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Dual Polarized Rectangular Microstrip Patch Antenna for 5G Wireless Application

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Abstract - *A novel dual polarized rectangular patch antenna for 5G wireless application is proposed. The patch antenna is designed using dielectric substrate FR4 (flame retardant) epoxy, with dielectric-constant (ε_r) of 4.4 and height 1.6mm. The overall volume of the antenna is 34x27x1.6 mm^3 and ∂=0.01. The proposed antenna will be resonating at the NR range of 3.3 to 4.2GHz. The conventional antenna resonates at 3.87GHz with return loss of -15.97dB and has a peak gain of 6.61dB. Significant upgrade of the gain is noticed when proposed antenna is designed. Resonates at 3.92GHz with return loss of -22.04dB and has a peak gain of 12.43dB. The proposed antenna can be used for 5G wireless communication. Work in both S and C band.*

Key Words: **Dual-polarize, 5G applications, rectangular patch, FR4 epoxy**

1. INTRODUCTION

After 4 generation network 5G is the new standard network, 5th generation mobile network for broadband cellular network in telecommunication. It is organized succession to 4G network. The same previous network but these services are divided into smaller region called cells. The benefits of 5G are large bandwidth, higher download speed (1). Wireless communication became more necessary in different applications. In numerous cases the wired system can't be fixed it can be done using wireless communication. This demanded for best broadband experiences which inspired the world to look for better network to meet the future demands. So 5G may be the set of technical component needed to handle all these demands. 5G helps in developing the present technique to improve capacity. Other motivation for 5G is high speed, low latency and high quality broadband coverage.5G is not important because of speed but also it offers safety and security of services and also make life better by making advancement in automated task in the field of automobiles.Dual polarized antenna has many advantages so broadly used in wireless communication (2) and they have high capacity, less installation charges (3). There are many types of antenna but microstrip patch antenna(MPA) provide lots of advantages like; flat structure, less expensive, less weight, small in size, easy to fabricate, suitable for array motivated designing of MPA for 5G(4) and MPA resonates at particular frequency(5). Antennas are designed at the frequency range of 3.3 to 4.2 GHz for first installation of 5G globally (6). This band have large coverage area and also have high capacity so good environment for 5G. 5G spectrum also has mm- waves (24-40GHz) ultra fast but having a limitation of ultra short range. So to cover large area 3.3-4.2 GHz frequency range is used for 5G installation (7). MPA is prominently used printed antennas. Used in many applications in wireless communication system. Circular or square patch antennas are used in satellite communication. In global positioning satellite circularly polarized Microstrip antenna is used. Microstrip antennas are also used in RFID, mobile communication and healthcare. Most of the Microstrip Patch Antennas are designed using formulas. MPA is designed for the mid range 5G technologies. The proposed MPA is resonating from 3.3GHz to 4.2GHz frequency band to cover 5G mid range. This is faster than previous 4G network and operates at high speed with large coverage area and antenna has high gain and good isolation (8). This frequency range is applies in IOT like smart phone, smart cities, smart home. FR4 epoxy is used as substrate because many PCB use this as substrate because it is low cost and high mechanical properties it has loss tangent of 0.01 and operates at the large frequency range (9). Microstrip line feed provide planar structure this is advantageous because easy to fabricate and simple modeling (10).

2. ANTENNA DESIGN

MPA consists of mainly 3 layers patch, ground plane and substrate with dielectric constant ε_r with height h. Patch is flat sheet it is the source of radiation in antenna which will be placed on another metal surface called ground plane and are separated by a dielectric substrate. Complete antenna structure is placed inside a plastic box to protect it and all are designed above the printed circuit board. Patch antenna may be narrow band or wideband. The metal strip is the highly conductive material of any shape. Substrate may be thicker or thin. Substrate is chosen in such a way that their permittivity is in between 2.2 to 12. MPA are used at frequency 1 to 100GHz. MPA is analysed by Transmission line model. It is the easiest method gives good physical insights and has better numerical efficiency, these model are used to predict the input characteristic of rectangular microstrip antenna but are less accuracy. (11)

2.1 Design of Basic Rectangular Patch Antenna

The design of patch antenna starts with selecting the resonating frequency (f_0) and then considering the substrate with dielectric constant (ε_r) and height (h). Then calculate effective dielectric (ε_{reff}), effective length (L_{eff}), the width (W) and length (L) of patch using the design formula. And calculate width and length of substrate (L_s, W_s) and ground plane (L_g, W_g). (12)

- 3.3 to 4.2 GHz is the range of Resonating frequency selected here for 5G application.
- Dielectric substrate selected here is the FR-4 epoxy with dielectric constant ε_r=4.4 and thickness h=1.6mm and loss tangent ∂=0.01.
- Width of the patch is calculated using the below formula

