Dual Band Circularly Polarized Antenna for Ka Band Applications

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Abstract- In **present scenario dual band high gain microstrip patch antennas are very much desirable in view of 5G mobile communication implementation in near future, So, this paper presents a new dual band Circularly Polarized (CP) patch antenna operating in 5G band. A rectangular slot at angle 45^0 is used for the design of this compact dual band CP patch antenna. The proposed antenna can operate at 28 GHz and 38 GHz having bandwidth 900 MHz and 1.3 GHz, respectively, which are useful in mobile 5G communication and multimedia wireless systems. Axial Ratio Band Width (ARBW) is 210 MHz at 28 GHz and 300 MHz at 38 GHz. The gain of the proposed antenna is 7.5 dBi and 7.7 dBi at 28 GHz and 38 GHz, respectively. The proposed dual band microstrip patch antenna has been simulated, optimized and miniaturized by using EM simulator software HFSS.**

Index Terms— **Dual band antenna, Circular Polarization, Ka band, 5G.**

I. INTRODUCTION

IN present time wireless technologies are growing very speedily and technology is moving upward in frequency spectrum. Ka band and millimeter wave band are under research for wireless access technologies and multimedia wireless systems. Patch antenna at Ka band and millimeter wave band are in great demand due to their low profile, conformability, robustness and compact design. In past researchers designed majority of the dual band antennas suitable for lower frequencies but antenna for Ka band is relatively new topic of research. In [2-8], authors have design different dual band antenna operating in the 28/38 GHz bands using different techniques. For Ka band high gain is very essential requirement because of various link losses. As in comparison to linearly polarized antennas, circularly polarized antennas are preferred due to their advantages over linearly polarized as they can effectively lessen delay spread and have shorter read range.

In this paper, single element microstrip patch antenna element with desirable axial ratio (AR) with only microstrip line feed, over two center frequencies in Ka band is proposed. The proposed antenna consists of an angular slot etched in the ground plane. A slotted section on the patch is imbibed for circular polarization. The proposed patch antenna can be designed by using RT/Duroid substrate with dielectric constant 2.2, height 10 mils and loss tangent 0.0009. The proposed antenna is designed and simulated in HFSS simulator software. Dimensions of square patch is calculated using analytical design equations given in [1].

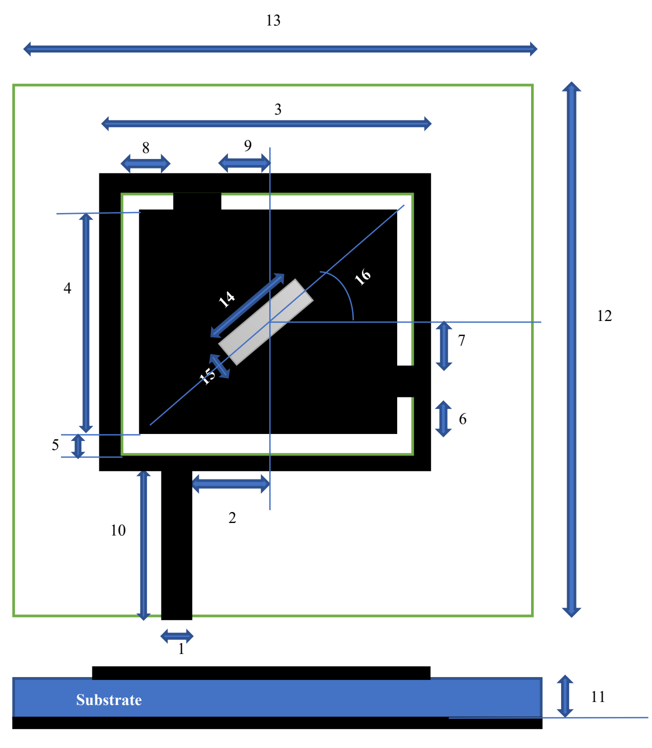

Figure 1. Design layout of proposed antenna

Next, a rectangular slot is etched in the ground plane to achieve dual band circular polarization in the antenna. In HFSS a parameter-based optimization has been done to achieve better impedance matching and desirable AR. The final design has been tuned by changing slot dimensions accordingly at the two 5G frequencies viz 28 GHz and 38 GHz. Tuning can also be done using slot sections between two nested patches. On comparing from some recent designs to proposed design, it is found that proposed design has very good gain along with impedance matching, circular polarization and axial ratio bandwidth.

II. ANTENNA DESIGN

Design layout of single patch antenna element for dual band is shown in Fig.1. Geometry of patch antenna is simple monolayer structure with a slot in ground plane at the center of patch. For dual band operation two patches are made which are separated by slot sections. These slots pass current to inner nested patch from outer patch. These slots change capacitive and inductive properties of nested patches which results in dual band resonance.

