High gain of 28 GHz transparent antenna for 5G NR Networks

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Abstract. A new compact transparent patch antenna for 5G new radio (NR) is presented in this paper. Small rectangles are cut out from the patch to produce the desired frequency 28 GHz. The AgHT-8 material is used to from the radiator and the ground of the antenna while the glass is used as a substrate with a relative permittivity of $\varepsilon_r = 4.6$, $\tan\delta = 0.0036$ and thickness of 1.1mm. The suggested antenna occupies a small footprint of only 104,72 mm2 (11mm x 9.52 mm). The frequency bandwidth operation of the antenna is 3.624GHz (26.369 - 29.993 GHz) centered at 28GHz, the efficiency is 76% and the gain is about 5.1 dBi. The excellent performance allows the transparent antenna suitable for 5G applications.

1 Introduction

For many decades, Wireless systems were widely used to provide communication links between various points. Numerous standards were developed and installed, such as 2G, 3G, 4G, and most recently 5G.

The 5G was established in order to fulfill the user demands, the NR-5G which stands for New Radio of the fifth generation is an enhancement of the LTE (4G) standard. It allows a very high-rate data, a high low latency, and huge network capacity.

The 5G technology is emerged and used as in IoT [1], autonomous vehicle (AV) [2] and other areas. Recently, many multiple researches have been published [3] [4] that are suitable for the 5G applications. For each communication system, the antenna is the critical element. Thus, the main challenge for designer in the modeling is the obtainment of a very compact sized antenna to get the same Uplink and Downlink that should be operated at the given band.

Planar antennas have been used in various technologies such as WLAN [5], medical [6], satellite communication [7], etc. Numerous previous designs were presented [8-9-10] made with a nontransparent material. However, many applications also require a compact transparent antenna.

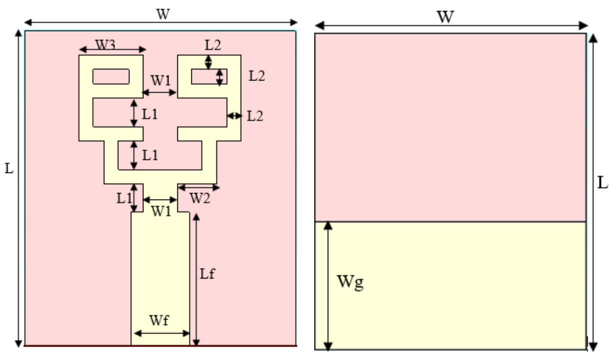
In 1997, the first transparent antenna was made with AGHT in order to demonstrate the possibility of use of a transparent antenna [11].

Recently, various thin film TCO (Transparent Conducting Oxides [12], such Like Fluorinated Tin Oxid (FTO), indium Tin Oxid (ITO), Aluminum doped Zinc Oxid (AZO) and Gallium doped Zinc Oxides (GZO), have been used in many applications such as LED, solar cells, touch screen [13], and panel technologies. In [14] an optically transparent antenna using AgHT-8 for 2.4 GHz and 5.32 GHz is proposed suitable for Local Network, a transparent antenna is presented also in [15] for the unlicensed medical (ISM) band [16] and industrial scientific.

In this work, a compact transparent-based high gain antenna operating at 28GHz is presented for 5G applications. The simulation is done by using CST software.

2 Antenna design

The geometry of the studied antenna is presented. The substrate of the considered antenna is made with transparent glass which the relative permittivity is 4.6 and a thickness of 1.1. The resonator element and the partial ground plane are made of AgHT-8 which the thickness is 0.00025mm. Fig.1 illustrates the top side and the down side of final structure studied in this paper.



(a) (b)

Fig. 1. Final Geometry of transparent antenna: (a) Front view; (b) back view

The following Table 1 gives the optimum dimensions of the antenna Arshown in the Fig.1 after a parametrical study using CST Microwave Studio. Table 2 should be used.

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Table 1. Parameters of the designed antenna.

Parameters	Value (mm)	Parameters	Value (mm)
W	9.52	T	0.00025
L	11	H	1.1
Wf	2.049	L2	0.5
W1	1.2	L1	1
W2	1.3755	Lg	4.44
W3	2.251	Lf	4.66

2.1. Design evolution

The steps to design the transparent antenna are demonstrated in Fig.2. Firstly, a conventional micro-strip patch antenna produces no resonance.

The second step T-slot was etched that resonate at 30.1 GHz, the third step two rectangles are etched in the bottom of patch and resonate at 28.8, and the last step other rectangles are etched in the shape of symmetrical "9" and resonate at 28.4 GHz. Fig. 3 appears the return loss of the evolution process of the antenna.