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

- Effective dielectric constant ε_{reff} is calculated using

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

- For effective length L_{eff} of the patch can be calculated using

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

- Length extension (ΔL) is calculated using

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

- Length of patch is calculated using

$$L_{eff} = L + 2\Delta L \quad (5)$$

- Length of ground plane L_g is calculated using

$$L_g = 6h + L \quad (6)$$

- Width of ground plane W_g is calculated using

$$W_g = 6h + W \quad (7)$$

Table -1: Design Parameters of Basic Antenna

Dimensions	Values in mm
Width of patch(W)	24
Length of patch(L)	17
Width of ground plane(W_g)	34
Length of ground plan(L_g)	27
Width of substrate(W_s)	34
Length of substrate(L_s)	27

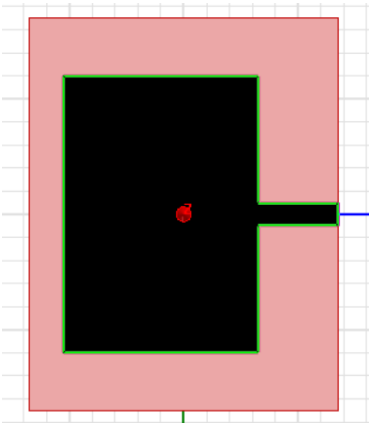

Fig -1: Basic Rectangular Patch Antenna

2.1 Design of Proposed Patch Antenna

After designing a basic patch antenna for particular frequency as in fig1 it is modified to obtain the proposed antenna. 1x1 mm² square wedges are etched along the circumference of the patch and circle of radius 2mm is etched from the patch shown in fig 2.

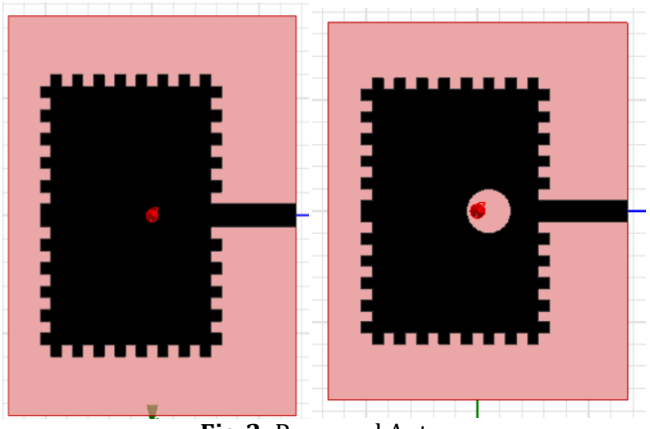

Fig-2: Proposed Antenna

3. RESULTS AND DISCUSSION

Mathematically return loss at the output port is expressed by the equation and the return loss is always in decibel. The frequency is plotted along x-axis and return loss in dB at y-axis.

$$RL_{input}=20\log_{10}|S_{11}|dB \quad (8)$$

Fig 3 shows the S_{11} plot of patch antenna the frequencies along x-axis and return loss is along Y axis. It is a single band antenna because there is only one tip at 3.92 GHz has crossed the -10dB at all other parts there is no sharp tip. The basic antenna resonates at 3.87GHz and it has upper cut off frequency at 3.96GHz and lower cut off frequency at 3.78GHz and bandwidth is 0.18GHz (180MHz). Fig 4 shows the gain plot of basic antenna has gain of 6dB.

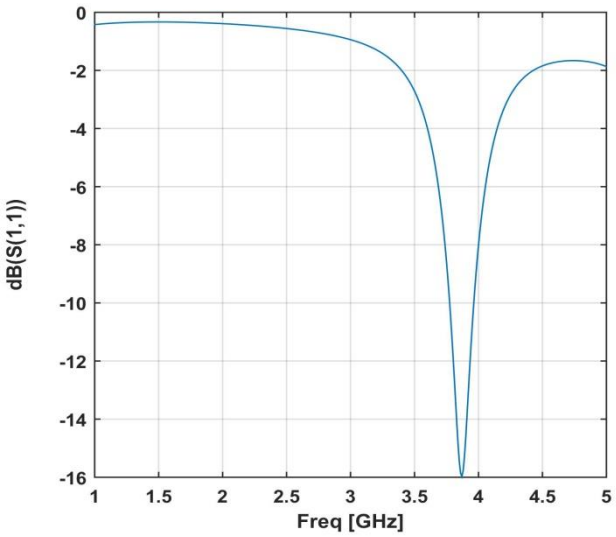

Fig-3: S_{11} Plot of Basic Microstrip Patch Antenna

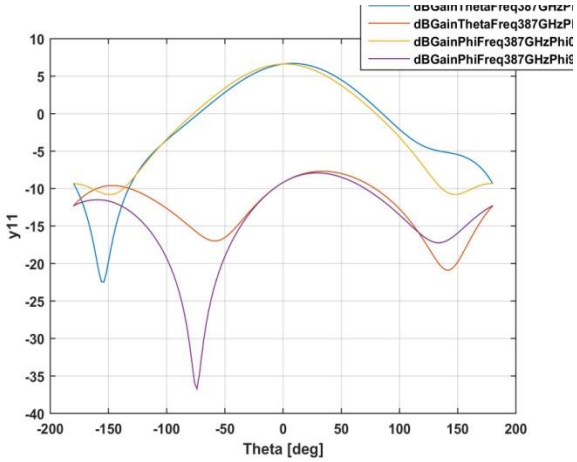

Fig-4: Gain Plot of Basic Microstrip Patch Antenna

Fig 5 shows the S_{11} plot of proposed antenna resonates at 3.9GHz and it has upper cut off frequency at 4.02GHz and lower cut off frequency at 3.83GHz and bandwidth is 0.19GHz (190MHz). Fig 6 shows gain plot of proposed antenna has gain of 12dB.

