Millimeter Wave Circular Microstrip Patch Antenna for 5G Applications

Gana U Kumar, Sanish V S

Department of Electronics and Communication Engineering , Jawaharlal College of Engineering and Technology, Mangalam, Lakkidi, Ottappalam, Palakkad, Kerala, India

Abstract **– 5G is expected to support significantly faster mobile broadband speeds and heavier data usage than previous generations while also enabling the full potential of the Internet of Things. A circular microstrip patch antenna and it's array for future 5G mobile communication networks. The antenna has resonating frequency of 28GHz. The antenna is designed on a Rogers RT5880 (lossy) substrate with dielectric constant of 2.2 and loss tangent (tanδ) of 0.0013. The antenna has a compact size of 6×6×0.578mm^3. Array configurations is used to achieve more gain, required for mobile communication. The proposed array has resonance frequency of 28GHz, with maximum gain of 8.9 dB and radiation efficiency of 98.75%. Centre series fed technique is used for the excitation of array. . The antenna dimensions were calculated and simulated results have been displayed and analyzed using HFSS.**

Keywords **– High Frequency Structure Simulator (HFSS)**

I. INTRODUCTION

Mobile wireless technology has been assessed from 0G to 4G, bringing the revolution in mobile communications. Each generation is an old, improved version. 4G technology has many applications, such as remote host monitoring, video call data flow and machine type communication. 4G has some advantages but is unable to solve the problems of poor quality, poor coverage, loss of connections, high energy consumption, bad interconnectivity and overcrowded channels. Due to the rapid growth of communication system connected devices, current 4G technology will not meet the recent demand. Therefore, the mobile communication system must be upgraded to the next generation (5G) in order to meet the future demand of high data rates. Research is underway for 5G mobile communications and is expected to be commercialized early in the 21st century.

5G technology was introduced in a new era of digital mobile communications systems, which introduces the Internet of Things (IOTs) into the network of devices (D2Ds) with wider bandwidth, lower battery consumption, higher data rates and better coverage, and will solve various challenges such as latency, security, reliability, availability and equipment costs. Spectrum allocation is one of the main concerns of 5G communications. Some of the expected bands recommended for 5G mobile communications are: 26.5–29.5GHz, 33.4–36GHz, 37–40.5GHz, 42–45GHz, 47–50.2GHz, 50.4–52.6GHz and 59.3–71GHz. However, for cellular communications, the 28GHz and 38GHz bands are advantageous, but operating at higher frequency bands will bring complexity in the antenna design of mobile communication system.

Millimeter wave radio frequency can provide the basic ground for the new Generation (5G).Millimeter wave have unexploited spectrum (3GHz-300GHz) to fulfill the new generation needs. The spectrum of 5G application is 20-90GHz. 5G antennas are designed at frequencies 28Ghz, 38GHz, 72GHz having bandwidths of 500 MHz, 1 GHz, and 2 GHz as they are all suitable for high data rate and low latency system. They are highly directional and obstacle sensitive due to narrow beam width they can be used for cellular applications. Many Substrates are available but as all substrates' dielectric constants are below 10GHz, except Rogers substrate, therefore Rogers substrate is best for millimeter wave. It is most suitable for UHF (ultra high frequencies) because of low dielectric loss and low dispersion.

The design complications such as complexity and larger size along with low radiation efficiency, low gain are some of the main concerns associated with the cited research. The aim is to overcome the low performance and design complexity of the microstrip patch antenna for 5G mobile communication networks. An easy to fabricate microstrip patch antenna is proposed here, having a circular radiating patch over a Roger RT-5880 substrate, due to its low dielectric constant and low loss dispersion, which is considered as a suitable material for ultrahigh frequency (UHF). The required gain and radiation pattern for mobile communication is achieved by using an array structure.

High Frequency structure Simulator (HFSS) is a computer software that is used for antenna model design. Numerical simulations can be performed using HFSS software to obtain different specific design parameters of the microstrip patch antenna.

II. ANTENNA THEORY AND DESIGN

The first important step in designing an antenna was the selection of the substrate. The impedance matching and bandwidth of an antenna are highly influenced by the parameters of substrate like height, dielectric constant and tangent loss (tanδ). High copper losses may occur due to using a very thin substrate while a thicker substrate can degrade the performance of antenna due to surface waves. In the proposed antenna design, a Roger RT-5880 substrate is used whose dimensions and electrical properties are given in Table 1. To obtain the desired resonance frequency of 28GHz, a circular patch of a particular radius (Rp) is used relating to Equation (1). The circular patch of the antenna is fed by using a 50Ω microstrip line.

$$R_P = \frac{F}{\sqrt{1 + \frac{2h}{\pi \varepsilon F\left[\ln\left(\frac{F\pi}{2h}\right) + 1.7726\right]}}} \quad (1)$$

$$F = \frac{8.791 * 10^9}{f\sqrt{\varepsilon}} \quad (2)$$

Rp = the radius of the patch, h = the height of the substrate, f = the resonance frequency in hertz, ε = the effective dielectric constant of substrate.

