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High Gain Co-Planar Parasitic Patch Antenna Design for 5G sub-6GHz Applications

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Abstract: A simple coaxial probe fed patch antenna with two co-planar parasitic stepped patches is proposed for the enhancement of gain. The bandwidth is also enhanced by merging the additional resonance due to two symmetrical parasitic patches along with the main radiating patch. The parasitic patch elements affect the field distribution based on the variation in its dimensions, and consequently increasing the gain. The three circular defects on each of the parasitic patches further increase the gain to 10.36dBi at the designed center frequency of 3.5GHz. The 10dB impedance bandwidth obtained is from 3.37GHz to 3.57GHz which falls under the n78 (3.2GHz to 3.67GHz) band used at sub-6GHz range for 5G applications.

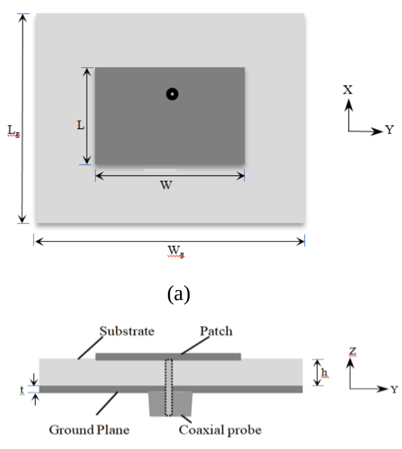
Keywords— circular defects; microstrip patch antenna; parasitic patch antenna; 5G; sub-6GHz

1. Introduction

The evolution of wireless technologies in a faster way has major challenges in the design of antenna to satisfy the ever growing needs of customer requirements [1]. Microstrip patch antennas are the promising candidates for the 5G deployment of base stations as it can be easily mass produced using microwave integrated circuit (MIC) technology. There is a great deal in designing a simple antenna with low cost and profile to be compatible with 5G requirements [2], [3]. The parasitic patch technique is one of the most common and successful way to enhance the gain and bandwidth of the conventional microstrip patch antenna which basically suffers from narrow bandwidth, low gain and high cross polarization. The wideband antenna in [4] has four rectangular parasitic patches across each side of the main patch for achieving broadband of 17%. The double layer antenna uses short circuited stepped impedance structure with shorting metal via to reduce mutual coupling in extended array configuration. The gain obtained using single antenna is just 5.7dBi and the size is large due to the use of four parasitic elements and the dual layer increases the overall height of the antenna. The MIMO antenna in [5] uses square parasitic patches along E and H planes to improve the bandwidth to 14% with a low gain of 5.2 to 6.8dBi and good isolation. This structure is simple but uses more space due to multiple parasitic elements. The resonant cavity antenna in [6] is a high gain antenna with superstrate layer consisting of middle square patch surrounding the ring parasitic elements. The multiple via used in the main patch enhances the gain to 15dBi and the hybrid parasitic patches increases the bandwidth to 10.7%. The parasitic patch antenna with semicircular ground plane in [7] uses co-planar waveguide to achieve wide band of 74%. The multiple bands are obtained which covers the WLAN, Wi-max, RFID and 5G sub-6GHz bands but gives very low gain of 3.87dBi. The triangular patch antenna with parasitic patches of different shapes in [8] provides wide bandwidth. The insertion of shorting vias to the main patch further improves the bandwidth to 17.8%. On extensive literature review, it is found that the coplanar parasitic patch antennas achieves wide bandwidth with moderate gain but the size and complexity of the antenna is more due to additional circuitry. In this paper, a coplanar parasitic patch antenna with edge truncated and circular cuts on the patch is presented. The two symmetrical parasitic patches placed along the width of the radiating patch gives additional resonance such that the bandwidth is improved. The stepped variation or edge truncated two parasitic patches on either side of the main radiating patch enhances the gain.