The size of square patch for both the frequency of operation is calculated by general design equations for $\frac{W}{h} > 1$

$$\epsilon_{r\,eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (1)$$

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \quad (2)$$

given in [1]. By equation (2) size of square patch at 28 GHz is calculated as 3.5 mm but due to slots in patch size of patch is reduces to approximately 3 mm. Size of second internal patch is 2.5 mm approximately as calculated by equation at frequency 38 GHz. There are multiple design parameters such as L1, t2, t3, t4, t5, ground slot length, ground slot angle, ground slot width. After rigorous study of parameters, it was concluded that ground slot length parameter is good regulator for selecting desired frequency for both the 5G mobile communication bands. Optimized design variables are shown in Table-1

Table-1 Design parameters

S.No	Parameters	Unit -mm	S.No	Parameters	Unit -mm
1	Wf	0.2	9	t5	0.4
2	Df	0.9	10	Lf	1.5
3	L1	3	11	h	0.254
4	L2	2.5	12	ws	6
5	t1	0.1	13	Ls	6
6	t2	0.5	14	ss	0.6
7	t3	0.5	15	sst	0.2
8	t4	0.7	16	angss	-45

III. RESULTS AND DISCUSSION

To study antenna results, simulated responses of antenna have been plotted. Fig. 2 shows the S_{11} parameter graph of antenna which confirms that our proposed design exhibit dual-band operation. At 28GHz impedance bandwidth is 900 MHz (3.2%) and at 38GHz it is 1300 MHz (3.4%) for general limits of (S11≤-10dB). Fig. 3 and Fig. 4 shows the AR versus frequency graph for 28 GHz and 38 GHz which shows acceptable AR for better CP operation. Axial ratio at 28.1GHz is 1.8 dB and at 38 GHz it is 0.33 dB which is acceptable value. Axial ratio bandwidth is 210 MHz at 28 GHz and 300 MHz at 38GHz. Fig. 5 shows gain variation of proposed antenna at 28 GHz and 38 GHz. Gain in broadside direction at 28 GHz is found to be 7.5 dBi and at 38 GHz is found to be 7.7dBi. It was observed that we can increase polarization bandwidth at 38 GHz at the cost of polarization bandwidth at 28 GHz by increasing slot section sizes. Surface current distribution at both the frequencies are shown in Fig. 6 and Fig. 7.

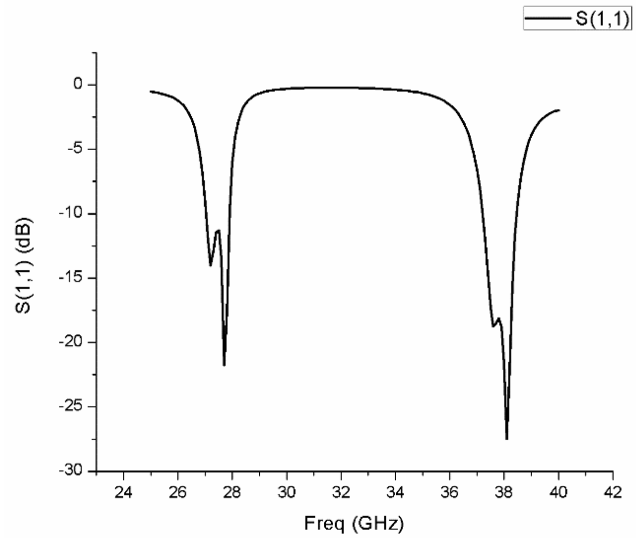

Figure 2. S-parameter graph of proposed antenna

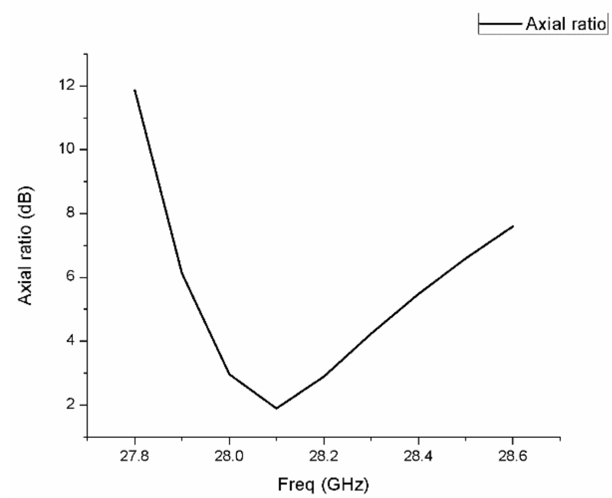

Figure 3. Axial ratio graph for lower band (28 GHz)

For better comparison with some of the recent designs on 5G dual band antenna at same frequencies, these designs have been compared with our proposed design. In Table-2 a comparison is shown between recent designs and proposed design . It can be seen that H. Aliakbari et al [2] has made a very good design but its gain on same substrate is less and impedance bandwidth at 38 GHz is 750MHz which is also very less in comparison to proposed design's impedance bandwidth on same frequency i.e. 1.3 GHz bandwidth. Ashraf et al [3] made a good design for dual band 5G antenna but it was not circularly polarized. Gain in [3] is also less in comparison to proposed design. Zhou et al [5] has made a very good circularly polarized 5G antenna but only at one frequency i.e. 28 GHz. In comparison to all recent 5G dual band antenna design, proposed antenna is better in all aspects of design and performance.