Table 1. Dimensions and electrical properties of Rogers RT-5880.

Parameters	values
Dielectric constant	2.2
Loss tangent	0.0013
Dimension	6×6mm
Substrate height	0.508mm

Table 2. Design dimensions of the proposed circular patch antenna operating at 28GHz

Parameter	Description	Value
fo	Operating frequency	28GHz
Ls	Substrate Length	6mm
Ws	Substrate width	6mm
H	Substrate height	0.508mm
Rp	Patch radius	2.02mm
Mt	Patch Height	0.035mm
Wf	Feed line Width	0.38mm
Lg	Ground Length	6mm
Wg	Ground width	6mm

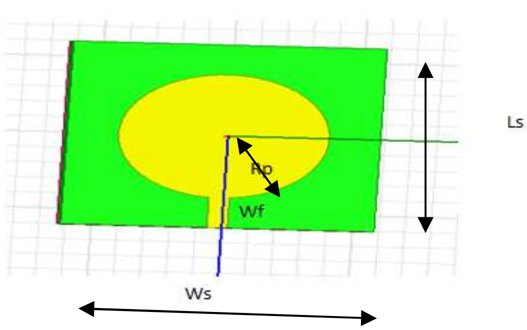
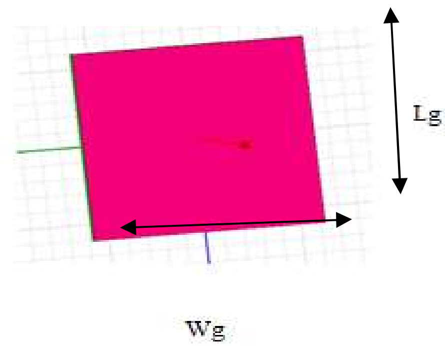


Figure 1. The proposed antenna design. (a) Front view



(b) back view

2.1. Array Design

For the aim of achieving more gain for 5G Mobile communication applications, a series array of 1×4 elements is implemented. The array is fed at the centre, and the configuration is shown in Figure below

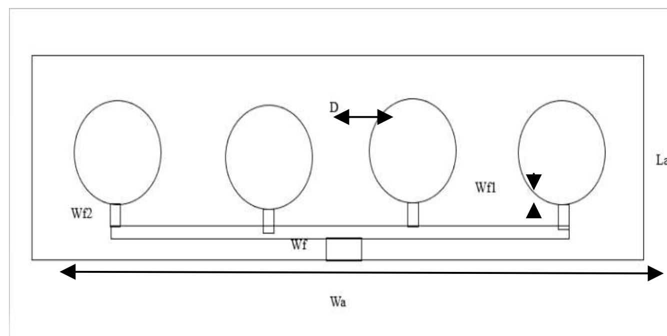


Figure 2. Front view of the proposed array with design dimension variables.

The array resonates at 28GHz respectively. All elements of the array resonate at the same frequency and are designed for radiation in broadside direction. The array is split into two linear subarrays and fed in the middle through quarter-wave transformer. The cross polarization level of the array is improved by this type of symmetric arrangement. It also prevents the beam pointing direction from varying with frequency. In this way, the cross polarization generated from two opposite sides of the array are cancelled out in broadside direction. Unit cells are kept 4.4mm apart for the necessary prevention of the interference. The array is fed with center series fed technique. Dimensions of the array are given in the Table 3.

Parameters	Description	Value
D	Distance b/w unit cells	4.4
Wa	Array width	31
La	Array length	7
Wf	Centre fed	1
Wf1 = Wf2	Series fed	0.19

III. RESULTS AND DISCUSSION

In this section the simulated and measured results of the proposed unit cell design of the antenna are discussed. In Part A and Part B VSWR and S11 (dB) commonly known as voltage standing wave ratio and return loss of the microstrip patch antenna as a unit cell and series fed 1×4 array configuration are presented. Parts C, D and E explain 2D plots of the radiation patterns, current distribution and 3D gain plots, respectively, of both microstrip patch antenna as a unit cell and 1×4 array configuration.

(a) MICROSTRIP PATCH ANTENNA

A single circular microstrip patch antenna and its array is been simulated by using HFSS software. The simulated microstrip patch antennas is shown in the figure. Here substrate material used is Rogers RT/duroid 5880 height is h= 0.508mm εr=2.2.

