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Design and Analysis of Micro Strip Patch AntennaSWR Antenna Metamaterial 28 GHz

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ABSTRACT

The popularity, demand, and usefulness of 5G Communication Systems are rapidly increasing. Since the future of 5G Communication systems requires higher gain and efficiency, a rectangular microstrip patch antenna has been designed in this project. The proposed model has a better return loss and a healthy efficiency characteristic. The operating frequency of 28 GHz (Ka-band) was used here, one of the prominent frequency bands for 5G communication. The Patch's architectural structure is 7.885 mm*8.935 mm*0.5 mm, with the help of a return loss of -48.309 dB, a gain of 7.425 dB, VSWR of 1.007129, and directivity of 8.141 dBi have been achieved in the proposed model. Also, the efficiency of 91.16%, Bandwidth of 1.2 GHz, and a surface current of 760.4 A/m were successfully achieved, which is also helpful for faster 5G communication. Considering all these mentioned parameters, the designed antenna can be suitable for 5G communication technology soon.
Keywords—5G Communication, Ka-Band, Microstrip Patch Antenna, Feedline, Gain, VSWR, Radiation efficiency, MillimeterWave, HFSS.

I. INTRODUCTION

The fifth-generation wireless technology (5G) is the latest in cellular technology designed to increase network speed and wireless networks [1]. With the 5G communication system architecture, data transmitted through cellular broadband networks will fly at very high speeds (in the scale of Megabits), with a theoretical peak bandwidth of up to 20 Gigabits per second (Gbps). However, these speeds exceed the wire line network speeds and provide around one-millisecond latency or even less, useful for applications that require feedback in realtime. Following that, 5G allows a sharp improvement in the amount of data transmitted over wireless networks due to the usable spectrum's utilization and improved antenna technologies to a great extent [2]. Considering the current situation, a healthy number of countries of the world have entirely shifted their communication system to 5G networks. Other countries are also planning to deploy the 5G networks and infrastructure systems stepwise over the next few years to meet the growing reliance on smartphones and internetenabled technology. However, cellular networks consist of cell sites separated into numerous sectors that relay the data with radio waves' help [3]. The fourth-generation (4G) Long-Term Evolution (LTE) systems provide the foundation for 5G network systems. Considering the 4G systems, which require extensive and high-powered tower cells for radiating signals over longer distances, the 5G wireless signals are transmitted through large numbers of small station cells located in various places such as roofs or light poles. Multiple small cells are required because of the millimeter-wave (MM wave) frequency between 25 and 310 gigahertz (GHz) [4]. Considering numerous issues, the telecommunications sectors are now exploring the use of a low-frequency band for 5G networks so that network providers could use the band they currently own to build up their new structures. There are microstrip patch antennas with better data transfer speed, efficiency, lightweight, and lower fabrication cost [5]. The current 4G network technology cannot meet modern wireless technology demand as they are significantly rising [6]. Several bands are aimed at 5G systems, and one of them is 28.5 GHz, which lies under the Ka-Band. Proceeding to these millimeter waves will create modern challenges in designing antennas for smartphone devices and base station towers. However, there are numerous negative issues of using millimeter-wave frequencies, such as propagation loss, path loss, signal attenuation, and atmospheric distractions [7]. For overcoming these challenges, high gain and high directional antennas are required that can be applied to overcome the difficulties existing at millimeter-wave frequencies, such as path loss and propagation loss. The problem with using these high-frequency bands is that the path loss or free space loss is intense in these bands, which results in the deterioration of signal to interference plus noise ratio (SINR) [8]. In this paper, the proposed rectangular microstrip patch antenna introduces a high realized gain of 7.425 dB and a value of higher return loss of -48.309 dB, which are the essential requirements for overcoming future challenges of 5G Wireless Communication Systems. In the proposed model, an efficiency of over 91% and a bandwidth of 1.2GHz have been achieved. The antenna model also provides a higher realized gain and a higher return loss than many other referred works, which means the proposed design works more efficiently.

