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Design and Analysis of 28 GHz Circularly Polarized Micro Strip Patch Antenna for 5 G Applications

[1]Umesh Chandra , M-Tech Scholar [2] Om Mishra, Assistant Professor , [3]Manisha Yadav, Assistant Professor

[1,2,3]Institute of Engineering and Technology, Dr. Ram Manohar Lohia Avadh University, Ayodhya (India)

[1]email id:candraveenesh1981@gmail.com [2]email id:Shriohm18m@gmail.com

Abstract: In this article, a right hand circularly micro strip patch antenna is proposed for 5G applications. The square patch are designed and simulated. The size of the square patch is 3 mm x 3 mm x 0.508 mm. The impedance matching is done by using the quarter wave transformer. First, an antenna is designed with a resonating frequency of 28 GHz, and then a rectangular slot of dimension 0.8 mm x 0.16 mm. The various parameters, such as return loss, gain, radiation pattern, axial ratio etc., are investigated. It is found that the slotted patch antenna has a return loss of -32 dB with a band width of more than 1.8 GHz at a resonating frequency of 28 GHz. The axial ratio is 1.05 at the resonating frequency. The impedance matching is done by quarter wave transformer. The simulation of the proposed antenna is done by using HFSS tool.

Index Terms: 5G, patch antenna ,circular polarized

I.INTRODUCTION

The wireless mobile sector has progressed significantly in the last ten years. It has evolved from fourth-generation (4G) LTE systems to the fifth-generation (5G) LTE systems with the highest data rate (5G). The 4G wireless communication networks have been introduced in a number of nations. However, 4G does not alleviate several issues, such as high data speeds, congested spectrum, and high energy usage [1-5]. New call-handling technologies are being developed in response to the increased demand for telecommunications services. Each successive generation of mobile technologies has introduced faster data transmission, better connection quality, and new features. Since 2009, the fourth generation (4G) technology has been available in usage all over the world. A variety of new services, including those connected to the Internet of Things (IoT) and the notion of smart cities, will be enabled by the fifth generation (5G) network. The new technology will employ low, mid, and high frequency bands, each with its own set of benefits and drawbacks. However, deploying a 5G network on a large scale necessitates the construction of antenna infrastructure as well as the installation of new technological solutions. Apart from antennas for mobile devices, a large number of antennas will be deployed within buildings, particularly public utility buildings such as stadiums, train stations, and retail malls. At this stage, it's worth noting that antennas used in crowd-prone areas would be smaller than those used in existing macro cell transmitters. This is a crucial distinction and a common source of misunderstanding in public debate. The power is emitted according to the set spatial parameters in a typical antenna system. As a result, the geographical area in which users can be found is predetermined. The power of a 5G antenna, on the other hand, is directed and concentrated on individual users or groups of users. To focus on mobile users, antenna radiation directions can alter almost automatically [5-7]. Because of its unequalled qualities, the micro strip patch antenna is the most popular antenna design in wireless communication. Because the antenna is less in size, the end devices will be smaller as well. Antennas based on micro strips can be easily etched on any PCB. Microstrip patches come in a variety of shapes, such as rectangular, square, and triangular, and are easily etched. They have a reduced cost of manufacturing and can thus be mass produced. They can work with a variety of frequency bands (dual, triple). They support both linear and circular polarization types. They're not too heavy. [8, 9].

Millimeter wave radio frequency can serve as a foundation for the next generation of technology (5G). To meet the needs of the next generation, millimetre wave has untapped spectrum (3GHz-300GHz). 20-90GHz is the frequency range for 5G applications [7]. 5G antennas are built for frequencies of 28GHz, 38GHz, and 72GHz with bandwidths of 500 MHz, 1 GHz, and 2 GHz since they are all suited for high data rate and low latency systems [10, 11]. Because of the limited beam width, they can be employed for cellular applications [12, 13-17]. They are extremely directed and obstruction sensitive.