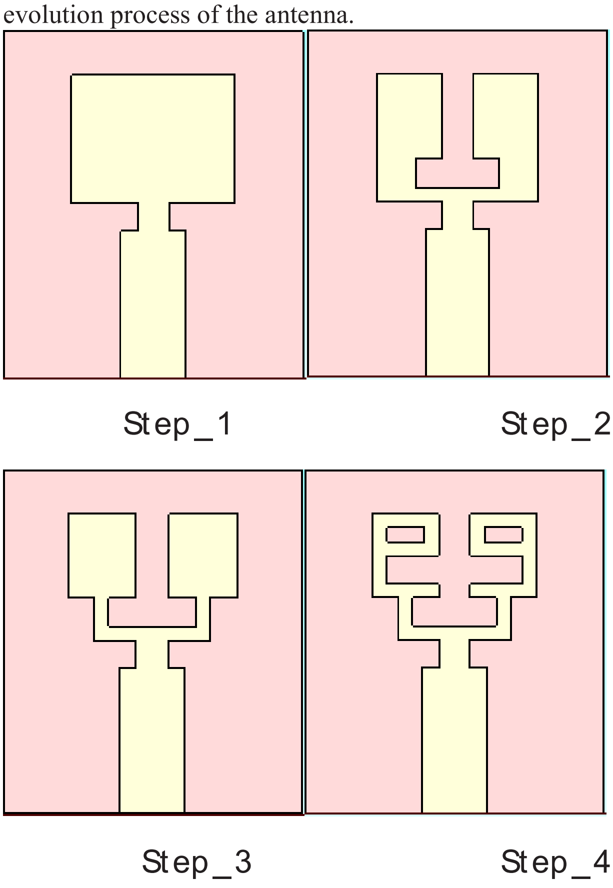

Fig. 2. Structure evolution for the 5G antenna

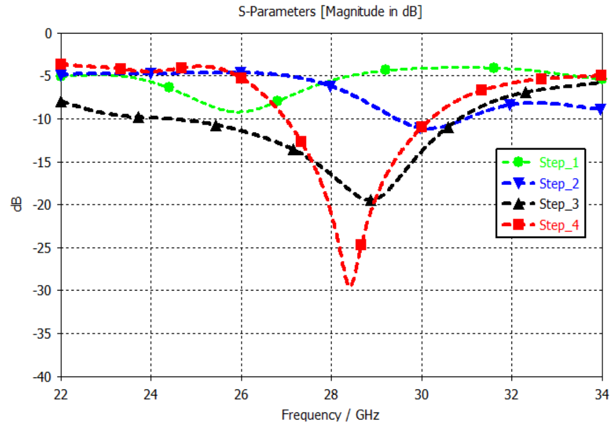

Fig. 3. Return loss S11 for all steps structures.

3 Simulation results and discussion

3.1. Effect of L1

Intending to optimize the geometry design of the antenna, a parametrical study is achieved. The simulated reflection coefficients for various as length L1 are illustrated in Fig.4. It is apparent that an increase in L1 generates a diminution in the resonance frequency. For the best adaptation, the value of 1 mm has been chosen for L1.

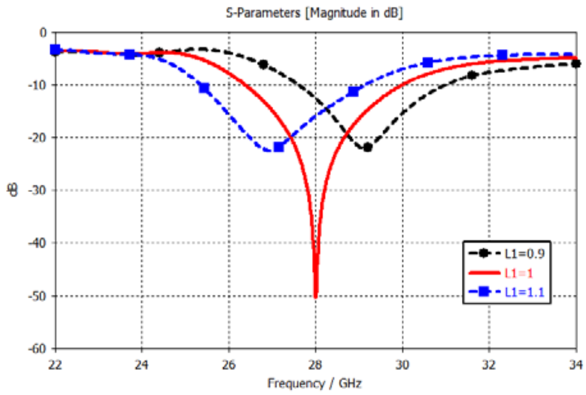

Fig. 4. Return loss S11 with variation in terms of L1.

3.2. Effect of W3 and W1

Fig.5 and Fig.6 show the simulated return loss for various lengths of W3 and W1 respectively.
From this figure, it is worth noting that the resonance frequency disincrease when the parameter W3 is changed from 2.151 mm to 2.351 mm. On the other hand, the resonance frequency increase when the parameter W1 is changed from 1.1 mm to 1.3 mm. The optimum values are W3 =2.251mm and W1 = 1.2 mm .

