Design of 28/38 GHz Dual-Band SIW Slot antenna for 5G Applications

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***Abstract*—As communication technology is advanced the millimeter wave (mm-Wave) band is considered as the potential possibility for high-speed communication services in 5G networks because of its wide bandwidth. This paper shows a dual-band linearly polarized substrate integrated waveguide (SIW) antenna with two slots on the substrate for future 5G communication networks. The proposed antenna structure is resonating at 28 GHz and 38 GHz frequency bands,which are suitable for 5G mobile communications. The presented SIW antenna is designed on low loss Rogers RT/duroid 5880 substrate with dielectric constant εr of 2.2 and loss tangent tanδ of 0.003. The dimension of the proposed design is 30*7.50*0.254 mm^3. The antenna shows the bandwidth of 0.99 GHz and 0.40 GHz at 28 and 38 GHz separately. The acquired directive gain and efficiency of the proposed designfor 28 GHz is 7.2dBi and 93.28% respectively, and for 38 GHz the directive gain is 11.2dBi and efficiency is 85.68%. Computer Simulation Technology (CST) Microwave Studio 2018 is used for design and simulation of the antenna.**

***Keywords*—5G, 28GHz, 38GHz, computer simulation technology (CST), dual-band, millimeter-wave, RT/duroid 5880, slotted antenna, substrate integrated waveguide (SIW), vias.**

I. Introduction

With the advancement in technology, the increasing demand for wireless data bandwidth and mobile data experience for users keeps on expanding and develop, putting increasing demand on network use of available wireless spectrum. Moreover, the bandwidth of wireless networks becomes a very important concern for 5G telecommunication. Fifth-generation (5G) cellular systems are operating in the millimeter-wave (mm-Wave) frequency bands of 30 to 300 GHz [1]. Many researchers are indicating their interest in the available mm-Wave frequency spectrum of 28 GHz, 38 GHz, 60 GHz, and 73GHz for the usage in 5G systems. As we move towards higher frequency the atmospheric absorption and attenuation increase. At 28 and 38GHz band the loss of free space propagation, oxygen absorption, and rain attenuation is lower than the other mm-Wave bands [2], [3].

For millimeter-wave communication systems, different antenna configurations have been investigated. In the mm-wave band, high-gain antennas with higher efficiency are essential due to the huge propagation loss. To achieve high gain substrate integrated waveguide (SIW) technology has been used in the millimeter-wave antenna design because of low losses, low fabrication costs, and easy integration [4]. The most notable benefit of SIW technology is the possibility of complete integration of all the components on a similarsubstrate, including passive components, active elements, and antenna. [5], [6]. Substrate integrated waveguide (SIW)technology is a fusion of conventional waveguide and microstrip patch antenna.

SIW is a rectangular waveguide like structure which can be synthesized and fabricated by utilizing two rows of conducting cylinders or slots inserted in a dielectric substrate that electrically connects two similar metal plates [7]. As compare to microstrip antenna design SIW antenna improve gain, bandwidth, and also lower the cost of material/fabrication, package, and installations [8]. As advancement in wireless communications to keep the device size firm the interest for dual-band antenna systems is expanding. So at the mm-wave frequency, some dual-band 28 and 38GHz antennas are proposed. Table – 1 encapsulates the analysis done in the field of dual-band antenna design for various applications [9]-[17].

There are different transition methods to feed the antenna. In this paper proposed antenna is fed by microstrip to SIW transition. Paper [18] shows the transition between a rectangular waveguide and microstrip line at 28 GHz to improve return loss, bandwidth, and other parameters. So the microstrip to SIW integration is fully suited at mm-wave frequencies.A SIW antenna with one longitudinal slot is designed in [19], tapered with microstrip to SIW transition to achieve high gain. Different single-band and dual-band slotted SIW antennas are presented in [20] – [23].

