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Substrate integrate waveguide and microstrip antennas at 28 GHz

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ABSTRACT

In this paper, two antennas are designed using substrate integrated waveguide (SIW) and microstrip technology at 28 GHz. Parametric study for both antennas is presented to demonstrate the performance at millimeter wave frequency for wireless communication network (5G application). Roger RT5880 substrates with permittivity 2.2 and loss tangent 0.0009 are used to implement the antennas with two thicknesses of 0.508 mm and 0.127 mm respectively. Both antennas have the same size of substrate 12x12 mm with a full ground plane was used. Structures designs have been done by using computer simulation technology (CST). The simulation results showed that the antenna with SIW and roger RT 5880 substrate thickness 0.508 has better performance in term of return loss and radiation pattern than the microstrip patch antenna at 28 GHz. A return loss more than -10 dB and the gain are 6.4 dB obtained with wide bandwidth range of (27.4-28.7) GHz. This proving to increase the realized gain by implementing SIW at millimeter wave band for 5G application network.

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1. INTRODUCTION

Recently, the demands for high gain antenna with low profile for millimeter wave (mm-Wave) are needed. The target is to increase the receiver sensitivity at the user point. However, the pathloss and components loss are the major factors that should be taken in consideration in the mm-wave frequency [1]. Various techniques are based on the finite-difference time-domain technique or the finite-difference frequency domain [2], the boundary integral-resonant mode expansion (BI-RME) technique [3], the method of lines [4], and the transverse resonance method [5].

There are antenna configurations that have been done in the literature. A modified Vivaldi radiator was introduced in [6]. It consists of a dual V-type linearly tapered slot antenna, with centre frequency at 36 GHz. Also, this antenna topology suited for integration in substrate integrated waveguide (SIW) technology. Cavity-backed SIW antennas have been improved [7-9]. The single structure was offered in [7]. It contains a slotted SIW cavity supported by a coplanar waveguide, compact, single-substrate cavity-backed slot and patch oscillator antennas were offered in [10], respectively, a non-detailed schematic of the design circuit. Various techniques of active antennas, such as injection locking, cavity control, varactor tuned antenna, and oscillation feedback loop, have been presented [11].

Microstrip patch antennas (MPAs) have been used in wireless and telecommunication systems but it offers lower gain also It has lower power handling capability [12]. Recently, SIW has been used more than common waveguide and microstrip because it is bulky and expensive [13]. The parameters of the SIW cavity should be designed with care. The vias spacing (S) and diameter (D) affect considerably the return and radiation losses, whereas, the waveguide width substrate integrated waveguide (WSIW) controls the cut-off frequency and propagation constant [14]. The current flowing through the probe makes a magnetic field, which matches with the magnetic field inside the SIW structure [15]. At millimeter-wave frequencies, high gain antennas are required to overcome the signal attenuation due to oxygen molecules absorption [16]. To make the antenna radiate two-band need to request in order to use the currently available allocated 5G spectrums in a wave system [17, 18]. The antenna consists of a 1-to-8-way SIW power divider and 8 Vivaldi elements however this design wide bandwidth (38.9~45.1 GHz) with this high-frequency be a complex design [19, 20]. Multiple-input-multiple-output (MIMO) and designed with the guidance of a genetic algorithm (GA) antennas are broadly used for the improvement of antenna capacity and this technology has been done for 4G as well as 5G communications. Wireless systems have taken an increased interest, as new applying for millimeter waves (mm-waves) is being introduced and improved. In fact, a kind of application has been recently offered in the frequency range over 60-94 GHz, including wireless networks [21], automotive radars [22], imaging sensors [23], and biomedical devices [24].

This paper introduces four types of antennas. Two antennas implemented by using microstrip technology with different thickness and the other antennas implemented using SIW technology with various thicknesses. To prove the concept of SIW performance better than microstrip at mm-wave frequency in term of gain and return loss, a simulation has been done by using computer simulation technology cst software to compare the performance of the four antennas.

2. RESEARCH METHOD

The general structure of SIW is shown in Figure 1. It consists of a rectangular waveguide, two rows of periodic holes, and a substrate at the top and bottom of ground planes, structure [25, 26]. The proposed SIW antennas were designed using Rogers RT5880 substrate. The substrate has a dielectric constant of 2.2 and loss tangent of 0.0009. Two different substrate thicknesses were chosen, which are 0.508 mm and 0.127 mm.