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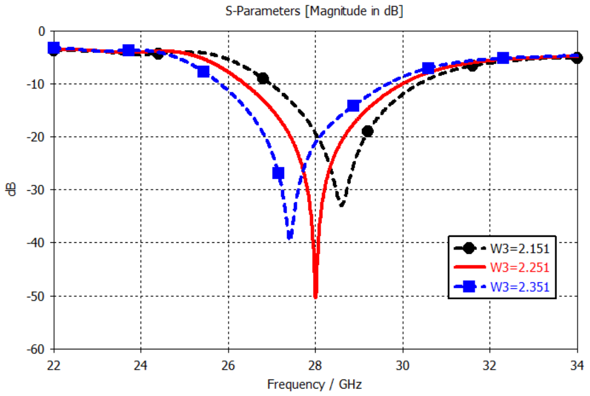


Fig. 5. Return loss S11 with variation in terms of W3.

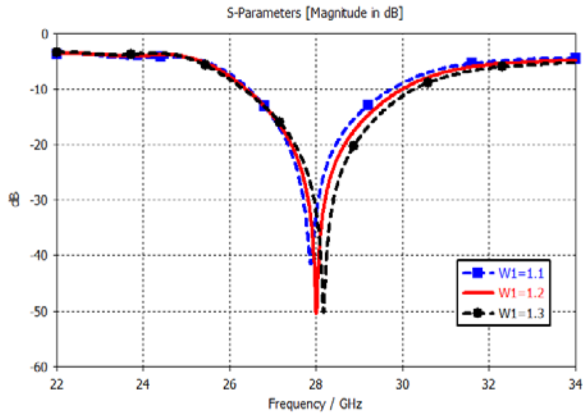


Fig. 6. Return loss S11 with variation in terms of W1.

The obtained S11 value decreases until -50.389 dB, the antenna has frequency bandwidth 3.624 GHz (from 26.369GHz to 29.993 GHz), and perfectly resonate at 28 GHz which is suitable for 5G.

3.3. Influence of materials

The comparison of simulated reflection coefficient versus frequency for different materials (optical transparent materials (AgHT-4, AgHT-8) and a nontransparent material (copper)) is shown in Fig.7. As observed, the transparent AgHT-8 gives the desired frequency 28 GHz.

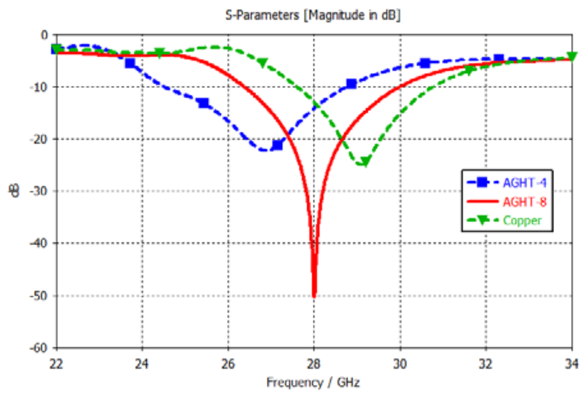


Fig. 7. Return loss S11 for different materials.

3.4. Gain, Efficiency, surface current, and radiation pattern

The variation of simulated gain and efficiency are shown in Fig.8. The proposed antenna presents a peak gain of 5.1 dBi at 28 GHz and has a radiation efficiency of 76%preparing them.

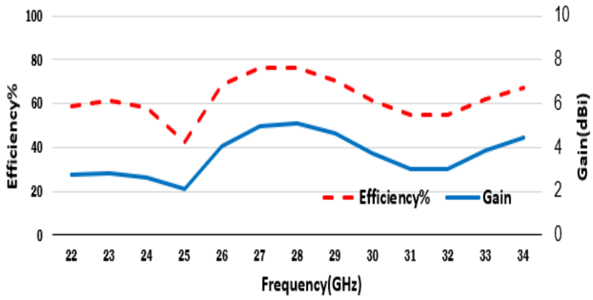
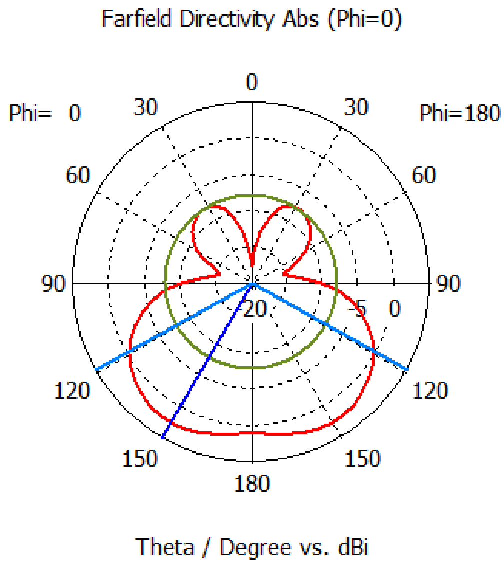
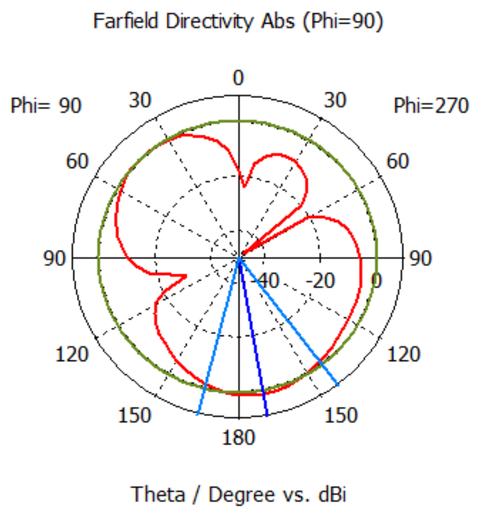