The manuscript is organized as follows: In section II the design strategy of the planned single antenna element and its geometrical parameters are introduced at 28 and 38GHz. Section III talked about simulation results that incorporate gain, bandwidth, radiation pattern, return lossand efficiency of the proposed design. Section IV concluded the work.

TABLE I. Review of dual-band mm-wave antenna

Ref.	Area (mm^3)	Return loss (dB)		BW (GHz)		Gain (dBi)	
		28 GHz	***38 GHz***	***28 GHz***	***38 GHz***	***28 GHz***	***38 GHz***
[9]	6.9x7.2x0.127	-12	<-10	N/A	N/A	4.2	6.9
[10]	4.9x7.6x0.127	-35	-13	1.5	2	5.5	4.5
[11]	5.0x5.0x0.75	-26	-20	4.7	4.1	6.0	6.5
[12]	8.0x8.0x0.8	-10	-20	1.43	3.54	2.7	6.0
[13]	3x7.0x1.20	-10	-20	1.4	3.3	3.7	5.0
[14]	8.0x7.5x0.127	<-10	<-10	N/A	N/A	4.2	6.9
[15]	5x5.x0.127	<-10	<-10	N/A	N/A	5.0	5.3
[16]	5x5.0x0.127	<-10	<-10	N/A	N/A	3.7	4.7
[17]	3.8x5.5x0.127	-22	-14	0.8	0.3	5.6	6.3
This work	30x7.50x0.254	-16	-29	0.9	0.4	7.2	11.2

II. THEORYOF SIW

This section introduces the process of the designed linearly polarized dual-band slotted SIW antenna at 28 and 38 GHz. Fig. 1, and Fig. 2 depicts the top sight and bottom sight of the antenna. The proposed antenna is designed on substrate Rogers RT/duroid 5880 with a heightof 0.254mm, dielectric constant (εr) of 2.2, and loss tangent (tanδ) of 0.003. To create a SIW structure, metalized vias or holes are designed. The radius of metalized via or holeis 0.25mm. The structure involves two slots to improve the performance of the antenna that are etched in the metallic plane of the SIW cavity.The distance between the slots is 2.26mm. For slot 1 length and width is W_1 and L_1, respectively and $L_2$is length, and$W_2$is width for slot 2.

The antenna is fed with a 50-Ω proximity-feed microstrip line placed on the other side of the substrate with length L_f, and width W_f. There is a transition section between the feed line and SIW structure with dimensions W_t and L_t represent the width and length, respectively. This is called microstrip to SIW transition. Additionally, impedance matching is created close to the transition section to improve the impedance. For the proposed antenna diameter of via d is 0.5 mm and the distance between two vias D is 1.0 mm, so this design satisfying $D/d < 2.5$. The dimensions of the proposed antenna are introduced in Table – II.

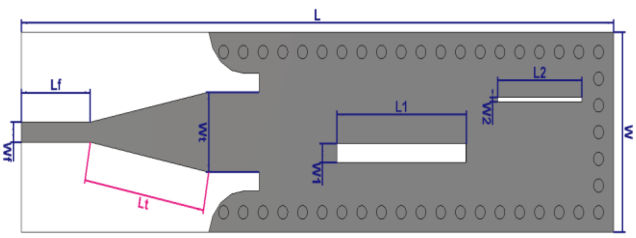


Fig. 1. Top view of proposed design.

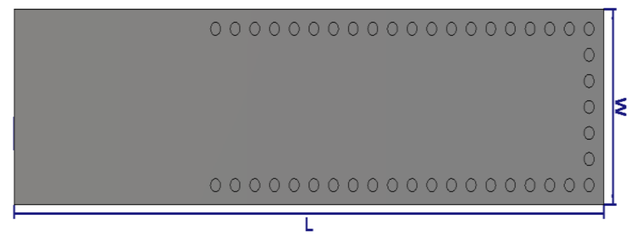


Fig. 2. Bottom view of proposed design.

