DESIGN AND FABRICATION OF DOUBLE C DUAL BAND SLOTTED MICROSTRIP ANTENNA FOR 5G TECHNOLOGIES

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Abstract: The fifth generation (5G) promises more advantages and benefits to the world. It will create an essential difference over 4G. The design of 5G antenna providing broad bandwidth is very important to ensure the performance of 5G networks. In this research, design of double c dual band slotted microstrip antenna for 5G technologies is designed and simulated. The patch has a compact structure of 6mm x 8mm x 1.6mm. The proposed antenna resonates at 28.9GHz with a return loss of -21dB, Bandwidth of 900MHz, gain of 7.47dB and 38GHz with a return loss of -28dB, Bandwidth of 1.47GHz, gain of 7.89dB. An inset feed transmission line technique is used for matching the radiating patch and 50 ohm microstrip feed line. In the design, a FR4 (lossy) substrate was used. The geometry was displayed and analyzed using Computer simulation Technology (CST) Microwave studio.

Keywords: CST software; mm wave; dual band microstrip patch antenna; 5G.

1. INTRODUCTION

The technology related to antennas in the modern wireless system has been continuously improved with the corresponding increase in the number of requirements for 5G communications. This leads to new challenging network requirements as well as in the antenna design for 5G communication systems in order to meet the expected data rate and capacity.

The frequency greater than 6GHz is called as mm wave spectrum, carriers are likely to use the 28, 38GHz bands that will become available for future technologies. Based on the requirements for 5G, antennas with light weight, low profile (compact size), low cost mass production, ease of installation, conformable to planar surface and also non-planar surface, mechanically robust when mounted on rigid surface and compatible with monolithic microwave integrated circuit are quite important. We proposed a slotted microstrip patch antenna which will satisfy the above requirement.

In this design, the microstrip feed line feeding technique is used. In the proposed antenna, the Double C and H slots are loaded on the patch. The 50 ohms microstrip line feeding is used and the results are simulated in the CST software. The proposed antenna is designed to resonate at 28/38GHz.

After the simulation, the antenna is fabricated using photo-lithography technique.

2. Antenna Design

A dual band microstrip patch antenna of shape as depicted in fig.(1) is designed with the dimensions of 6mm x 8mm at 28/38 GHz for millimeter wave 5G applications. The slots are loaded on the patch with different dimensions. The patch is delivered by the 50 ohm microstrip line feed and the antenna is simulated on a FR4 lossy dielectric substrate having relative permittivity of 2.2, loss tangent of 0.0009, and height of 1.6 mm.

CST software is used for simulation purpose. The copper sheet with dimensions of 6mm x 8mm is used as the ground plane. The Double C and H slot cuts which are used to increase the impedance bandwidth, are made on the patch. The length of the patch is 3 mm and width is 3.5 mm. The length and width of the H slot is 2.5 mm and 2 mm. The C slots have an inner radius and outer radius of 0.9 mm and 0.55 mm. The microstrip feed lines have a length and width of 0.5 mm and 3.25 mm. The dual band antenna has been designed at the work 28/38 GHz millimeter wave frequency.

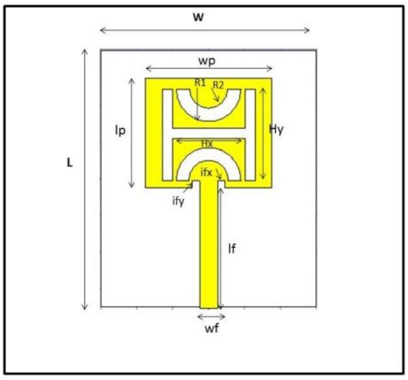


Fig. 1: Geometry of the proposed Microstrip Patch antenna

The dimensions of the microstrip patch antenna were designed using the approximation equation below.

1. The Patch width, W.

$$W=\frac{c_0}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (1)$$

Where co is velocity of electromagnetic wave in free space, fr is operating frequency, **εr** is dielectric constant of the substrate.

2. Effective Dielectric Constant, εreff.

$$\varepsilon reff=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-0.5} \qquad (2)$$

Where h is thickness of the substrate in mm, w is width of the patch in mm.