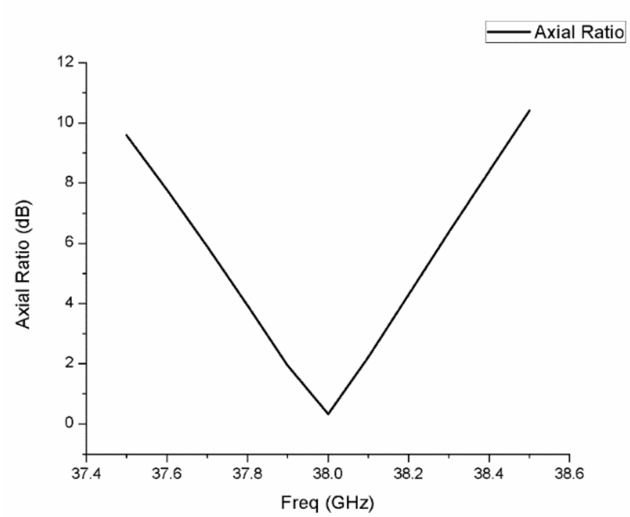

Figure 4. Axial ratio graph for upper band (38 GHz)

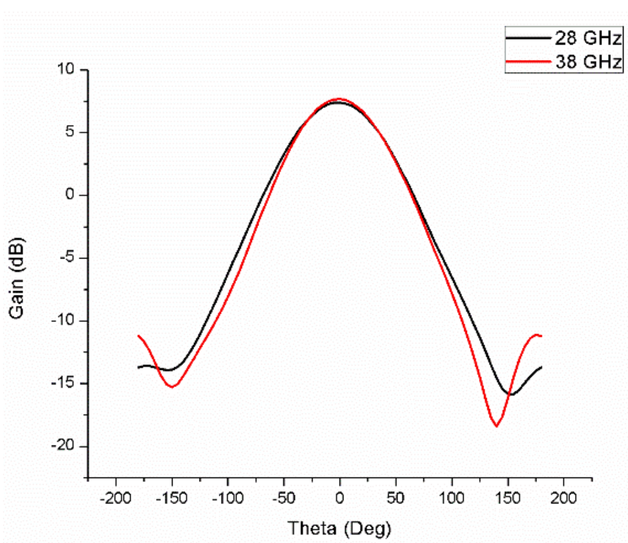

Figure 5. Gain of proposed antenna for 28GHz and 38GHz

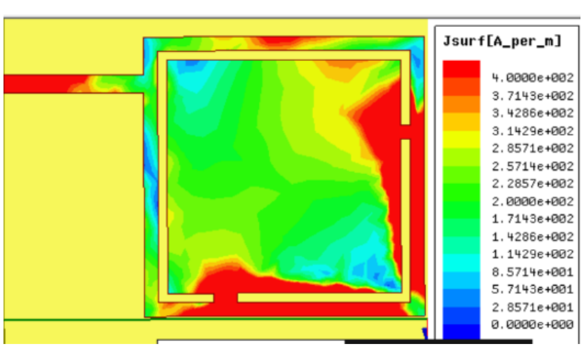

Figure 6. Surface current magnitude of the proposed antenna at 28 GHz

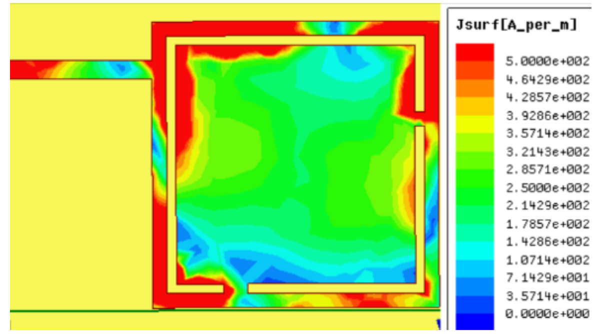

Figure 7. Surface current magnitude of the proposed antenna at 38 GHz

Table-2 Comparison with some recent designs in Ka Band

Reference	Gain at 28 GHz	Gain at 38GHz	10dB BW at 28GHz	10dB BW at 38 GHz	Axial ratio BW at 28 GHz	Axial ratio BW at 38 GHz
[2]	4dBi	4.5dBi	850MHz	750MHz	200MHz	400MHz
[3]	5.2dBi	5.9dBi	450MHz	2.2GHz	-	-
[5]	Not given	-	1.3GHz at 27.8GHz	-	370MHz at 27.8 GHz	-
Proposed	7.5dBi	7.7dBi	900 MHz at 28 GHz	1.3 GHz	210 MHz	300 MHz

IV. Conclusion

For 5G communication a dual band antenna for 28/38 GHz (frequency ratio ~1.35) with high gain and circularly polarization is needed and proposed design is a simple single feed design with defected ground structure working in these dual frequencies with good axial ratio bandwidth and gain. Hence it is concluded that in comparison to some recent work this design is very competitive and can be used for commercial purpose for 28/38 GHz 5G applications.

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