Design of Patch Antenna for 5G Network using CST Software

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***Abstract*—This research paper discusses the outcomes of designing and simulating patch antennas for the 5G frequency band. Different patch geometries, such as rectangular, circular, and square, were created and tested using CST software at frequencies of 5.3GHz and 7.5GHz. Various antenna parameters like directivity, gain power radiated, and antenna efficiency were assessed. The results indicate that the circular patch antenna exhibited superior performance compared to the other designs at 5G frequencies.**

Keywords—Patch, efficiency, gain, directivity

I. INTRODUCTION

Patch antennas (PAs) are compact antennas that lie flat on a substrate, making them suitable for situations where space, ease of installation, cost, weight, and performance are important considerations. They are versatile and can be used interchangeably in applications like mobile radio and wireless communication, which have similar requirements, offering flexibility and convenience in deployment.

[1]. They are becoming increasingly useful since they printed on circuit boards and have become widespread.

[2]. Patch antennas (PAs) are widely sought after due to their numerous advantages, including their compact size, affordability, and lightweight construction. However, they do have certain limitations such as narrow bandwidth, low efficiency, limited gain, susceptibility to surface wave excitation, and challenges in controlling dielectric constant tolerance at microwave frequencies.

[3]. Improving bandwidth and reducing size are becoming crucial design factors for practical PA applications.

[4]. The PAs usually formed from etching a patch of conductive material on a dielectric material also called as substrate. It includes very thin metallic patch whose thickness is for lesser than the free-space wavelength (fig 1). The antenna is crafted to ensure the peak radiation pattern aligns perpendicularly to the patch. This paper aims to simulate and juxtapose the performance of PAs within the 5G frequency band, employing rectangular, circular, and square shapes. The goal is to determine which geometry is best suited for efficient performance in 5G application

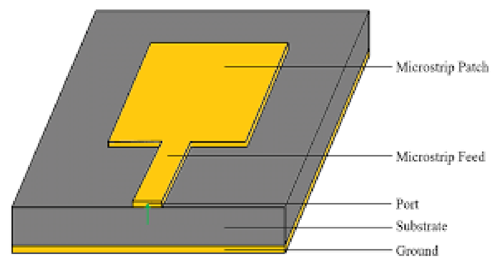

Fig 1: Patch antenna design

II. MATERIALS AND METHODS

To evaluate the performance of the patch geometries, single element rectangular, circular and square patch antennas were designed and simulated using CST Microwave studio.FR4 material and PEC, with a dielectric constant of 4.3 and thickness of 1.6mm as the substrate while pure copper with a thickness of 0.035mm as the material for the conducting elements(patch and ground)of the antennas and was fed using microstrip feedline technique.

Patch Antenna Geometries Design

According to ,the width of patch was calculated using :

$$w = \frac{c}{2f\sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

Also, the length L patch was calculated using:

$$L = \frac{c}{2f\sqrt{\varepsilon eff}} - 0.824h\left[\frac{(\varepsilon eff+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon eff-0.258)\left(\frac{w}{h}+0.8\right)}\right] \quad (2)$$

Where,

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right] \quad (3)$$

The circular patch radius was calculated using

$$r = \frac{c}{2f\sqrt{\varepsilon eff}}$$

Table 1: Dimensional specification of designed rectangular and square PAs

Shapes	5.3GHz		7.5GHz	
	Width (mm)	Length (mm)	Width (mm)	Length (mm)
Rectangular	17.36	15.74	15.28	8.98
Square	17.36	15.74	15.28	8.98

