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DESIGN AND DEVELOPMENT OF NOVEL PATCH ANTENNA FOR 5G APPLICATIONS

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Abstract
Antenna design plays vital role in developing the faster communication technology like 5G. In this paper novel patch antenna is presented for 5G communication under 6GHz band frequency. In this paper rectangular and circular patch antenna configuration were combined to develop a new kind of antenna for enhanced 5G applications working in 4.5GHz resonant frequency. This antenna is developed over FR4 substrate with 1.6mm height of substrate and dielectric permittivity of 4.4 with the dimension of 40 mm width and 50mm length. The copper patch is designed over the substrate at the height of 0.035mm. This antenna is designed and simulated in CST Microwave studio v2018. The performance of the proposed design is found satisfactory and the results obtained are as follows, return loss -37.92dB, VSWR 1.025, bandwidth of 340MHz, and the gain of the proposed antenna is found to be 4.14dB in the resonant frequency 4.5GHz. This novel patch antenna is suitable for 5G Communication.

Keywords:
Microstrip Patch Antenna, 5G Communication, CST

1. INTRODUCTION

The definition of antenna by IEEE "an antenna as a part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves" Micro Patch antennas are popular forms of antenna getting huge attention among the researchers these days because of its advantages such as light weight, ease of fabrication, low cost, low profile, portability, integrability with millimeter, and microwave circuits, reduction in patch size, enhancement of bandwidth, and suppression of unwanted cross polarized radiations of patch antenna [1].The fundamentals of patch antenna in real time applications and design procedures were given in [2-3]. Recently 5G development plays important position in increasing the data transfer rate with enhanced performance level. LTE and Other major wireless communication technologies have been already using bands under 6GHz which are getting more popular and therefore in the upcoming 5G technology the sub 6GHz band which is 4.5GHz for operation is easy in implementation in existing network infrastructure. A large-scale field experimental trial of downlink TDD Massive MIMO for the 4.5GHz band using the developed 5G test bed is given in [4]. Therefore, the development of 4.5GHz patch antenna will help us to increase the use of 5G technology at low cost high performance antenna systems. Literature review has been done using the recent developments of patch antennas for 5G Communications [5-13] is detailed in further part of this introduction section. A compact dual-band antenna is designed for 4.5GHz and 7.8GHz 5G and C-band applications the antenna satisfied the -10dB impedance bandwidth is 64MHz (4.468GHz-4.532GHz) and 128MHz (7.736GHz-7.864GHz) [5]. Dual-band miniaturized planar inverted F-antenna is designed for WLAN and 5G applications which has been designed to operate in the WLAN (2.4GHz), Bluetooth (2.4GHz), LTE2500 (2.5GHz) and 5G communication (4.5GHz) [6].

A rectangular patch antenna for 5G applications and the antenna results show that the ultra-wideband impedance of 35.41GHz (from 50.86GHz to 85.27GHz) which is 45.5% of the central frequency [7]. A single layer compact antenna for 5G applications is presented which has been proposed for wireless transmission applications, printed on a dielectric substrate (RT-Duroid 5880) and resonating at 28.00GHz and 38.00GHz frequencies [8]. A new type of parasitic path antenna for the 5G applications is presented and the proposed antenna permits the coverage of multiple wide bands above 6GHz [9]. A novel substrate integrated low-profile magneto-electric dipole antenna and the antenna obtains a broad bandwidth of 14.7% from 5.10 to 5.91GHz [10]. A 4.5GHz circularly polarized silver antenna with 3dB gain improvement is discussed in [11]. Broadband printed-dipole antenna and its arrays for fifth-generation (5G) wireless cellular networks is demonstrated and the usefulness of antenna as a beamforming radiator by configuring 8-element linear arrays in [12]. Polypyrrole based 4.5GHz antennas was presented and compared with an equivalent copper microstrip antenna and gain observed was 2.42dB is lowest in [13]. Therefore, from the literature review it is found that there is a need for developing antennas for supporting the 4.5GHz 5G communications with the improved gain which has been taken as an objective for this research work. The organization of paper is as follows: section 2 includes the design methodology, section 3 contains of the discussion of results and the section 4 completes the paper with the conclusion.

