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Research Article

Design and implementation of Triple Frequency Microstrip patch antenna for 5G communications

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ABSTRACT

Wireless Communication has evolved over the past three to four decades, the evolution brought about major changes in the type of technology been used, the speed of data transfer, capacity latency, and network coverage, amongst several other key factors. In this paper we are going to design a microstrip patch antenna for 5G applications using 5G wave range of 24.5 to 50 GHz. This design is simulated and analyzed using HFSS software. The proposed antenna resonated at triple frequencies 31 GHz, 34.2 GHz and 38.4 GHz by using slotting techniques of good return loss, high gain and VSWR<2. This proposed design has benefit for the wireless communications and high-speed internet.

Keywords: Capacity latency, microstrip antenna, Network coverage, return loss, wireless communications.

I. Introduction

We all know 5G is revolutionizing the world today, not just in "fast internet" but in so many areas like IoT, Autonomous Vehicles, Space Communications, and more. 5th generation wireless systems, abbreviated 5G, are improved networks deploying in 2018 and later and may use existing 4G or newly specified 5G Frequency Bands to operate. 5th generation wireless systems, abbreviated **5G**, are improved networks deploying in 2018 and later and may use existing 4G or newly specified 5G Frequency Bands to operate. The primary technologies include: Millimetre wave bands (26, 28, 38, and 60 GHz) are 5G and offer performance as high as 20 gigabits per second; Massive MIMO (Multiple Input Multiple Output – 64-256 antennas) offers performance "up to ten times current 4G networks". However, you need high-speed data rate and large bandwidth during the streaming of ultra-high-quality videos. This existing 4G data rate cannot handle for such viewing 4K/8K Ultra high. Here, to get high frequencies, designed a microstrip patch antenna of rectangular shape patch using 5G millimetre wave bands.[1]

The frequency bands for 5G wireless technology are classified into FR1 and FR2 frequency ranges. FR1 (4.1 GHz to 7.125 GHz) band of frequencies are used for carrying most of the traditional cellular mobile communications traffic, while the FR2 (24.25 GHz to 52.6 GHz) band of frequencies are focused on short-range, high data rate capabilities.[2]

Microstrip patch antennas have been widely used in the field of wireless communications like mobile, radar and satellite because of its unique features such as compact size, ease of fabrication, low profile, less weight, and ease of installation.[3]

Now days, the antenna with multiband and wideband characteristics are more preferred in the wireless systems [4]. These antennas can work on different applications when installed on wireless devices. Using multiband or wideband antennas a single device can be used for various wireless applications under specified range of frequencies [5]. Due to these features and large demand, microstrip antennas become a major area of research for the researchers [6]. Numerous researches have been carried out in recent years by the researchers to achieve multiband and wideband applications [7]. Slotted patch antennas are designed to achieve multiband characteristics [8]. But few drawbacks have been observed in this antenna design such as it exhibits less bandwidth and less value of gain [9]. These antennas can be capable of work under various wireless applications such as WiMAX, WLAN, Wi-Fi, Bluetooth, satellite communication and radar communication [10].

Microstrip patch antenna has a vital role in the field of wireless communication. It has a dielectric substrate, ground plane and thin metallic patch of copper or gold. The patch and the ground plane have separation from the dielectric substrate. There are different types of patch antennas such as circular, rectangular, square, elliptical, triangular and dipole [2]. The most generally used Microstrip antennas have a circular and rectangular shape. These two patch antennas have the most demanding applications especially in the field of 5G applications.

In this paper rectangular microstrip patch antenna is designed to radiate at multiple frequencies by using slotting.

II. Antenna Design And Configuration

Proposed antenna is designed by using the frequency of 26 GHz, which lie in the range of 5G application. The rectangular microstrip patch antenna has the best configuration among all geometry of patches available and therefore it is widely used [11]. To design this that best suited for 5G application like e-learning, choosing the best electric substrate with a lesser dielectric constant is important in which used Rogers RT/ Duroid substrate materials with substrate height of 0.65 mm with dielectric loss tangent of 0.0010. The next important step is finding out the length and width of the patch from equation (2) and (1) respectively.

Table I. Design Parameters Of An Antenna

Parameters symbols	Parameters	Value(mm)
W_s	Width of Substrate	6.0
L_s	Length of Substrate	6.0
W_f	Width of Microstrip line feed	0.6
L_f	Length of Microstrip line feed	2.0
h	Height of Substrate	0.65

The following equations for the design are used to determine the width and length of patch [12],

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

where c is the velocity of light, f_r is the resonant frequency ar ε_r is the dielectric constant of substrate.