Table 2: Dimensional specification of designed circular PAs

Circular Radius in mm	5.3GHz	7.5GHz
	14.57	9.85

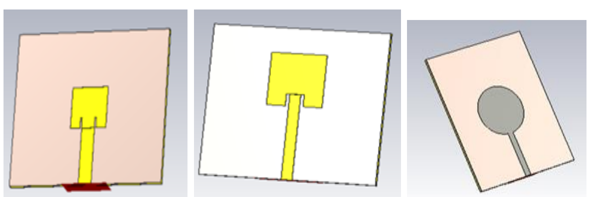

Fig: 2a Fig : 2b Fig : 2c
Fig 2: Designed and simulated a) rectangular, b) Square and c) Circular PAs geometries

III. SIMULATION RESULT

The power emitted by an antenna quantifies its strength or the power focused within the main lobe. fig 3a to 3f show the power radiated by the designed and simulated PAs geometries at 5G network frequencies of 5.3GHz and 7.5GHz respectively.

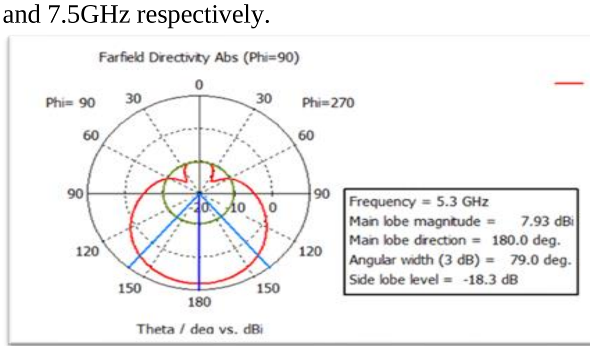

Fig : 3a

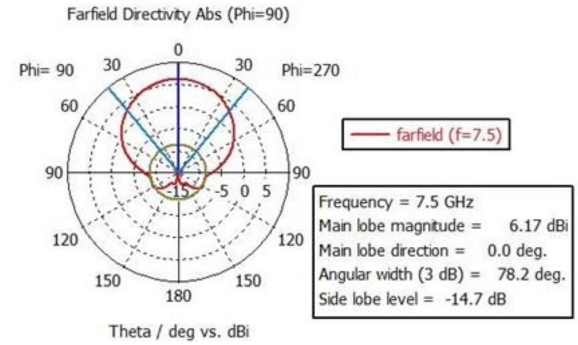

Fig : 3b

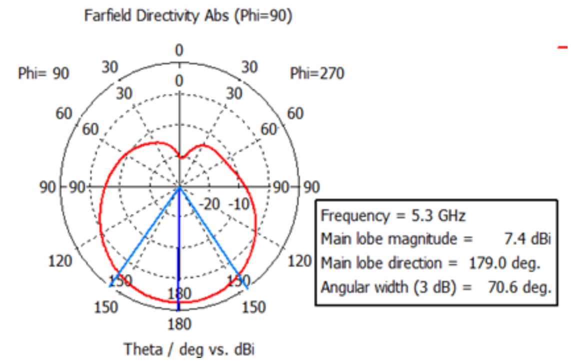

Fig : 3c

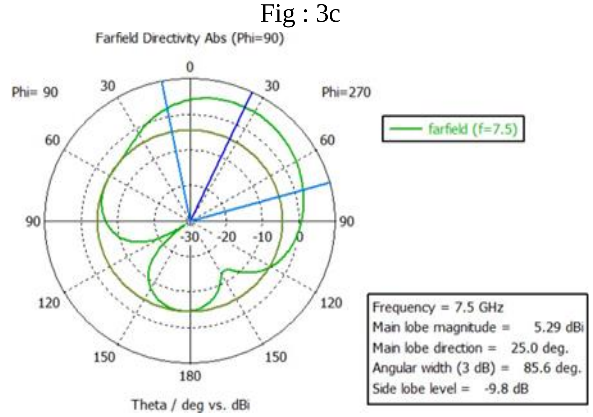

Fig : 3d

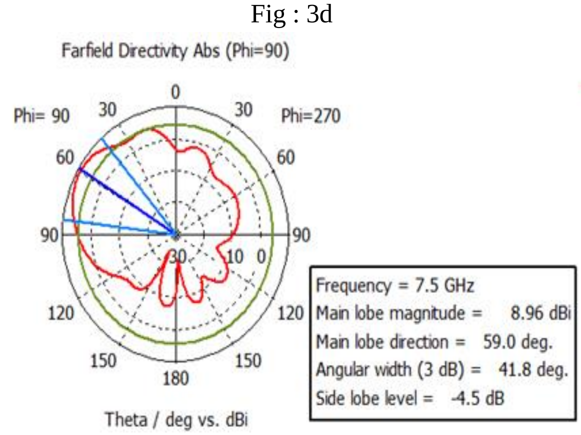

Fig: 3e

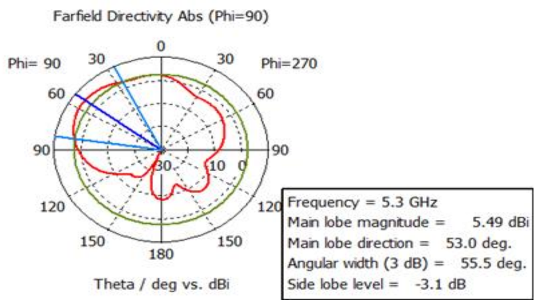

Fig: 3f

Fig 3: Radiation patterns simulated PAs geometries; (3a) rectangular PAs at 5.3GHz, (3b) rectangular PAs at 7.5GHz, (3c) square PAs at 5.3GHz, (3d) square PAs at 7.5GHz, (3e) Circular PAs at 5.3GHz, (3f)Circular PAs at 7.5GHz

Table 3: Directivity

Frequency (GHz)	Directivity (dBi)		
	Rectangle	Square	Circular
5.3	7.926	7.40	6.172
7.5	7.539	5.289	8.962

Table4: Radiation Efficiency

Frequency (GHz)	Radiation Efficiency (dBi)		
	Rectangle	Square	Circular
5.3	-5.91	-8.6	81.4
7.5	-10.98	-8	74.5

Table5: Gain

Frequency (GHz)	Gain (dBi)		
	Rectangle	Square	Circular
5.3	2.06	-1.217	87.63
7.5	-3.437	-2.796	83.48

Table6: Power Radiation

Frequency (GHz)	Power Radiation (dB)		