2. DESIGN METHODOLOGY

In this section the design procedure of the novel patch antenna for 5G applications is presented. There are many shapes of patch antenna are available such as rectangular, circular, cylindrical, square and triangular shaped patch antenna is available each configuration has its own design considerations and advantages. The theoretical design equations for rectangular patch antenna and circular patch antennas have been discussed in [1]. The design parameters of this antenna have been arrived after several iterations from the simulation. In this paper the research work focuses on combining the simplest rectangular configuration with powerful circular patch configuration into developing novel patch antenna which is given in Fig.1. The dimensions for the proposed antenna consists of a = 40mm, b = 50m, c = 33.27mm, d = 14mm, e = 11.70mm, f = 20mm, g = 5mm, h = 5mm. The substrate consists of FR4 Epoxy substrate material with permittivity 4.4, loss tangent tanδ = 0.02, height of the substrate h = 1.6mm.

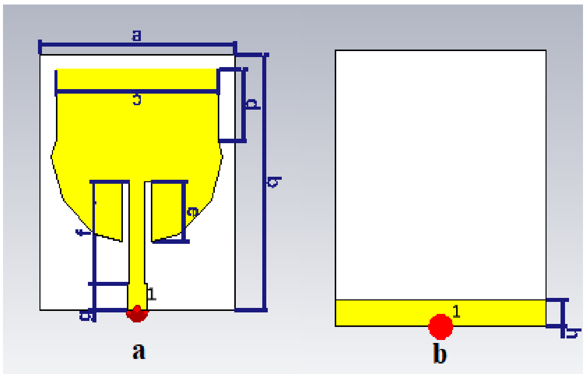

Fig.1. (a) Front view (b) Back view of the Proposed Antenna

The substrate is covered with the double side copper cladding with electrical conductivity of $5.8e^{+007}$ with a thickness of t = 0.035mm. The proposed novel patch antenna consists of rectangular shape at the top portion and circular shape at the bottom portion of the front side of the patch antenna. The back side of the proposed antenna has modified ground plane which is optimized for best performance at 4.5GHz after several iterations done for various dimensions in CST simulation environment. The inset feeding is used for the proposed antenna and it has been modified for the best performance in the required resonant frequency. In further section the discussion of results is presented.

3. RESULTS AND DISCUSSIONS

There are several simulation software available such as HFSS, AWR, ADS, etc. out of which the proposed antenna is designed and simulated in CST Microwave studio v2018 because this is based upon Finite Integration in Technique and is a widespread among antenna designers due to ease in simulations and accurate results and its results were discussed below in this section.

3.1 RETURN LOSS

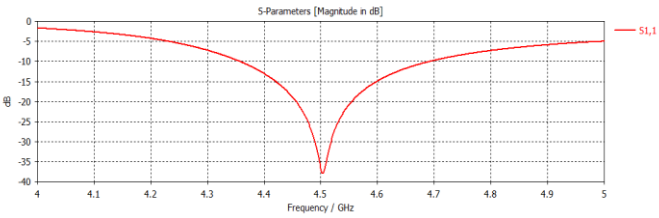

Fig.2. Return Loss

The minimum return loss obtained at 4.5GHz is -37.92dB for the proposed antenna which is given in Fig.2. The -10dB Bandwidth obtained at 4.5GHz is 340MHz for the proposed antenna. This validates that the proposed design is well suitable for the 5G applications.

