$

Where, 'μ' and 'ϵ' are the permeability and permittivity of the medium respectively. The relation between the width of dielectric filled and air filled waveguide can be calculated as :-

$$W_d = \frac{a}{\sqrt{\epsilon_r}}$$

Where 'a' is the width of air filled waveguide, with same cut-off frequency . Then SIW Width can be written as [7]

$$W = W_d + \left(\frac{d^2}{.95s}\right)$$

Table 1: Dimensions of the design

d	Diameter of via	1.0mm
S	longitudinal spacing	1.5mm
W	SIW width	14.99mm
L	SIW length	40.0mm
Ls	Microstrip line length	5.30mm
Ws	Microstrip line width	2.42mm
a	Width of substrate	21.2mm
d'	Diameter of larger via	1.2 mm
w'	Transverse spacing between larger via	8.8mm
s'	Longitudinal spacing between larger via	6.6mm

Results and discussion

The proposed SIW slot Antenna resonates at 11.8 GHz. Return loss (S11) at 11.8 GHz is -17.74dB. Bandwidth around 11.8 GHz is 342.7 MHz which is about 2.9 % of centre frequency.

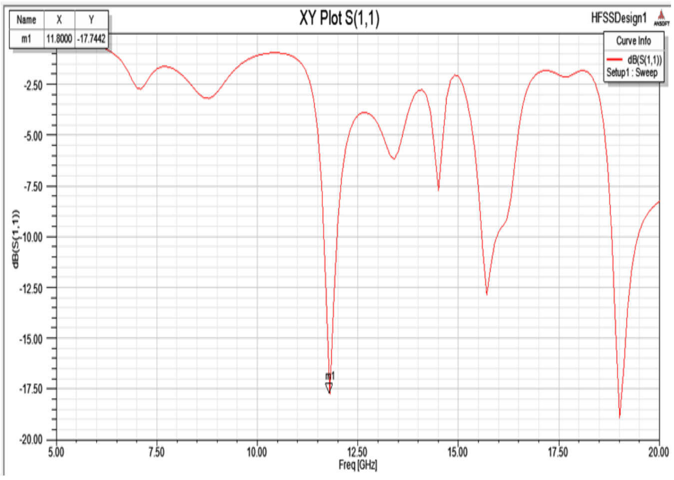

Figure 2: S Parameter of Antenna

From figure 3, it is clear that voltage standing wave ratio (VSWR) at resonant frequencies are less than 2. At 11.8 GHz , VSWR is 1.29 .

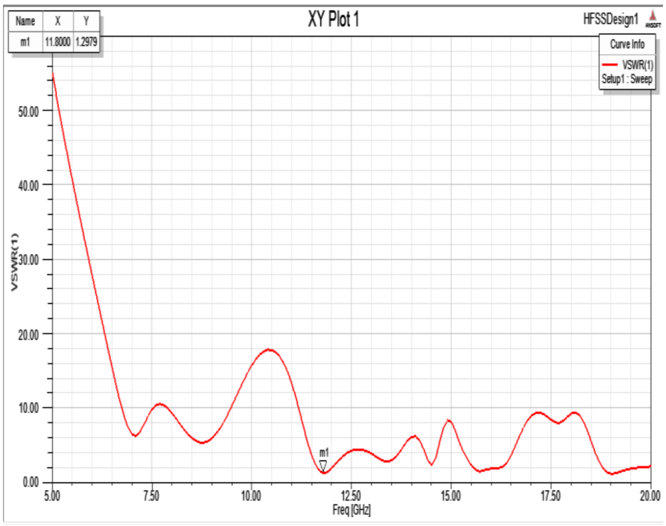

Figure 3: VSWR of Antenna

Gain and 3D radiation pattern of the antenna are shown in the figure 4.

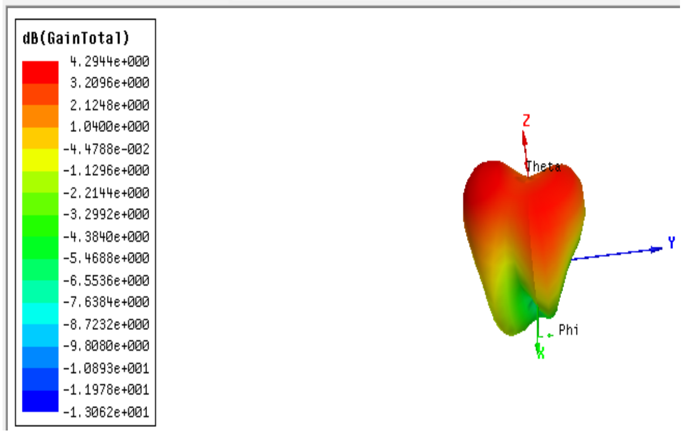

Figure 4: Gain at 11.8 GHz

From above figures it is clear that radiation pattern is highly directional and back lobe level is quite low. Gain at 11.8 GHz is 4.29 dB .

Table 2: Study of simulated results

Parameters	Simulated result
Resonance Frequency (GHz)	11.8
Bandwidth (MHz)	342.7
Gain (dB)	4.29
VSWR	1.29
Return loss (dB)	-17.74

Conclusion

In this paper work we have designed a high gain SIW slot antenna and simulations were done using HFSS software. The antenna resonates at 11.8 GHz which is under X-Band. VSWR of antenna were studied. The structure has good radiation characteristics which make it useful for X band in RADAR application, terrestrial communication and networking, space communication.

References

[1] M. Bozzi, A. Georgiadis and K. Wu. “Review of Substrate-integrated waveguide Circuits and Antennas,” IET Microw. Antennas Propag., vol. 5 iss. 8, pp. 909-920, 2011.

[2] S. Kumari, S. Srivastava. “Losses in Waveguide and Substrate Integrated Waveguide (SIW) for Ku Band : A comparison " , International Journal of Modern Engineering Research , vol. 3, Issue.1, pp, 53-57, 2013.

[3] F. Xu, K. Wu. “Guided-wave and leakage characteristics of substrate integrated waveguide”,

IEEE Transaction on Microwave Theory and Techniques, vol. 53, pp.1 , 2005.

[4] Z. Kordiboroujeni, J. Bornemann. "New wideband transition from microstrip line to substrate integrated waveguide", *IEEE transaction on Microwave Theory and Techniques*. vol. 62, pp 12, 2014.

[5] D. Deslandes. "Accurate modeling, wave mechanisms, and design considerations of a substrate integrated waveguide", *IEEE Transaction on Microwave Theory and Techniques*. , vol. 54, pp 6, 2005.

[6] S. Doucha, M. Abri. "New design of leaky wave antenna based on SIW technology for beam steering", *International journal of networks and communications*, vol. 5, pp 5, 2013.

[7] Chen X et al. "Substrate integrated waveguide (SIW) linear phase filter", *IEEE Microwave and Wireless Components Letters*, pp 5, 2005.