Fig. 8. Simulated Gain and Radiation Efficiency of the transparent antenna.

Fig.9 below illustrates the radiation patterns of the transparent antenna. The E-plane (phi=0°) and H-plane (phi=90°) are presented respectively at 28 GHz.



(a)



(b)

Fig. 9. 2-D radiation pattern of the transparent antenna (a) E-plane (b) H-plane.

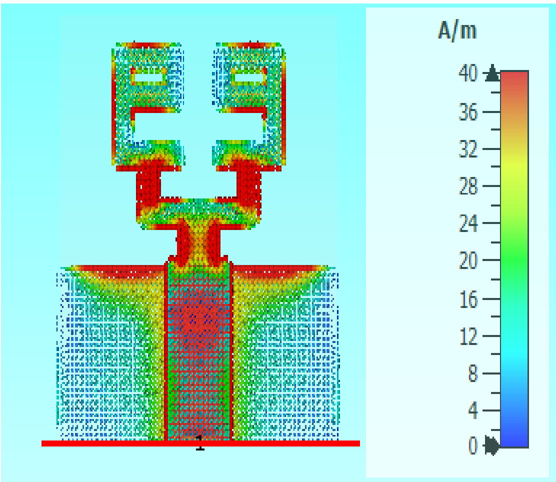


Fig. 10. Surface current density.

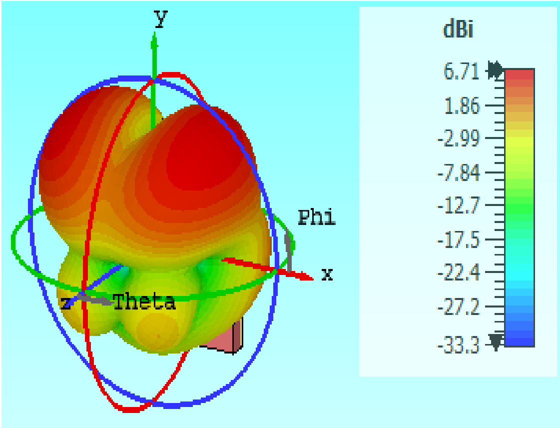


Fig. 11. 3D pattern radiation.

Fig.10 above illustrates the surface current density of the studied antenna. A symmetrical distribution appears on the radiator element, and concentrated at the edges of the structure. The Fig.11 shows the 3D radiation pattern at 28 GHz, the directivity of the simulated antenna is 6.71 dBi.

Finally, a comparison between the proposed antenna with reference antennas is achieved to valorize the performance of our new structure. The following Table2 gives a summary of this comparison for different characteristics. The proposed antenna shows good characteristics. In fact, it has a remarkable gain and a small size against both transparent [15-17-18] and non-transparent [19] antennas.

Moreover, the proposed antenna shows a high return losses value of -50 dB in comparison with all reference structures below.

Table 2. A Comparison between the designed antenna against other references.

Ref	Operating bands (GHz)	Size(mm2)	Gain (dBi)	Bandwidth (%)	S11	Transparent
[15]	25.86 - 33.444	21.3 x21.3	4.299	27.09	-31.573	Yes
[17]	23.92 - 43.8	10 x 12	2	59	- 18	Yes
[18]	26.02 - 29.46	12 x 8	4.93	12.4	-36.34	Yes
[19]	27.5-28.35	15.5x 14.5	2.33	3	-19	Non
P. A	26.369 - 29.993	11 x 9.52	5.1	12.86	-50.389	Yes

4 Conclusion

A compact size antenna with partial ground plane operates at 28 GHz is presented in this work. The volume occupied by the antenna is 11x9.52x1.1mm3 which is suitable for 5G applications. The Transparent antenna was designed and simulated using CST software. The results indicate that the required antenna operates at 28 GHz, the bandwidth is 12.86% and gain is 5.1 dBi. As well good radiation efficiency of more than 76% is obtained. This antenna shows good characteristics and it is a good candidate in comparison with many reference antennas operating at the same frequency 28 GHz for fifth generation applications.

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