TABLE II. DIMENSSIONS OF PROPOSED ANTENNA

Parameter	Description	Value (mm)
W	Substrate width	7.50
L	Substrate length	30.00
h	Substrate height	0.254
W_1	Slot1 width	0.70
L_1	Slot1 length	6.54
W_2	Slot2 width	0.17
L_2	Slot2 length	4.22
W_f	Feed line width	0.75
L_f	Feed line length	3.50
W_t	Transition section width	3.00
L_t	Transition section length	6.10

III. SIMULATION RESULTS AND DISCUSSION

The simulation and numerical evaluation of the presented antenna are done by using CST Microwave Studio software that allows each layer of the designed antenna to be assigned with equivalent physical and electrical properties. In this section, there are few parameters based on simulation results that will be discussed, which incorporate, reflection coefficient |S11|, gain, and total efficiency of the antenna at 28 and 38GHz.

A. S-parameter

S-parameter depicts the input-output interrelation between terminals and it is differing with frequency. S11 represents how much power is reflected from the antenna, it is also called return loss. For good antenna performance, it should not more than -10dB. Fig. 3 shows the S11 graph for the proposed antenna at both 28GHz and 38 GHz. The return loss is -19.118dB, -20.282, and impedance bandwidth is 0.99GHz, 0.40GHz for 28 and 38 GHz, respectively.

B. Radiation pattern and gain

The far-field radiation pattern of the proposed antenna is illustrated in Fig. 4 showing gain of the antenna. Radiation pattern plots envisage where the antenna transmits or receives power. The directive gain and efficiency at 28GHz are 7.2 dBi and 92%, and at 38GHz is 11.2 dBi and 85%. The plot for total antenna efficiency at the two frequencies 28 GHz and 38 GHz is shown in Fig. 5.

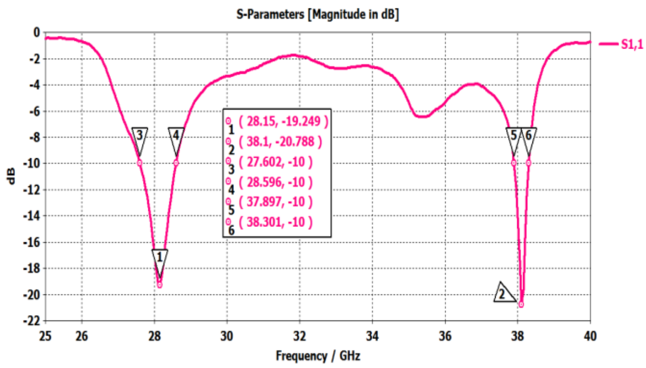
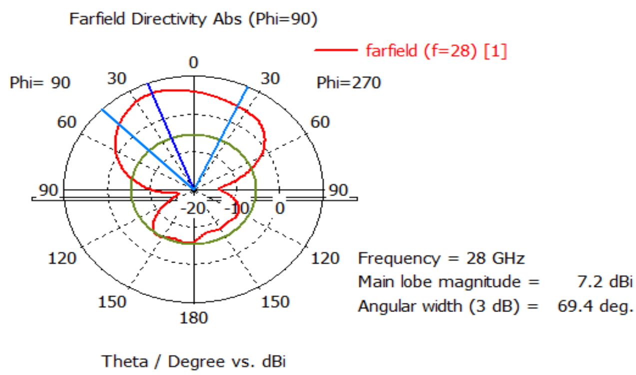
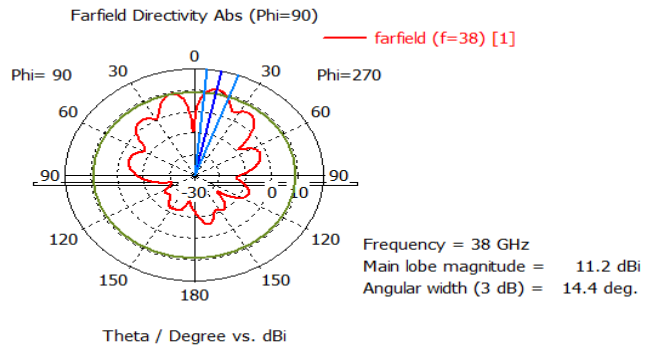


Fig. 3. Return loss (S11) for dual-band SIW antenna



(a)



(b)

Fig. 4. Radiation pattern showing antenna gain at (a) 28 and (b) 38GHz.