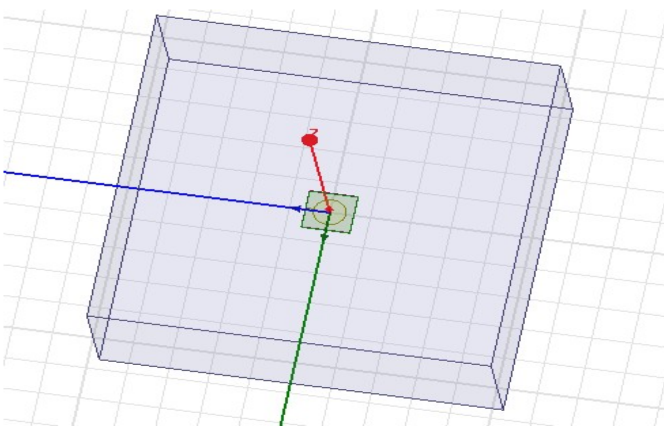


Fig 3. Simulated Single Microstrip Circular Patch Antenna

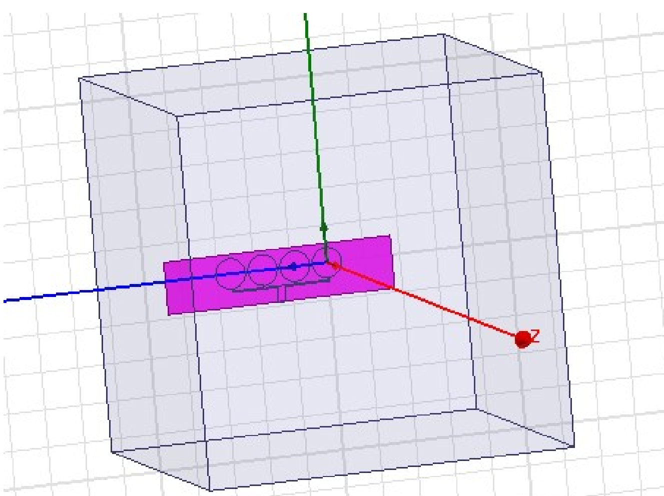


Fig 4. Simulated Microstrip Circular Patch Antenna Array

(b) RETURN LOSS

Return loss is the ratio of incident power to the reflected power of an antenna in decibels (dB). Return loss of an antenna is represented by S11 (dB). For an antenna to perform in effective way, S11 (dB) should be less than−10dB. The proposed antenna has S11 (dB) of −18dB at 28GHz, and array of the suggested antenna has return losses of −16dB at 28GHz as shown in Table. Graphs of both the unit cell and 1×4 array configurations are given in Figure.

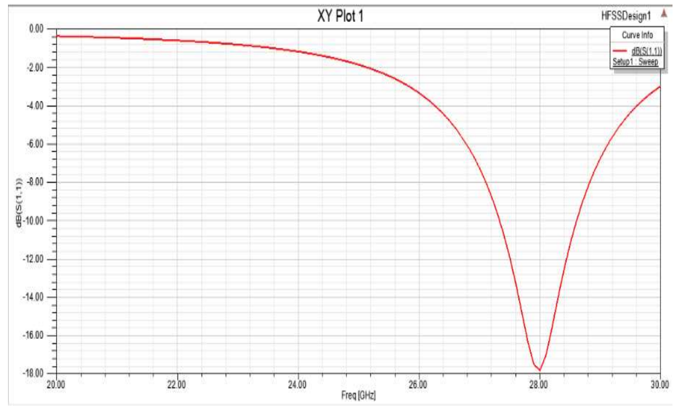


Fig 5. Return Loss of Unit Cell Microstrip Circular Patch Antenna

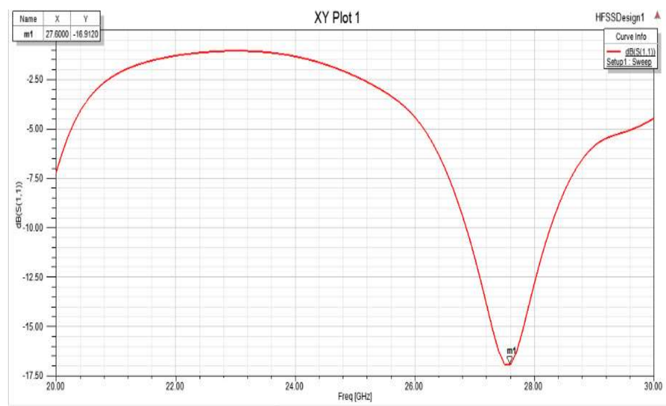


Fig 6: Return Loss of Circular Array

(C) VSWR

VSWR Impedance matching of the antenna and transmission line is a key factor in evaluating the antenna performance. VSWR parameter defines how well the impedance of antenna is matched with transmission line by taking the ratio of the reflected maximum and minimum voltage wave. A value of VSWR ≤ 2 is considered as the main requirement.