II. ANTENNA DESIGN

The antenna is designed on a substrate RT duroid 5880 of dielectric thickness 0.508 mm, relative dielectric constant of 2.2. The dimensions of the patch are calculated according to the following formulas [14, 15].

$$w = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \quad (3)$$

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

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

Where

c = Velocity of light in free space

f_0=Operating resonant frequency

ε_r = Relative dielectric constant

ε_{reff} =Effective dielectric constant of the substrate

h= Height of the substrate

w = Width of the substrate

The calculated dimensions of the patch antenna is Length (L) =3 mm and the width (W) = 4 mm, only the length is considered for the square patch. The edge impedance calculated by the following formula [9]

$$Z_{in}(R) = \cos^2\left(\frac{\pi R}{L}\right) Z_{in}(0) \tag{6}$$

Where $Z_{in}(0)$ is the input impedance when the patch feeds from the edge and, $Z_{in}(R)$ is the impedance at a distance R

$$G_1 = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{K_0 W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta d\theta \tag{7}$$

$$G_{12} = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{K_0 W}{2}\cos\theta\right)}{\cos\theta}\right]^2 j_0\left(K_0 L_p \sin\theta\right) \sin^3\theta d \tag{8}$$

$$Z_{in} = \frac{1}{2(G_1+G_{12})} \tag{9}$$

Where $K_0 = \frac{2\pi}{\lambda}$ is free space wave number and j_0 the Bessel function of the first kind of order zero and *W* patch width [9].

The calculated edge impedance is 144 Ohm. The input impedance of a transmission line of length L with characteristic impedance Z_0 and connected a load with impedance Z_A given by equation (10).

$$Z_{in} = Z_0\left[\frac{Z_A + jZ_0\tan(\beta L)}{Z_0 + jZ_A\tan(\beta L)}\right] \tag{10}$$

Here $\beta=\frac{2\pi}{\lambda}$ is the phase constant and λ is the wavelength of the electromagnetic signal. If the length of the transmission line is one fourth of the wavelength then the input impedance of the line becomes

$$Z_{in} = Z_0\left[\frac{Z_A + jZ_0\tan\left(\frac{2\pi\lambda}{\lambda\ 4}\right)}{Z_0 + jZ_A\tan\left(\frac{2\pi\lambda}{\lambda\ 4}\right)}\right] \tag{11}$$

So the result is

$$Z_{in} = \frac{Z_0^{\ 2}}{Z_A} \qquad (12)$$

So the characteristics impedance of the quarter wave transformer is $Z_0 = \sqrt{(144 * 50)}$ =84.8 Ohm .The width of the Quarter wave transformer and feeding micro strip line is calculated for characteristics impedance of 84.8 Ohm and 50 Ohm respectively from the following formulas.
For $\frac{w}{h} \geq 1$

$$\varepsilon_0 = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \qquad (13)$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}\left[\frac{w}{h}+1.393+0.667\ln\left(\frac{w}{h}+1.444\right)\right]}} \qquad (14)$$

The calculated width of the micro strip line is 1.56 mm and the width and length of the QWT is 0 .64 mm and 2 mm respectively. Figure 1. Shows the designed micro strip patch antennas.

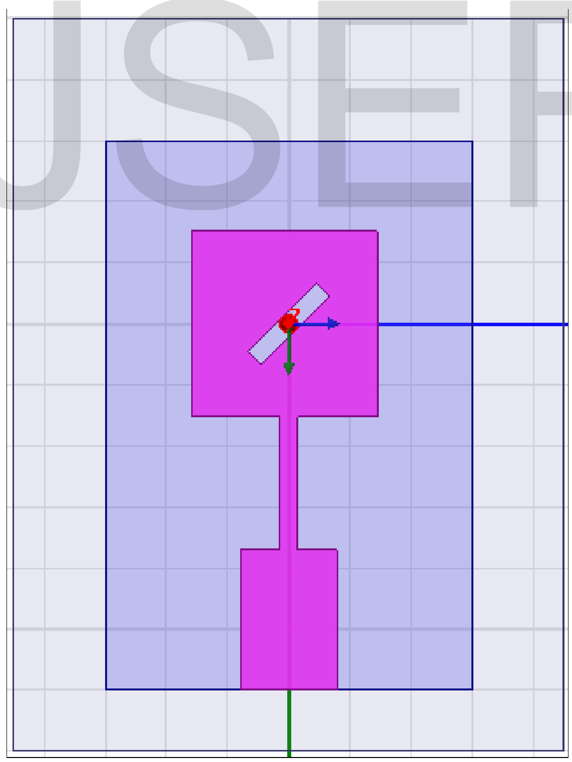

Figure 1. Designed microstrip patch Square patch antenna

III. RESULTS AND DISCUSSIONS

Figure 2. Shows the return loss vs frequency comparison curve for the designed micro strip patch antennas.