3. Effective Length, Leff

$$Leff=\frac{c_0}{2f_r\sqrt{\varepsilon_{reff}}} \qquad (3)$$

The patch of the antenna is electrically longer than the physical dimension due to fringing factor. This factor is subtracted from the effective length to give the actual length of the patch which is given by:

$$\Delta L=0.412\frac{\left(\frac{w}{h}+0.264\right)\left(\varepsilon_{reff}+0.3\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{w}{h}+0.813\right)} \qquad (4)$$

$$L=L_{eff}-2\Delta L \qquad (5)$$

Where ΔL is the length extension and L is the actual length of the antenna.

The proposed antenna was connected with 50 **Ω** inset feed transmission feed line. This technique was used because it requires no further additional matching element. The transmission feed line length and width are calculated using equation. To match the input impedance, the feed position was moved to 1.44 mm away from the edge whilst the gap between the patch and the feed line is 0.12mm.

$$Wf=\frac{7.48*h}{e^{\left(z_0\frac{\sqrt{\varepsilon_r+1.41}}{87}\right)}}-1.25*t \qquad (6)$$

Where Zo is the input impedance, t is the ground thickness in mm.

4. Ground Plane dimensions

$$Wg=6h+W \qquad (7)$$

$$Lg=6h+L \qquad (8)$$

Where Wg is the width of the ground plane in mm, Lg is the length of the ground plane in mm.

Figure 1 shows the geometry environment of the rectangular patch antenna respectively. The overall dimension of the antenna is with a ground length and width of 6mm and 8mm respectively. The dimension of the physical parameters was optimized as tabulated in table 1.

Table 1: Optimized Dimension of the proposed Antenna

Parameters	Dimensions(mm)
W	8
L	6
Wp	3.5
Lp	3
Wf	0.5
Lf	3.25
Ifx	0.2
Ify	0.2
Hy	2.5
Hx	2
R1	0.9
R2	0.55
H	0.2

3. SIMULATED RESULTS AND DISCUSSION

The design, modeling and simulation of the antenna were done in Computer Simulation Technology (CST) Microwave studio.

Return loss:

A Return loss value of -10 dB is taken as the base value which signifies that 10% of incident power is reflected i.e. 90% of the power is accepted by the antenna which is considered excellent for mobile communication. The Patch antenna have dual frequency band resonate at 28 and 38GHz with a return loss of -21.8 and -29.45dB respectively as shown in figure 2 below. The S11 parameter were obtained using waveguide port configuration. The antenna is having an impedance bandwidth of 900MHz and 1.49GHz respectively.

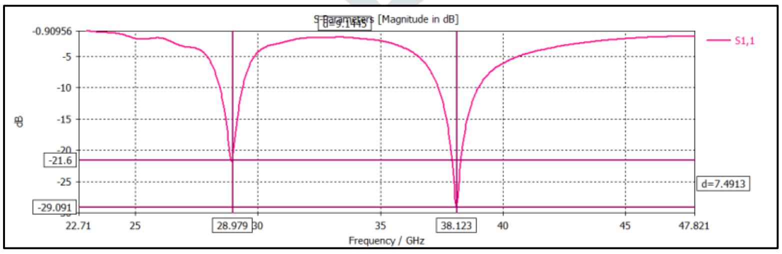


Fig. 2: Return loss vs frequency of dual band antenna

VSWR:

For a patch antenna, the VSWR should not be more than 2 and less than 1 along the bandwidth of efficiency. Ideally it should be 1. Figure 3 shows the voltage standing wave ratio against the frequency. As can be observed from figure 3, the VSWR value achieved at resonant frequency of 28 and 38GHz is 1.005 and 0.9983 respectively.