II. THEORY AND METHODOLOGY

For simplified analysis and better performance in the 5G Communications Systems genre, a rectangular-shaped microstrip patch antenna operating at 28.5 GHz for 5G application purposes has been proposed. Figure 1 shows the geometric orientation of the proposed model in free space.

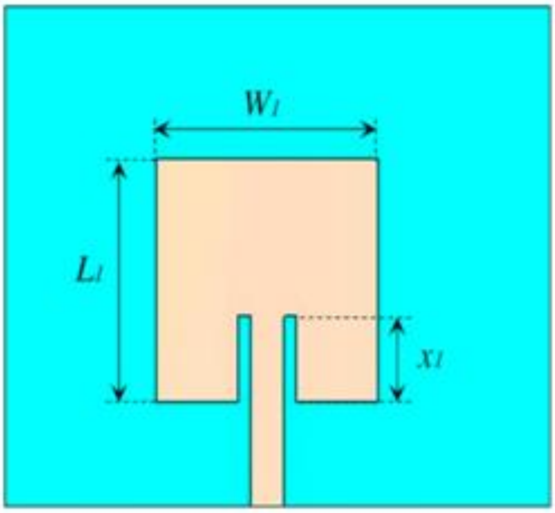


Fig. 1. The Geometry of the proposed Microstrip patch antenna (in free space)

At first, the range of frequency consisting of the maximum and minimum magnitude of the frequency is set, which resides as the 31GHz and 25GHz, respectively. Then, the substrate material Rogers RT5880 (lossy) was chosen along with the operating frequency of 28GHz was being selected, which has been used for calculating the Width of the Patch (W) and the Length of the Patch (L) simultaneously by using Equation 1 [9].

$$\boldsymbol{w} = \frac{C_\circ}{2f_{r}\frac{\sqrt{\varepsilon_{r+1}}}{2}} \quad (1)$$

Here Co represents the electromagnetic wave velocity in the free space that is 3*108 m/s. The fr represents the operating frequency of 28GHz and dielectric constant Ɛr of 2.2 Then using Equation 2, the Effective Dielectric Constant, εreff is calculated [9].

$$\epsilon_{reff=\frac{\varepsilon_{r+1}}{2}+\frac{\varepsilon_{r-1}}{2}\left(1+12\frac{h}{w}\right)-0.5} \quad (2)$$

Here, the h represents the thickness of the substrate of 0.5mm, and W represents the Patch width having the unit of mm.

Using the calculated value of the Effective Dielectric Constant εreff and Equation 3, the Effective Length, Leff is calculated [9].

$$\mathbf{L}_{\mathbf{eff}=\frac{c_\circ}{2f_{r}\sqrt{\varepsilon_{reff}}}} \quad (3)$$

Due to the fringing factor, the antenna's path is electrically longer compared to the physical dimensions. As a result, this fringing factor is subtracted from the effective length for determining the Patch's actual length, shown by Equation (4) [9]

$$\Delta\boldsymbol{L} = \mathbf{0.412}\,\frac{\left(\frac{w}{h}+0.264\right)\left(\varepsilon_{reff+0.3}\right)}{\left(\varepsilon_{reff-0.258}\right)\left(\frac{w}{h}+0.813\right)} \quad (4)$$

Here ΔL represents the length extension. Using the calculated value of ΔL and Equation 5, the Patch's actual length is determined [9].

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

Following that, using the specified formula, the respective values of the Ground Plane Width, Wg, and the Ground Plane Length, Lg, are being calculated using the following Equations.

Lg=2*L & Wg=2*W

Here L is the Patch's actual length, is the actual width of the Patch. However, the value of the Height of the Substrate, hs, has been chosen randomly, which has the dimensions of 0.5mm. After that, using Equation 6 the Feedline Insertion Fi has been constant and

actual length of the Patch [9]:

$$F1 = 10^{-4}\{0.001699\varepsilon_r^7 + 0.13761\varepsilon_r^6 - 6.1783\varepsilon_r^5 + 93.187\varepsilon_r^4 - 682.69\varepsilon_r^3 + 2561.9\varepsilon_r^2 - 4043\varepsilon_r + 6697\}\,{}^{L}/_{2} \quad (6)$$