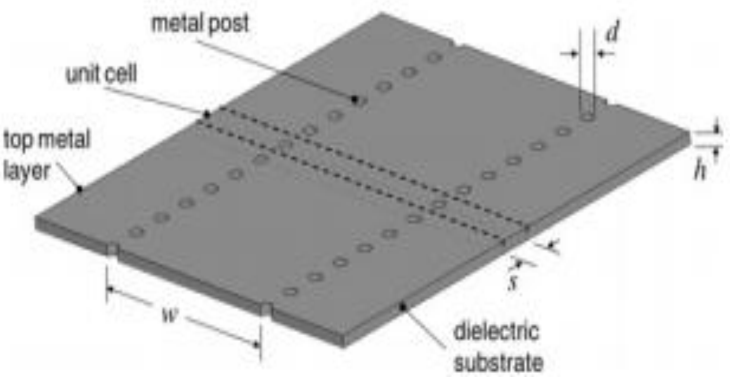


Figure 1. The prospective general structure of a substrate integrated waveguide [29]

Microstrip patch antenna is implemented using same substrate Roger RT5880 with two different thicknesses 0.508 mm and 0.127 mm. The vias diameter D and spacing S are calculated using equations in [27, 28]. Full ground plane is used for all the antennas. Figure 2 shows the dimensions of the proposed antennas at 28 GHz. As can be seen from Figure 2(a), the micro strip patch has the dimension of 4.6×8 mm with substrate thickness 0.508mm and Figure 2(b), the dimension of structure 7.24×7.8 mm with thickness 0.127mm. Figure 2(c) refers to the SIW antenna with thickness substrate 0.127 and the dimension of structure is 7.38×8.2 mm, Figure 2(d) to explain the SIW antenna with a thickness 0.508mm and the dimension of structure is 7.68×8.2 mm. On the other hand, the proposed dimensions of substrate of the SIW and microstrip antenna are 12×12 mm.

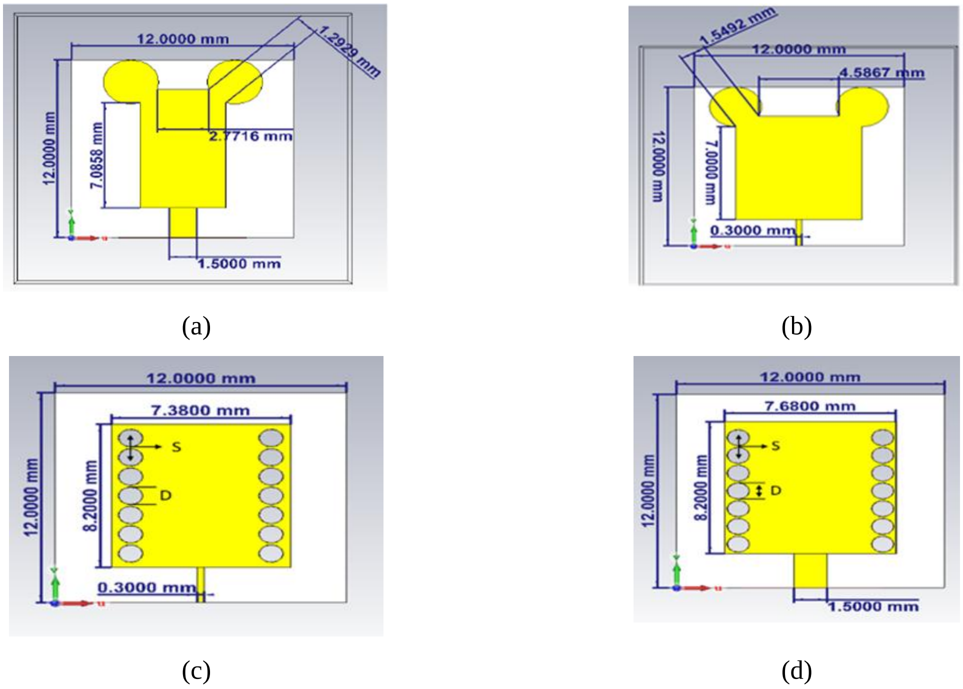


Figure 2. Proposed SIW and microstrip antennas with two different thickness of the substrate

3. RESULTS AND DISCUSSION

All the antennas were simulated by using CST program, the characteristics of computer which used to design are RAM 8GHz and processor intel CPU E3-1240 v2 @3.40 GHz (8CPU) with windows 10 operating system with this characteristic of computer the time simulation was around one hour for each design. The return loss of the proposed antennas is shown in Figure 3. It can be clearly seen that the SIW antenna with thickness of 0.508 mm has the best return loss of -34 dB at 28 GHz compared to others, the SIW antenna was able to achieve a bandwidth 1.3 GHz from (27.3- 28.7) GHz while the best results of the best patch antenna design was achieve 1.2 GHz (27.4-28.6) GHz with return loss 16 dB, On the aspect of return loss, it can be seen evidently that the SIW performed better than the patch antenna.