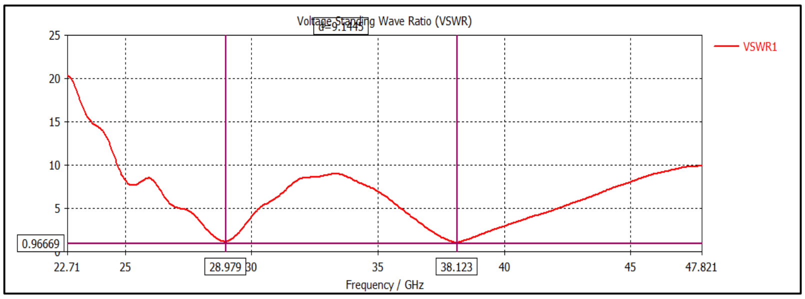
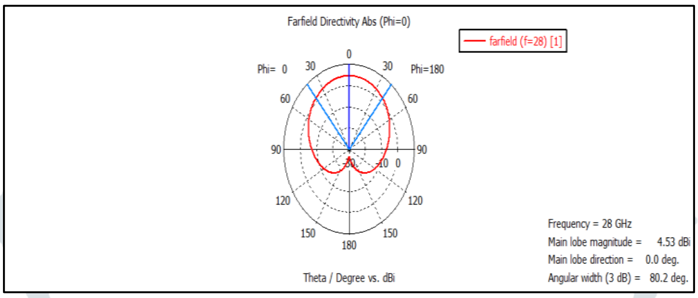


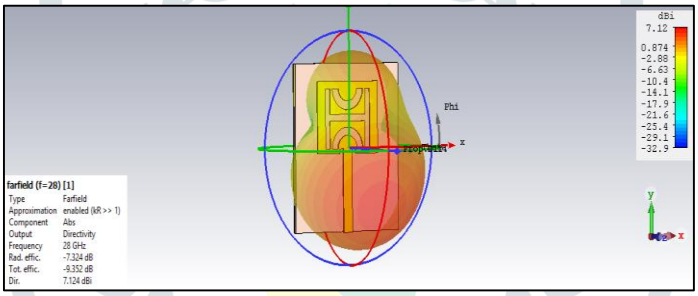
Fig. 3: VSWR of Dual band proposed antenna

Gain:

The antenna have a relative two high gains of 7.47 and 7.89dB which is considered very good for compact microstrip antenna and a half power beam width of 80.2° and 68.9° with side lobe level of -17.3dB shown in figure 4 and figure 5.

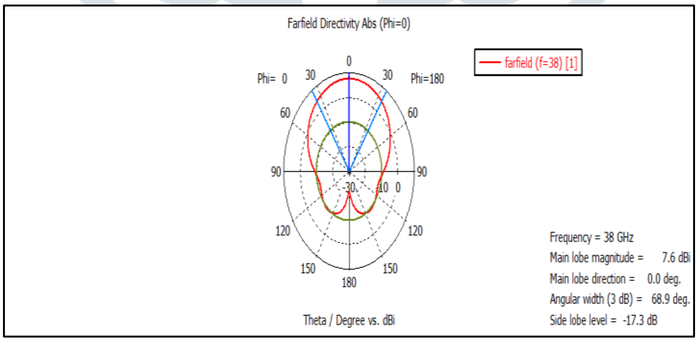


(a)

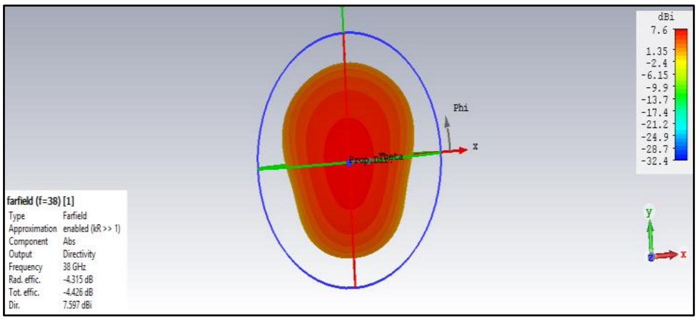


(b)

Fig. 4: (a) 2-D polar plot at 28GHz **(b)** 3-D Plot of the gain at 28GHz of proposed antenna.



(a)



(b)

Fig. 5: (a) 2-D Polar Plot at 38GHz **(b)** 3-D Plot of the gain at 38GHz of the proposed antenna.

Radiation Pattern:

Figure 4 (a),(b) and Figure 5 (a),(b) shows the 2-D and 3-D radiation pattern of the proposed antenna respectively. It shows that the antenna has a directivity of 4.53 and 7.6dBi respectively.