2. Materials and Methods

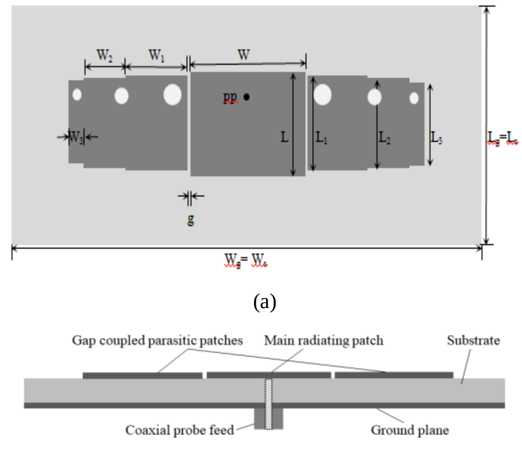
The conventional microstrip patch antenna using coaxial probe feed is designed using Rogers RT/duroid 5880 material of relative permittivity 2.2 and substrate thickness 1.575mm as shown in Fig.1. As illustrated in Fig.2, the proposed coplanar parasitic patch antenna is also designed using same single layer dielectric substrate. The main patch is at the center of the XY plane and is fed by a coaxial probe feed, exciting the dominant mode. The two parasitic patches on either side of the main radiating patch with stepped edges are placed. Here, the three circular slots with different radii are etched as a defected microstrip surface (DMS) on the symmetrical parasitic patches at the optimized position. The three circular slots have radii of 4mm, 3mm and 2mm and are placed at the distances of ±23mm, ±39mm and ±49mm respectively from the x-axis along the width of the patch. The overall height of the antenna is 1.645mm with ground plane dimension of 147mm x 71mm which makes the antenna a simple planar structure with improved performance in terms of gain, isolation and lower cross-polarizations.



(a)

(b)

Fig.1. Schematic diagram of conventional microstrip patch antenna (a) Top view (b) Side view, Parameters: W_s=W_g=77, L_s= L_g=70, W=34, L=27, h=1.575, t=0.035, pp = -5.6 (all dimensions in mm)



(a)

(b)

Fig.2. Schematic diagram of a proposed parasitic patch antenna (a) Top view, (b) Side view. Parameters: W=34, L=28, W_1 =17, W_2 =12, W_3=5, L_1=27, L_2=26, L_3=25, L_g= 71=L_s, W_g=147=W_s, g=1, pp = -9.5 (all dimensions in mm)

3. Results

The comparison of return loss characteristics of conventional and proposed microstrip patch antenna is as shown in Fig.3. The conventional MPA resonates at the designed center frequency of 3.5GHz. The proposed co-planar parasitic patch antenna is resonating at 3.55GHz frequency with good impedance matching of about -28dB. The gap coupled parasitic elements are properly placed with the radiating patch such that both their resonances merge together and hence the bandwidth enhances from 70MHz to 200MHz. The conventional and proposed MPA shows the broadside radiations in both the principal planes (E-plane and H-plane) as shown in Fig.4.

The E-plane radiation pattern of conventional patch has a peak gain of 8.03dBi with very low cross polarization. The gain of proposed parasitic patch is 10.36dBi and compared to conventional patch, the 2.33dBi gain enhancement is noticed. The broadside radiation is converted into directional in E-plane with

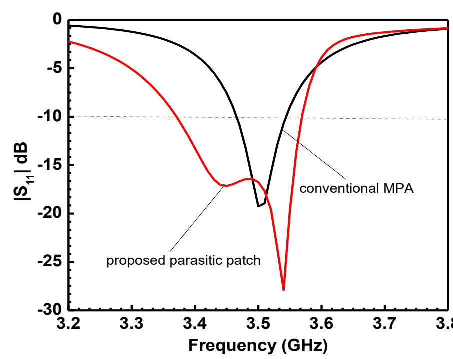


Fig.3. Comparison of return loss (S_{11}) characteristics of conventional and proposed microstrip patch antenna

$\pm 50^0$ in the proposed configuration which is very much required for 5G application.

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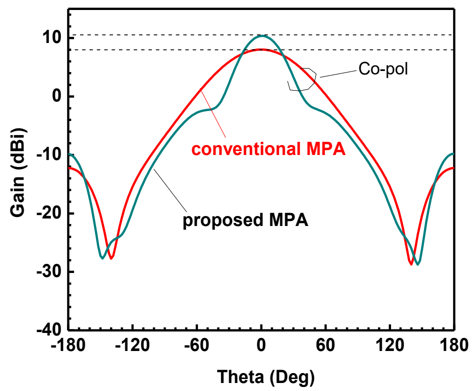
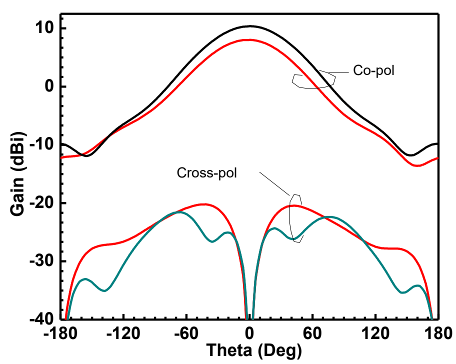


(a)



(b)

Fig.4. Radiation characteristics comparison of conventional and proposed microstrip patch antenna, (a) E-plane, (b) H-plane.