3.2 VSWR

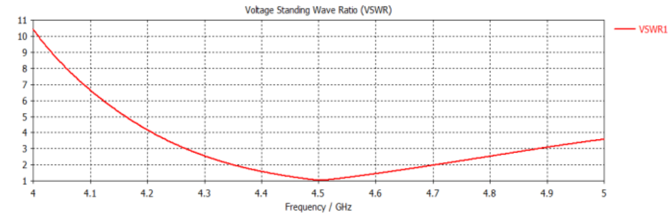

Fig.3. VSWR

The minimum VSWR (Voltage Standing Wave Ratio) obtained at 4.5GHz is 1.025 for the proposed antenna which is given in Fig.3. The VSWR value must be from 1 to 1.5 for the perfect antenna and the proposed design achieves the value of 1.25 which validates the proposed design.

3.3 E FIELD

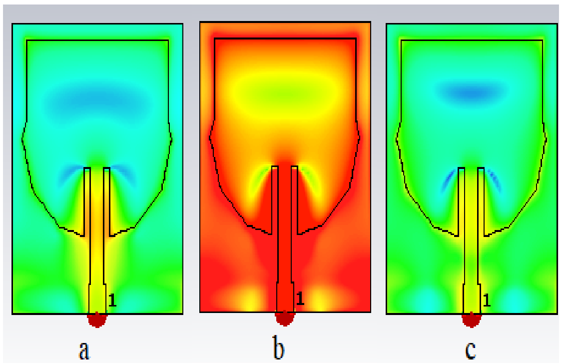

Fig.4. a) at 4GHz b) at 4.5GHz c) at 5GHz

The E field pattern is given in Fig.4 and from the E Field pattern presented it is observed that at 4GHz the E Field is 3160V/m. at 4.5GHz the E Field is 34238V/m and at 5GHz the E Field is 17956.7V/m. The green and yellow region defined less power and the red region defines high power generation. Therefore, it is observed at the required resonant frequency 4.5GHz the designed antenna performs well in E Field region.

3.4 H FIELD

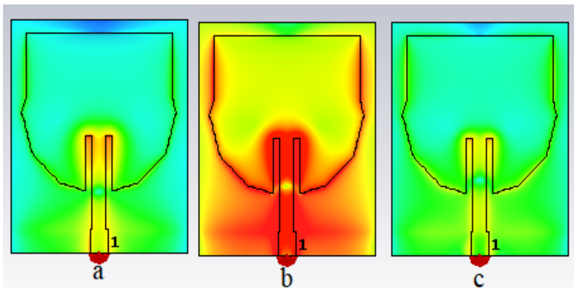

Fig.5. a) at 4GHz b) at 4.5GHz c) at 5GHz

The H field pattern is given in Fig.5 and from the H Field pattern presented it is observed that at 4GHz the H Field is 33.587A/m. at 4.5GHz the H Field is 138.567A/m. and at 5GHz the H Field is 69.0248A/m. The green and yellow region defined less power and the red region defines high power generation.

Therefore, it is observed at the required resonant frequency 4.5GHz the designed antenna performs well in H Field region.

3.5 SURFACE CURRENT DISTRIBUTION

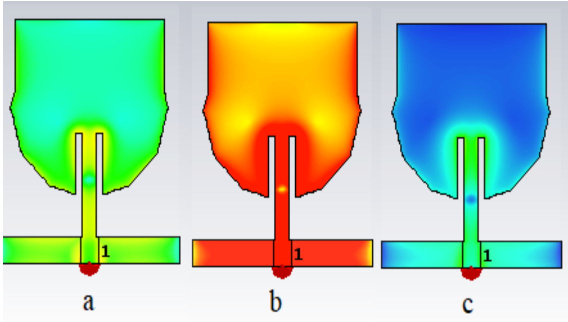

Fig.6. (a) at 4GHz (b) at 4.5GHz (c) at 5GHz

The surface current distribution can be a very useful plot for the analysis of design. The surface current distribution plot is given in Fig.6 obtained from the simulation. The values obtained from the surface current distribution are 58.124A/m, 112.117A/m, 55.8481A/m for 4GHz, 4.5GHz, 5GHz respectively. The results show that the current distribution is high at the resonant frequency 4.5GHz.