	Rectangle	Square	Circular
5.3	0.067	0.027	0.7
7.5	0.172	-2.2	7.1

IV. DISCUSSION

The designed and simulated PAs parameters performances were compared as illustrated in the table 2. The designed and simulated rectangular PA has the highest directivity of 7.926 dBi at 5.3GHz and the Circular PA has the highest directivity of 8.962 dBi at 7.5 GHz. Furthermore, the results of circular has the highest efficiency 81.4 dBi and 74.5 dBi at 5.3GHz and 7.5 GHz.

The functionality of designed and simulated PAs parameters were compared as shown in table 3. The results showed that the designed and simulated circular MPA has highest radiated power of 0.7 W and 7.1 W at 5.3GHz and 7.5GHz. The designed and simulated circular MPAs has the highest gain of 87.63 dBi and 83.48 dBi at 5.3 GHz and 7.5 GHz.

V. CONCLUSION

This work has revealed that Patch Antenna geometry has critical influence on its performance parameters particularly radiation pattern, power radiated, directivity and efficiency. Circular Patch antenna has given the overall best performance it has directivity of 6.172 dBi for 5.3GHz and 8.962 dBi for 7.5GHz and Radiation Efficiency of 81.4 dBi for 5.3GHz and 74.5 dBi for 7.5GHz, and it is most suitable and compatible for use as Patch Antenna in 5G network devices at the lower and mid frequency band, specifically at 5.3 GHz and 7.5 GHz respectively. The Power Radiation of Circular patch has 0.7dB for 5.3GHz and 7.1dB for 7.5GHz.

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