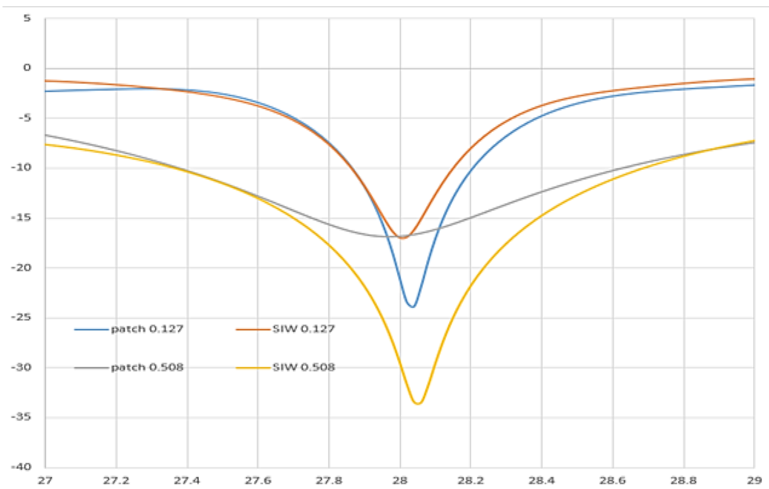
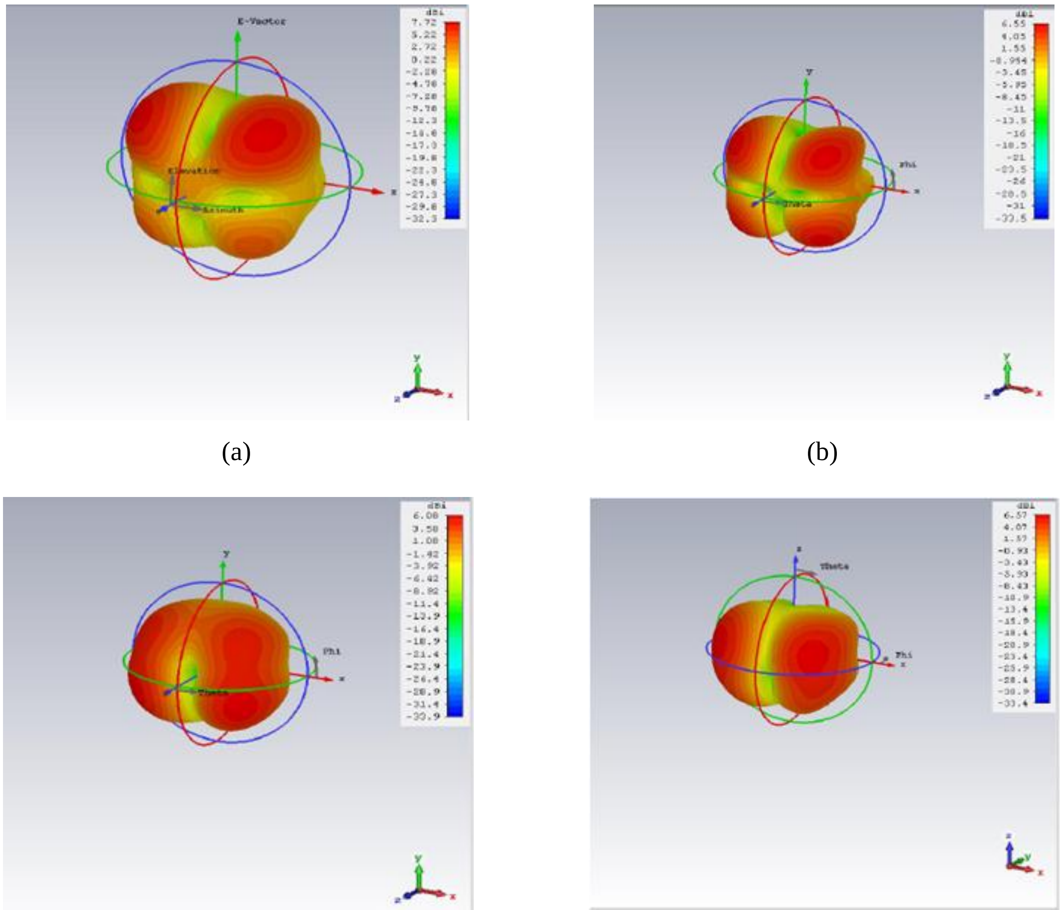