3.6 FARFIELD ANALYSIS

Farfield radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. The Maximum Efficiency obtained at 4.5GHz is 70.6% and the total Efficiency from 4 to 5GHz frequency range is 70.5% for the proposed antenna. The farfield directivity plots for Phi (0,90) and Theta (0,90) were given in Fig.8. The directivity achieved from the proposed antenna is 4.88dBi which shows that the antenna radiation is performing good in required directions.

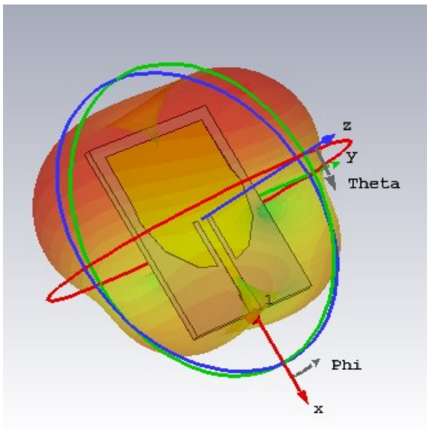

Fig.7. 3D Farfield Pattern

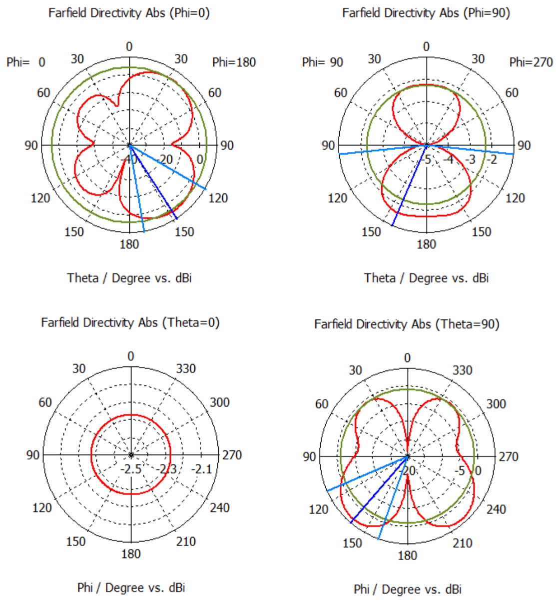

Fig.8. Farfield Directivity Plots

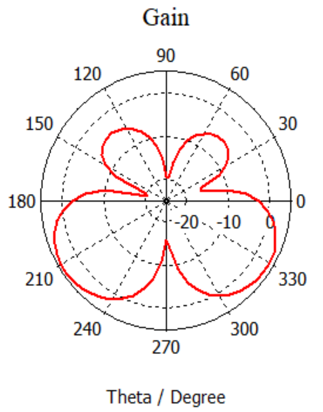

Fig.9. Gain

3.7 GAIN

The gain is given in Fig.9. The proposed novel patch antenna achieves the overall gain of 4.14dB. The Front to Back Ratio is the ratio of power gain between the front and rear of a directional antenna. Front to back ratio at 4.5GHz is 5.68 for the proposed antenna. The overall results were tabulated below in Table.1.

Table.1. Overall Results

Parameter	Value
Resonant Frequency	4.5GHz
Return Loss	-37.92dB
Bandwidth	340MHz
VSWR	1.025
Directivity	4.88dBi
Gain	4.14dB
Efficiency	70.60%
Front to Back Ratio	5.68
Resonant Frequency	4.5GHz
Return Loss	-37.92dB
Bandwidth	340MHz

4. CONCLUSION AND FUTURE WORKS

In this paper a novel patch antenna which consists of fusion of rectangular and circular shapes of micro patch antenna is presented. The proposed novel patch antenna has achieved return loss -37.92dB, VSWR 1.025, Gain 4.14dB and bandwidth 340MHz are achieved. This work will be key contribution in the upcoming 5G wireless mobile communication networks infrastructure development and advanced mobile communication services. Future work in this research will be focusing on fabricating and testing antenna in real time applications and tuning this antenna for other major 5G frequency bands for the improvement of its performance and applications.

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