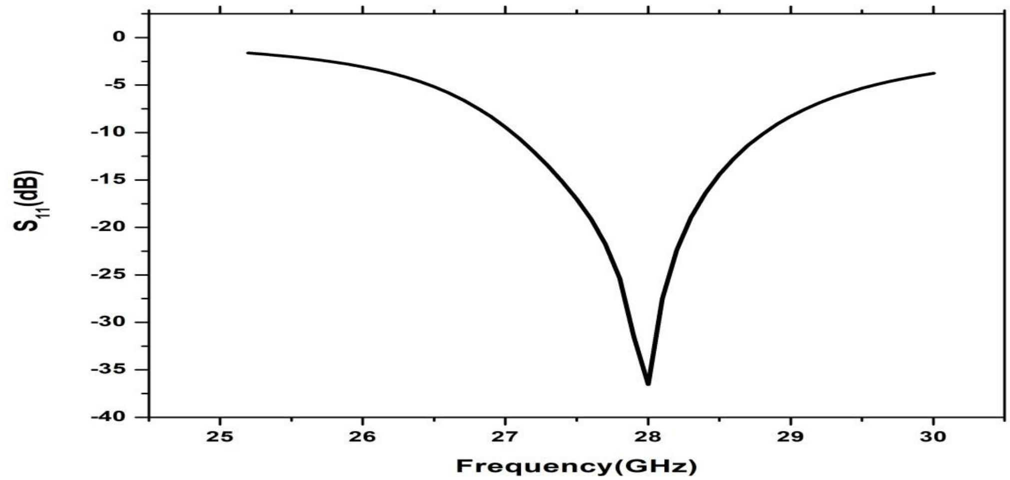

Figure 2. Return loss vs frequency comparison curve

From the above curve it is shown that the antenna without slot resonates at a single frequency 28GHz and antenna with the parallel slots in the patch resonates at dual frequency 28 GHz. The achieved bandwidth at 28 GHz is 1.8 GHz with a return loss of -37 dB and at. Figure 3 shows gain curve of the designed antennas. It is found that at a frequency of 28 GHz the total gain is around 6.5 dBi.

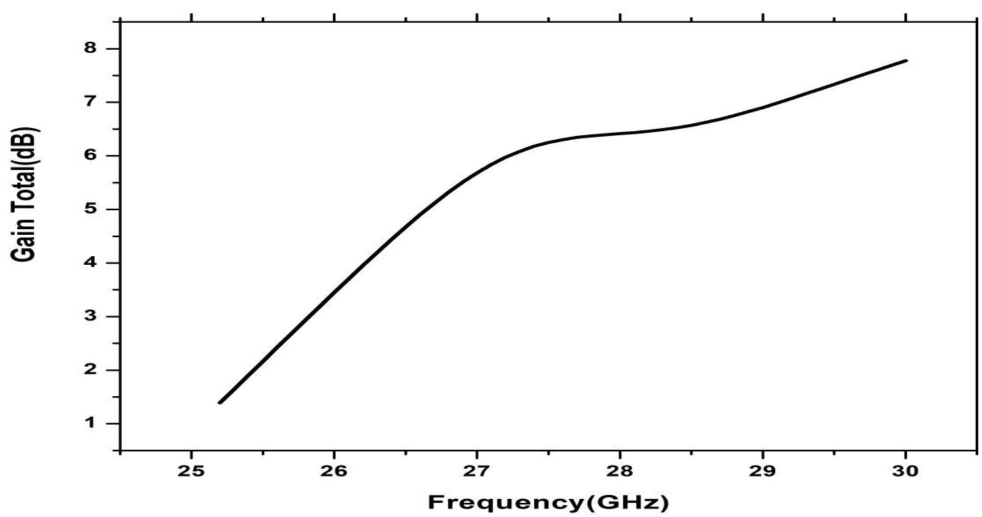

Figure 3. Gain vs frequency curve

Figure 4 shows the axial ratio of the proposed circular polarized microstrip patch antenna. It is seen from the above curve that at the resonating frequency of 28 GHz the axial ratio is 1.05 this is equal to the ideal value 1