Figure 3. the return loss of the microstrip and SIW antenna with different thickness

In this paper, there is relation between the thickness of substrate and the width of feedline. Two structures have been designed with different widths of feedline. The feedline frequency and the thickness of substrate have effect on 50-ohm impedance matching. The feedline have width of 0.3 mm with substrate thickness 0.127 mm and the feedline have width 1.57 mm with substrate thickness 0.508 mm.

The 3D radiation pattern of the proposed antennas can be seen in Figure 4. SIW antennas using Rogers RT5880 substrate with thickness 0.508 mm archived better gain, directivity, and return loss as compared to the different thickness and Table 1 summaries the performance of the proposed antennas at 28 GHz. In term of gain and directivity, it can be shows by the 3D radiate onto pattern that the SIW performed better than the patch antenna.



(a) (b) (c) (d)

Figure 4. 3D radiation pattern, (a) SIW with thickness 0.508 mm, (b) SIW with thickness 0.127 mm, (c) Microstrip with thickness 0.508 mm, (d) Microstrip with thickness 0.127 mm

Table 1. Performance comparison between microstrip and SIW antenna

Type of substrate	Size of thickness	Gain dB	Directivity dBi	S11
SIW antenna,	0.508	6.4	7.67	-33.44
Rogers RT5880	0.127	5.02	6.55	-16.9
Patch antenna,	0.508	5.59	6.08	-16.7
Rogers RT5880	0.127	5.07	6.57	-23.6

As shown in Figure 5 the radiation pattern 2D of the four structure, it explain the different radiation of the structures and can see the radiation of the microstrip antenna with two the thicknesses 0.127 mm and 0.508 in one direction, however it have back loop and side loop, and the SIW s design with thickness 0.127 mm has back and side loop also it not regular radiation, the radiation of SIW design with thickness 0.508 has wide radiation and regular.

It can be noticed from the above table, that the SIW antennas have better performnce in term of gain and return loss than common patch microstrip antenna. When the thickness is decreased in SIW the gain is reduced. Therfore, SIW anenna with substrate thickness of 0.508 is sutable at 28 GHz. Table 2 shows camparation between some articals which have deign by SIW at the same frequncy with this work.

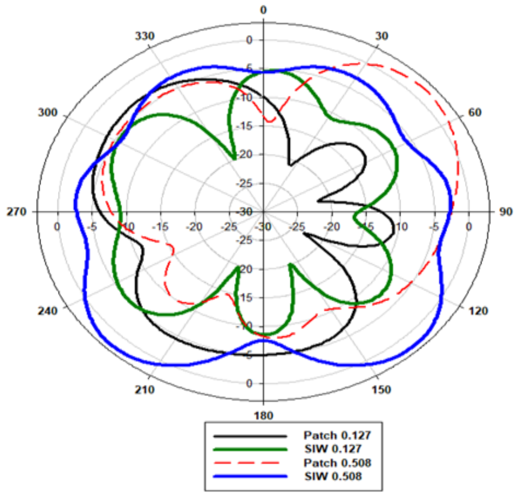


Figure 5. The radiation pattern 2D of the four structure

Table 2. camparartion between some article with SIW technology

Ref	Operating freq. (GHz)	Substrate/dielectric constant	Gain (dB)	B.W (GHz)	S-Parameter (dB)
[30]	28	Rogers 5880	7	5.7	-26
[31]	28	Rogers 4003	6.75	2	-28
[32]	28	FR4	4.7	5	-25
This work	28	Rogers 5800	6.4	1.3	-33

4. CONCLUSION

A substrate integrate waveguide and microstrip patch antenna are presented in this work by using CST, substrates Rogers RT5880 used to design SIW and patch antennas the performance and the results under this different substrate size, antenna gave different results. SIW with rogers RT5880 and thickness 0.508 gave better return loss -33.44 at 28 GHz with gain 6.4 dB and the directivity is 7.67, in addition, the side loops of the antenna reduced. Rogers 5880 RT with 0.508 thickness is suitable for the millimeter wave.

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