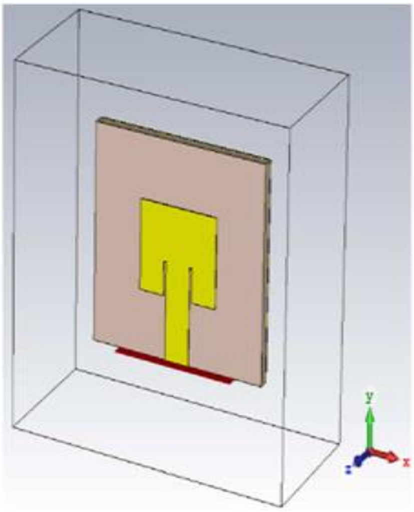
The proposed model of the antenna was connected to a 50ohm inset feed transmission feedline. However, the gap between the Patch and the Feedline is 0.12mm. In addition to it, the value of the Ground Thickness ht was randomly selected, and using Equation 7, the Width of Feedline Wf has been calculated [9].

$$w_f = \frac{7.48 \times h_s}{e^{\left(z_0 \frac{\sqrt{\varepsilon_r + 1.41}}{87}\right)}} - 1.25 \times h_t \quad (7)$$

Here, Z0 is the input impedance (in ohm), and ht is the ground thickness in the range of mm. Considering all the above Equations, the microstrip patch antenna's proposed model was designed using the hfss Studio Suite 2016 software.

III. DESIGN SPECIFICATION

The simulated design, its geometry, along with its respective different views, was determined using CST. Figure 2-7 shows the perspective, front, back, sideways, top, and bottom views of the microstrip patch antenna's proposed model.



Fig, 2. Perspective View (in free space)

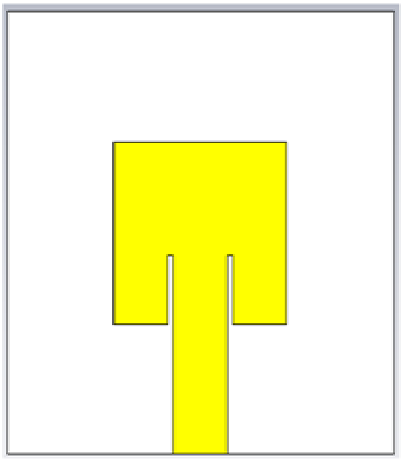


Fig. 3. Front View of the Proposed Design

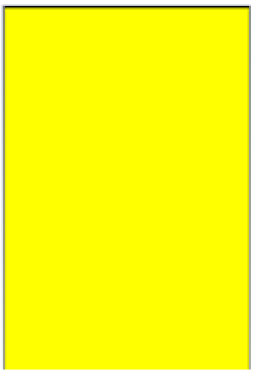


Fig. 4. Back View of the Proposed Design

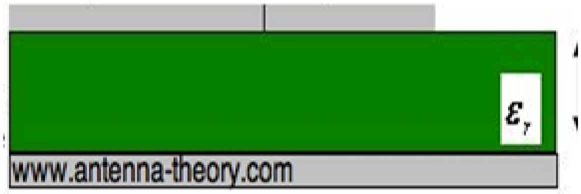


Fig. 5. Top View of the Proposed Design

The parameters that have been used in this proposed rectangular microstrip patch antenna are given below:

Parameter Descriptions along with their symbols	**Dimension (mm)**
Width of Patch, W	4.44
Length of Patch, L	2.8094
Width of the Ground plane, Wg	8.5
Length of the Ground plane, Lg	5.61
Width of Feedline, Wf	1.3
Feedline Insertion, Fi	1.25
Height of Substrate, hs	0.5
Ground Thickness, h	0.035

IV. SIMULATION RESULTS

A. Return Loss

In the telecommunication systems genre, return loss represents the magnitude of the signal that returns or reflects off the antenna either due to the optical fiber or the transmission line system's discontinuity. It is always measured in terms of dB [10]. A small magnitude of return loss is not that feasible, which means less energy is being passed to the antenna. Therefore, a higher magnitude of return loss is always preferable. Figure 8 shows the return loss of the proposed patch antenna that resonates at 28.462GHz. As per Figure 7, the Return Loss (S1,1) has a value of -48.309 dB and a bandwidth of 1.2GHz. However, this value of the S1,1 parameter was successfully achieved using the waveguide port configurations, where a sharp lower peak was reached successfully.