Surface Current:

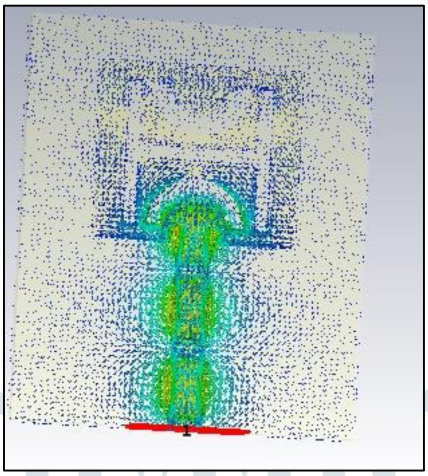


Fig. 6: Surface current distribution of the proposed antenna

Antenna parameters	Proposed antenna values	
Frequency	28GHz	38GHZ
Bandwidth	900MHZ	1.47GHz
Gain	7.47dB	7.89dB
Return loss	-21.8dB	-29.45dB
VSWR	1.005dB	0.9995dB
HPBW	80.2°	68.9°

Table 2: Summary of Simulated Results

4. FABRICATION

After the simulation is performed, photo-lithographic method is used for fabrication.

Photo-lithographic method requires ultra violet (UV) light of suitable wavelength and photo-resist sensitive to this wavelength. The photo-resist materials are of two types, positive and negative. The exposed portion of positive photo- resist dissolves in the photo-resist developer and that of negative photo-resist hardens. The step by step process for the microstrip patch antenna fabrication, used in the present work, is illustrated in the Fig. 7.

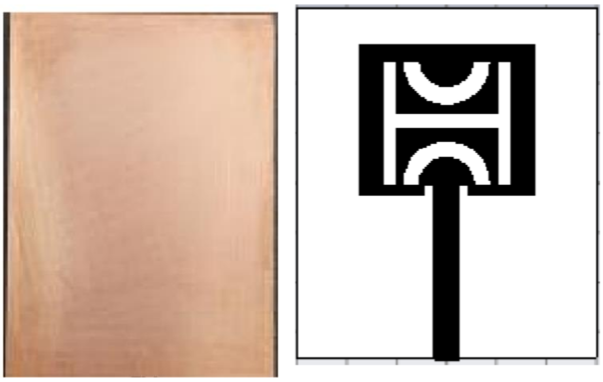


Fig. 7: Photo-lithographic Fabrication Initial Steps

The first step is computer aided design of the antenna geometry. A negative of this geometry printed on transparent sheet serves as the mask. A double side copper clad substrate RO3003T is thoroughly cleaned using acetone.

In the second step, a negative photo-resist film is laminated to the cleaned and dried copper clad substrate. The negative mask prepared in the first step is firmly placed on the photo-resist laminated copper clad substrate. The masked and photo-resist laminated copper clad substrate is exposed to ultra violet (UV) light.

The third step is to develop the UV exposed photo-resist laminated copper clad substrate. The photo-resist exposed to UV light becomes hard and dark blue in color while unexposed photo-resist remains light blue and dissolves in the developer solution. Sodium Carbonate is used as the developer. Finally, the developed copper clad substrate is chemically etched by Ferric Chloride $FeCl_3$ solution. The copper parts except underneath the hardened photo resist dissolve in $FeCl_3$. The etched substrate is rinsed in running water to remove any etchant and then dried. The hardened photo-resist is removed using Sodium Hydroxide. Now, the SMA connector is soldered in feed line. The photo-lithographically fabricated dual band microstrip patch antenna is shown in the Fig. 8.

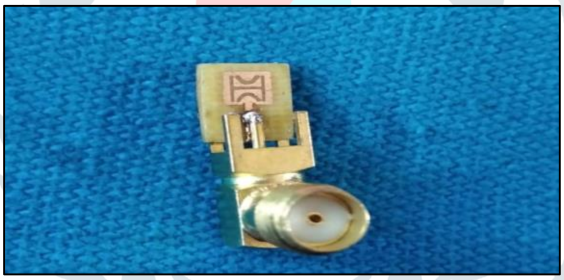


Fig. 8: Dual band microstrip patch antenna with SMA connector

5. CONCLUSION

Due to the increase in demand of mobile data and portable devices, a double C and H dual band microstrip patch antenna has been proposed for 5G application. The antenna resonates at 28 and 38GHz with a return loss of -21.8 and -29.45dB. The proposed antenna shows a gain of 7.47 and 7.89 dB. The result also shows that a bandwidth of 900 and 1.47 MHz respectively can be achieved as compared to previous work: 847 MHz. The antenna is fabricated using photo-lithography technique.

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