In H-plane, the cross-polarized (XP) radiation suppression is observed where the conventional MPA shows -20dB XP whereas the proposed MPA has obtained XP of -25dB. There is suppression of XP by 5dB around ±100^0. This suppression of XP by 5dB improves the isolation of co-pol to cross-pol radiations. This isolation enhancement will avoid the signal interference in the antenna. The gain variation of proposed MPA is compared with the conventional MPA as shown in Fig. 5, and its plot shows that the 2.33dBi gain is enhanced throughout the impedance bandwidth. The optimum design of the proposed coplanar parasitic patch antenna is obtained by properly placing the parasitic patches and the main radiator. The distance between these two patches is decided by series of simulation and by observing the response, particularly the impedance matching and resonance as shown in Fig.6. Here we have considered the 1 mm gap between the main radiator patch and the parasitic patches to get good impedance matching and hence the S11.

4. DISCUSSION

The proposed configuration is compared with some of the parasitic patch configuration reported in the literature and found that, it is simple in design, compact in size and has good gain. The table 1 shows the comparison of the earlier similar works and the uniqueness of the present work. The fabrication of the

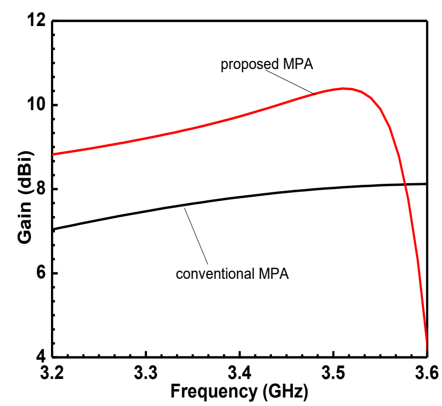


Fig.5. Gain of proposed parasitic patch compared to conventional microstrip patch antenna over the frequency range.

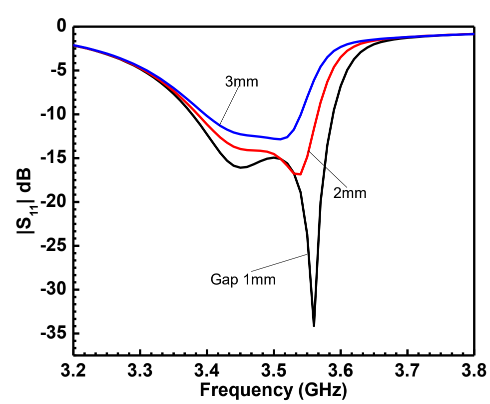


Fig.6. Optimization of gap between the main patch and the parasitic patch elements

prototype is to be done and experimental work is under progress for the measurement of antenna input and radiation parameters, the measured data is to be compared with the simulated predictions to validate the antenna for practical utilization. The complete measured data will be published in the future journal.

Table 1: Comparison between the recent parasitic MPAs with proposed antenna

Ref	*Size (mm^2)*	*Height (mm)*	*Centre frequency(GHz)*	*Gain (dBi)*
4	62X62	3.5	3.6	5.7
5	80X50	1.57	5.2	5.2-6.8
6	70X70	32.5	5.8	15.8
7	40X40	1	5.25	5.23
8	36X39	1.6	5.94	<5
Prop	**147X71**	**1.645**	**3.5**	**10.36**

5. CONCLUSION

The compact gap coupled parasitic patch antenna is proposed in this paper, this proposed MPA is a good candidate for 5G wireless communication that operates in the sub-6GHz frequency band. This antenna gives good impedance matching with the return loss of less than -28dB. The proposed MPA gives 200 MHz bandwidth with the peak gain of 10.33dBi. The obtained bandwidth is 5.71% and the cross polarization in H-plane is -25dB and 5dB XP is suppressed compared to conventional MPA. The proposed MPA also has good isolation between co-pol to cross-pol and is about 35.33dB, which avoids the signal interference in MPA.

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