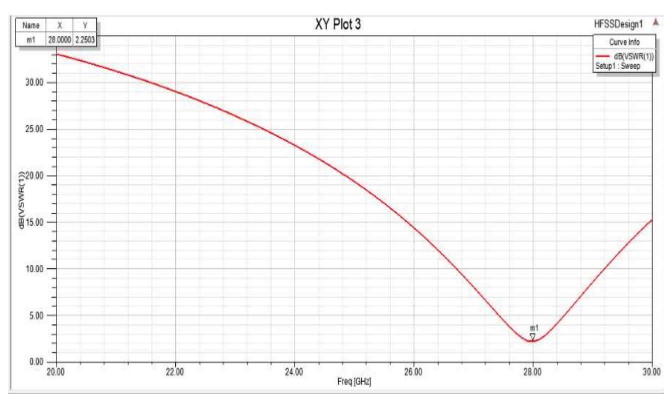


Fig 7: VSWR Plot For Unit Cell Circular Microstrip Patch Antenna

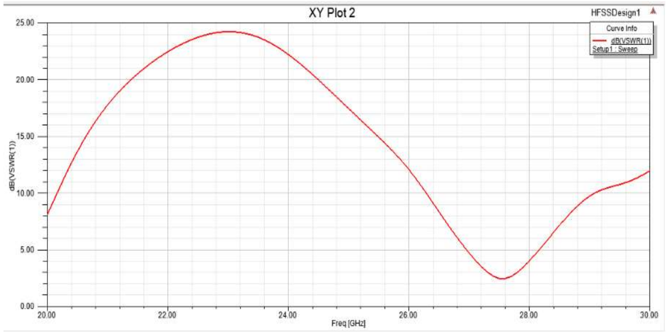


Fig 8: VSWR Plot For Microstrip Circular Patch Array

(d) 3D Gain Plots of the Proposed Antenna

Antenna gain is defined as the radio between the radiation intensity in a given particular direction and total input power. The radiation intensity Unexpressed the power radiated per solid angle. In terms of U the Antenna gain in a specified direction can be calculated.

G= $U\ Pin/4$

Radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. The antenna should not have the side lobes and back lobes ideally. Side lobes and back lobes cannot remove them completely but we can minimize them. Microstrip unit cell circular patch antennas can provide gain of 7.78dB. The resonating frequency is 28GHz.Similarly for radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. The antenna should not have the side lobes and back lobes ideally. Side lobes and back lobes cannot remove them completely but we can minimize them. Circular array can provide gain of 8.90dB

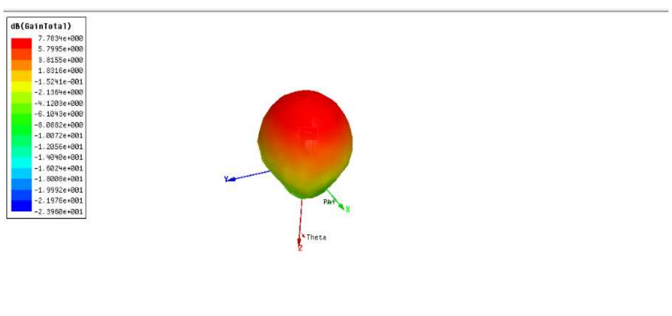


Fig 9: 3D Gain Plot Of Unit Cell Microstrip Patch Antenna

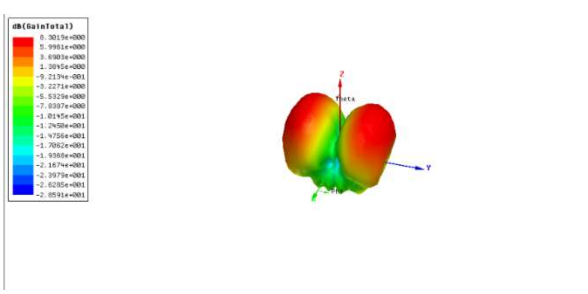


Fig 10: 3D Gain Plot Of Circular Patch Antenna Array

(e) RADIATION PATTERN

A radiation pattern defined as the variation of the power radiation from an antenna which is away from the antenna. The radiation pattern is a plot of the fare –field radiation properties of an antenna. The spatial coordinates which are specified by the elevation angle (ɸ) and the azimuth angle (Θ). It is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity. It can plotted as a 3D graph. It is an extremely important parameter as is show the antenna directivity as well as gain at various points in space.