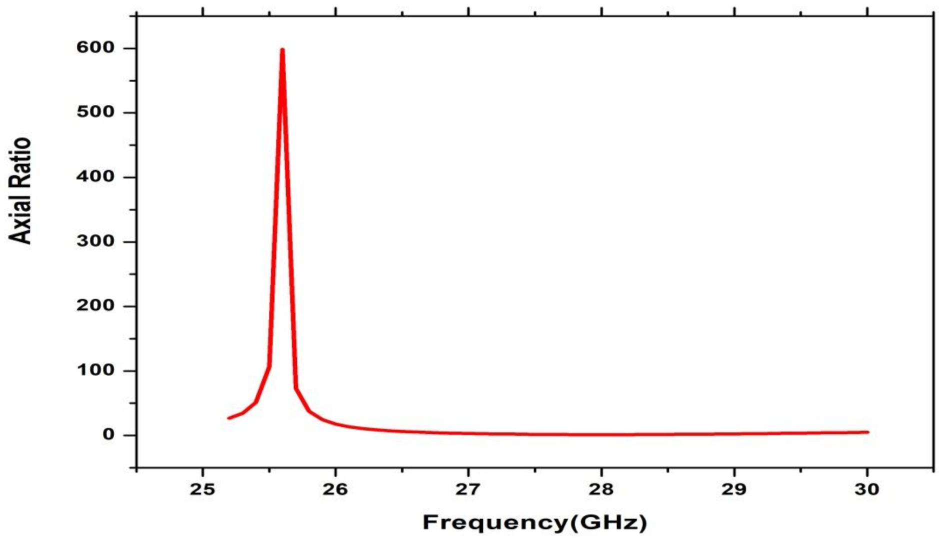

Figure 4. Axial ratio vs frequency curve

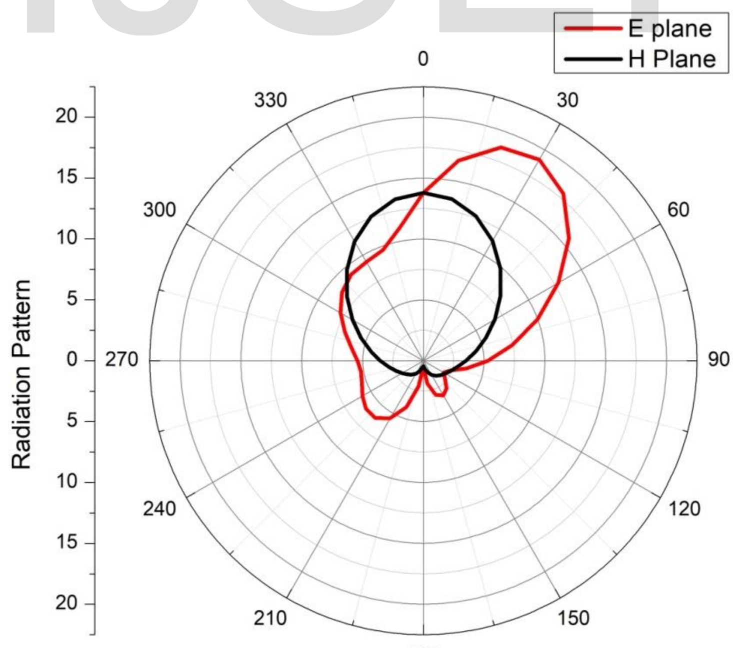

Figure 5 Radiation pattern at 28 GHz

Figure 7 shows the E plane and H plane radiation pattern of the circularly polarized micro strip patch antenna It is seen from both of the curve that at the resonating frequencies E plane and H plane radiation pattern is good.

V. CONCLUSIONS

In this work, a right hand circular polarized micro strip antenna is presented by making an rectangular slot in the radiating patch to produce a circularly polarized micro strip antenna for 5G applications; the antenna was simulated using HFSS software on RT duroid substrate with 2.2 relative dielectric constant, 0.508 mm thickness. Therefore, the proposed slotted antenna can be operated with good performance at the desired band (27.1–28.9 GHz), which can be used properly for 5G mobile communication system.

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