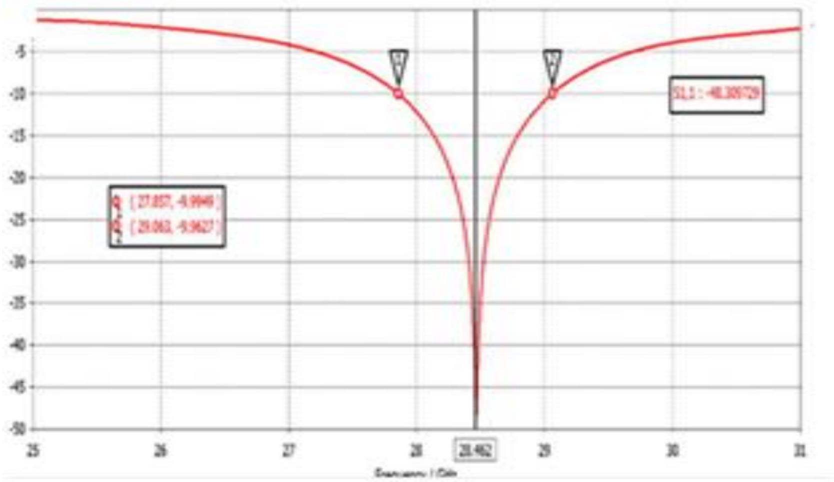


Fig. 7. S-Parameter vs. the Frequency (in free space)

B. VSWR

For delivering the required power to the desired antenna, the transmission line's impedance and the antenna must match appropriately to a significant extent. This is where VSWR plays an important role. VSWR stands for the Voltage Standing Wave Ratio, sometimes called VSWR, and is the measure of how efficiently the power of radiofrequency is transmitted from a specific power source into the load through a transmission line [11]. It can also be said that VSWR is a coefficient that resembles the power that reflects off the antenna. However, a lower magnitude of the VSWR means that the antenna is matched with the transmission line, and therefore more power is delivered to the antenna. Thus, it can be deduced that the lower the VSWR, the better it is. Figure-9 shows the obtained VSWR of the proposed antenna model, which is 1.0077129 at the operating frequency of 28.462GHz.

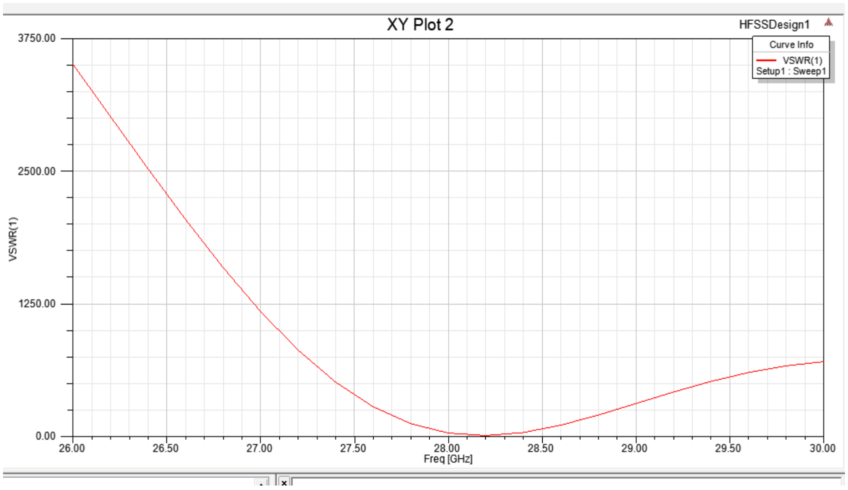


Fig. 9. VSWR vs. the Frequency (in free space)

C. Gain & Directivity

The Gain and Directivity are two essential parameters for assessing the performance of a specific antenna. Figure 10, Here, the gain represents the power transmitted to the main beam, while the directivity represents the measurement of the concentration radiation in a particular direction [12]. Figure9 portrays a brief idea about the proposed antenna model's Gain performance, including its 2D & 3D Polar Gain plots. In addition to it, Figure 13 & 14 respectively gives an overview of the 3D Plot and 2D Polar plot radiation pattern in the free space. For the proposed model, a gain of 7.425dB and a directivity value of 8.141dBi have been successfully determined from the simulation.