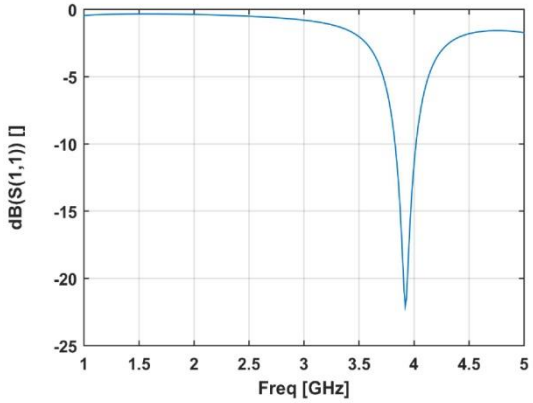

Fig-5: S_{11} Plot of Proposed Microstrip Patch Antenna

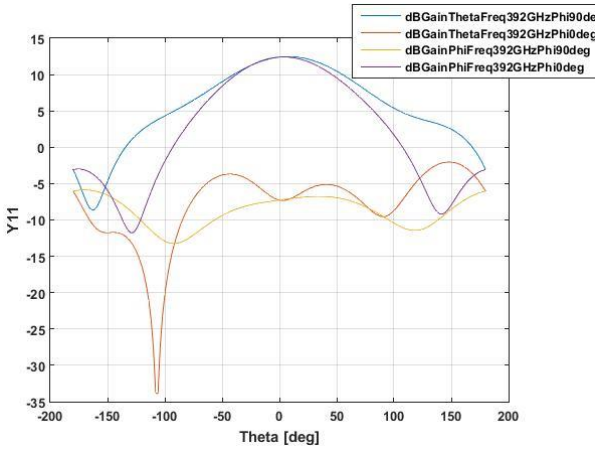

Fig-6: Gain Plot of Proposed Microstrip Patch Antenna

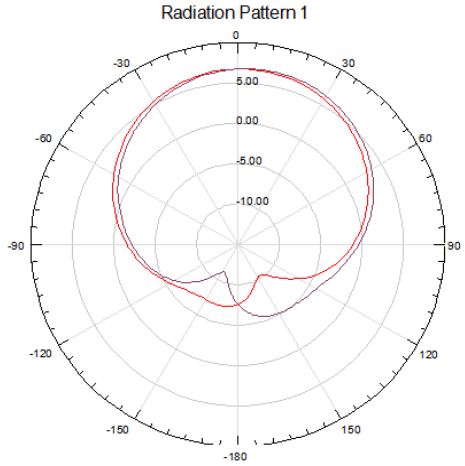

Fig-7: Radiation Pattern of Basic Microstrip Patch Antenna

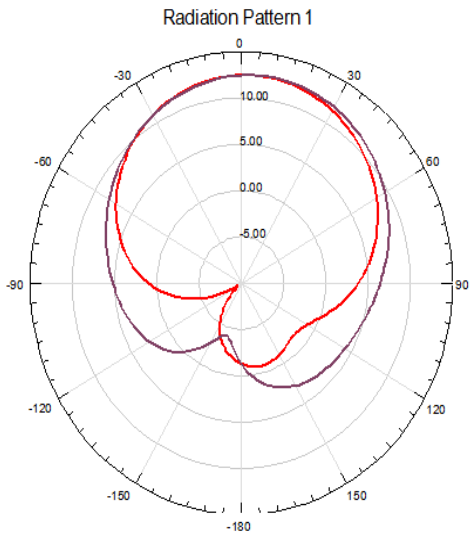

Fig-8: Radiation Pattern of Proposed Microstrip Patch Antenna

4. CONCLUSIONS

Rectangular microstrip patch antenna is designed to resonate at frequency range of 3.2GHz to 4.3GHz for 5G application using the substrate FR4 epoxy with dielectric constant ε_r=4.4 with height h=1.6mm. Regular antenna resonates at frequency 3.87GHz with return loss of -15.9732. and has gain of 6.6158dB. Patch of this regular antenna is etched at the circumference in the shape of square to form wedge like structure, and circle structure is created near the feed to improve the gain of the antenna. which resuts in antenna which resonates at frequency 3.92GHz with return loss of -22.0465 and gain is 12.4373dB.

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