A radiation pattern defines the variation of the power radiated by antenna as afunction of the direction away from the antenna. This power variation as a function of thearrival angle is observed in the antenna's far field.

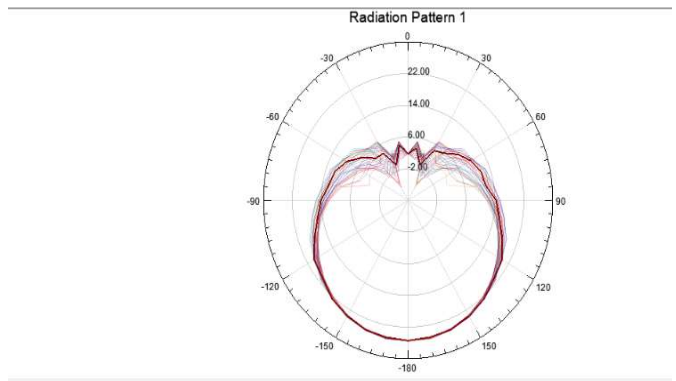


Fig 11: Radiation Pattern of Unit cell Circular Patch Antenna

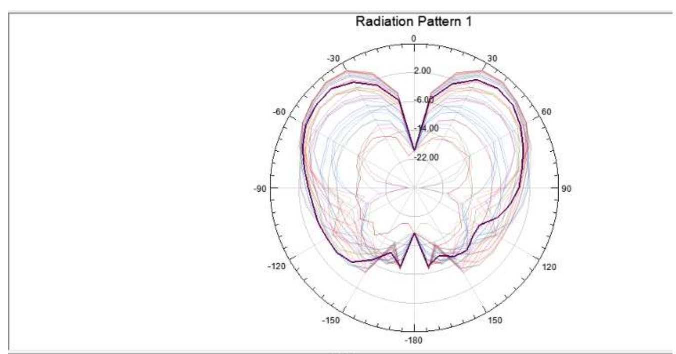


Fig 12: Radiation Pattern Of Circular Array

IV. CONCLUSIONS

The main goal of this project is to design and develop 5G antenna and it's array. A circular microstrip patch antenna with its array is presented for possible future 5G applications. The basics of microstrip fractal antenna are studied in detail and all the design considerations of the antenna is been examined. Thus here size reduction along with the large bandwidth and high gain are the major considerations for designing the antenna. According to the designing parameters the relevant feeding techniques are selected. A single microstip patch is designed and simulated using HFSS software. The 5G antenna is designed in an operating frequency 28GHz and simulated. The various design parameters such as return loss, VSWR, radiation pattern and gain are obtained using simulation. The antenna is further configured to an array of 1 × 4 linear elements to make it suitable for 5G mobile communication systems. This simple design is achieved on a Rogers 5880 substrate which resonates at millimeter-wave frequencies of 28GHz as a unit cell and with an array. These antennas can be used for 5G applications. The Millimeter wave microstrip patch antenna are simulated and can be further fabricated for 5G applications

ACKNOWLEDGMET

I gratefully acknowledge my guide for the support to complete this work and Wikipedia for the correct information source.

REFERENCES

[1]. **Hakimi, S. and S. K. A. Rahim,** "Millimeter-wave microstrip bent line grid array antenna for 5G mobile communication networks," 2014 Asia-Pacific Microwave Conference (APMC), 622–624, IEEE, November 2014.

[2]. **Ojaroudiparchin, N., M. Shen, and G. F. Pedersen,** "A 28GHz FR-4 compatible phased array antenna for 5G mobile phone applications," 2015 International Symposium Antennas and Propagation (ISAP), 1–4, IEEE, November 2015..

[3]. **Jandi, Y., F. Gharnati, and A. O. Said,** "Design of a compact dual bands patch antenna for 5G applications," 2017 International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS), 1–4, IEEE, April 2017.

[4]. **Reddy, N. K., A. Hazra, and V. Sukhadeve,** "A compact elliptical microstrip patch antenna for future 5G mobile wireless communication," IEEE Transactions on Engineering and Applied Sciences, Vol. 1, No. 1, 1–4, 2017.

[5]. **Loharia, N., S. B. Rana, and N. Kumar,** "5G futurecommunication: Requirements and challenges," 47 Mid-term Symposium on Modern Information and Communication Technologies for Digital India (MICTDI 2016), Chandigarh, India, 2016