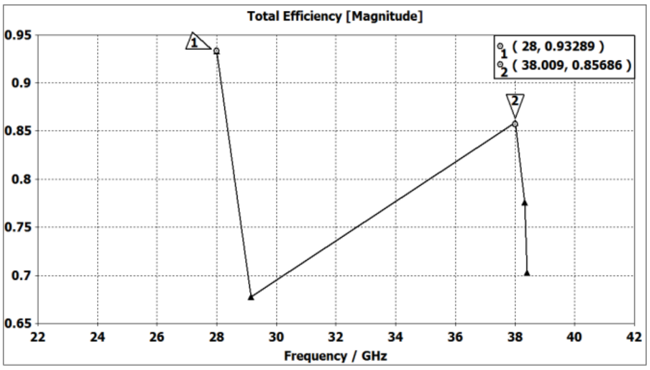


Fig. 5. Total efficiency of the antenna at 28 and 38 GHz.

The proposed design provide good side lobe levels and radiation characteristics. Fig. 6 and Fig. 7 shows the E- plane and H-plane radiation pattern at 28 and 38 GHz frequency.

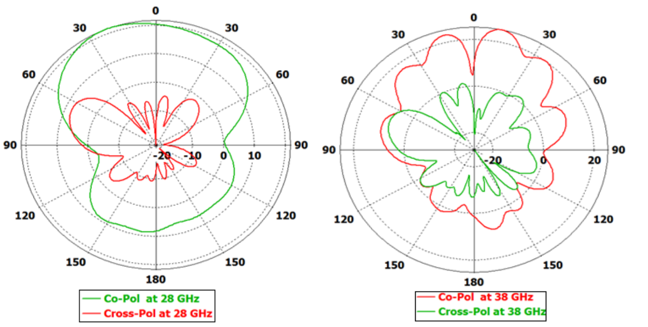
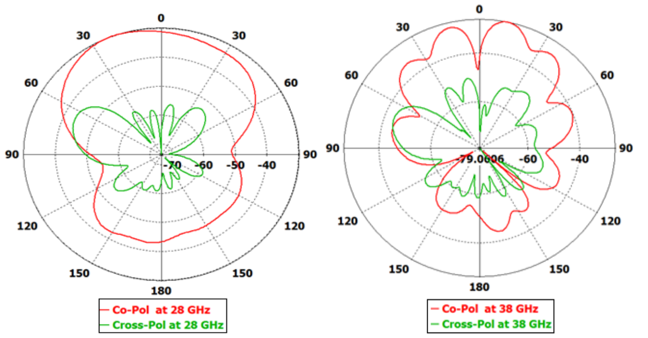


Fig. 6. E-plane radiation pattern at 28 and 38 GHz.



(b)

Fig. 7. H-plane radiation pattern at 28 and 38 GHz.

IV. CONCLUSION

In this manuscript, a dual-band single element slotted SIW antenna has been illustrated. The antenna comprises two slots and impedance matching gaps between the SIW structure and transition line to enhance the gain, bandwidth, and impedance. The proposed antenna working at28 GHz frequency band (27.448-28.475) GHz and at 38 GHz frequency band (37.88-38.32) GHz and offer adequate radiation pattern, impedance bandwidth, and gain. The single element realized 7.2 dBi and 11.2 dBi gain for the lower (28 GHz) and upper (38 GHz)band individually. The proposed SIW antenna is recommended for fifth generation applications because of its good performance.

ACKNOWLEDGMENT

I would like to thank my supervisor Professor Sunil Joshi for his expert advice and encouragement throughout this research work.

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