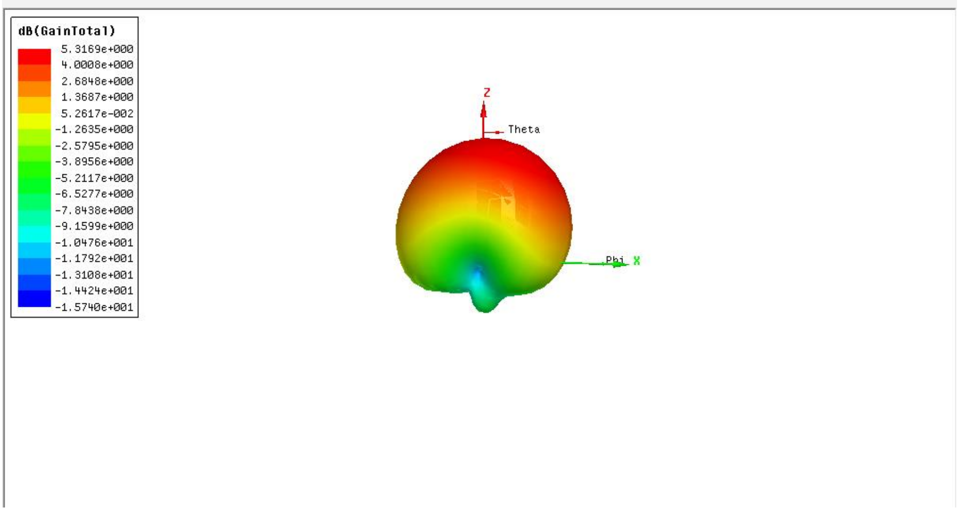


Fig. 10. 3D Plot of Gain of the proposed antenna (in free space)

TABLE II. Summary of the Obtained Parameters of the proposed antenna

Antenna Parameter	Values
Bandwidth	1.2 GHz
S 1,1	-48.309 dB
Gain	7.425 dB
VSWR	1.007129
Efficiency	91.16%
Radiation Efficiency	-0.7217
Directivity	8.141 dBi

V. RESULT ANALYSIS

This study has proposed a 28.5GHz rectangular microstrip patch antenna for the 5G communication systems. Firstly, the patch and ground plane's length and width have been calculated using the given formulas. After that, those estimated parameters were used to implement the simulation of the proposed model in the software. From the simulated result and the calculations, as per the magnitude of all the free space parameters, the proposed antenna has a very high gain, a healthy radiation efficiency, good VSWR, and a better bandwidth at the operating frequency of 28.462 GHz. Considering these parameters, the antenna is expected tooperate effectively for the 5G wireless communication network soon.

VI. CONCLUSION

For the next-generation 5G communication technology, there will be a necessity for high gain and adequate protection from path loss because of the antenna's mm wavelength. Considering the demand and numerous advantageous applications of 5G Communication Systems, in this paper, using the hfss software, a Microstrip Rectangular Patch Antenna model has been proposed that operates at a resonant frequency of 28.462 GHz. Moreover, in this paper, numerous parameters of the proposed model have been portrayed. The designed antenna model has an S1,1 value of -48.309 dB and a gain magnitude of 7.425dB with a bandwidth of 1.2GHz in the free space. The size of the model has been kept very compact so that it occupies less space. It also has a radiation efficiency of -0.7217 dB and an overall efficiency of 91.16%, definitely taking its effectiveness to a staggering altitude. The gain and efficiency that have been achieved in this proposed model can be easily upgraded for overcoming the challenges of the 5G Communication Systems.

VII. REFERENCES

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