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

where L_{eff} is effective length of the patch given as follows

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

where ε_{eff} is the effective dielectric constant given as follows

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{W} + \frac{\varepsilon_r-1}{W}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad (4)$$

and ΔL is the extended incremental length given as follows

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (5)$$

The figure shows the rectangular microstrip patch antenna with dimensions in the table 1.

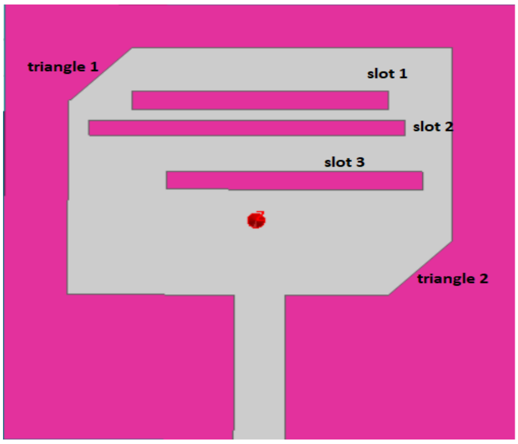

Fig.1: Rectangular microstrip patch antenna with slotted patch

Slotting in patch

In this antenna to get the multiple frequencies slotting techniques. As shown in the above figure 1 three slots are inserted in the patch of the antenna, which are rectangular in shape. The length and width of the 1st slot is 0.25mm and 3mm respectively. The 2nd slot length and width are 0.21mm and 3.7mm respectively. The 3rd slot length is 0.25mm and width is 3mm. The length is measured in x-axis and width is measured in y-axis.

Table 2. Dimensions Of Rectangular Slots

	Length(mm)	Width(mm)
Slot 1	0.25	3
Slot 2	0.21	3.7
Slot 3	0.25	3

These rectangular slots are inserted to get the antenna radiate at multiple frequencies. By moving the position of these rectangular slots, the number of frequencies the antenna radiated at differ. In the patch along with the rectangular slots, two cuttings are made using two triangles in the patch diagonally. These triangles are formed using three lines each and each line is made by two points.

Table 3. Dimensions Of Diagnol Cuts(Triangles)

	Triangle 1	**Triangle 2**
Point 1	(-2.4, -2.25) (-2.4, -1.5)	(1, 2.25) (0.25, 2.25)
Point 2	(-2.4, -1.5) (-1.65, -2.25)	(0.25, 2.25) (1, 1.5)
Point 2	(-1.65, -2.25) (-2.4, -2.25)	(1, 1.5) (1, 2.25)

By using this slotting techniques, we got three frequencies that are within in the range of 5G frequency band range(<50GHz) and are 31 GHz, 34.2GHz and 38.4 GHz.

III. Simulation Results And Analysis

This section presents the complete detail of simulated performance parameters of the proposed antenna such as return loss, VSWR, gain and radiation pattern. All the parameters have been obtained by using Finite Element Method (FEM) based simulator called High Frequency Structure Simulator (HFSS) version 13.0.

A. Reflection coefficient

Reflection coefficient is also called as return loss and is denoted by (S11). The performance of antenna generally depends upon a good reflection coefficient or return loss of at least -10 dB or greater than -15 dB because return loss in antenna is a ratio of incident power to that of reflected power. Consider that the reflection coefficient is 0 dB then nothing has radiated as all the power have reflected from antenna [13]. As shown in Fig.2, it has seen that the return loss is -23.63 dB at 31 GHz and is -22.93 dB at 34.2 GHz and is -21.48 dB at 38.4 GHz.

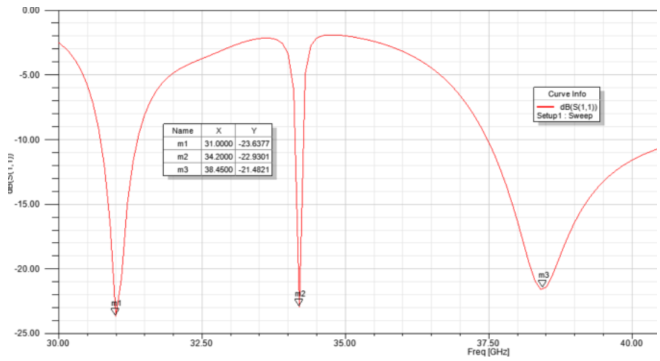

Fig.2: Return Loss

B. Voltage Standing Wave Ratio

The voltage standing wave ratio is also termed as standing wave ratio. For microstrip patch antenna design to be used for 5G applications this ratio should be in the range 1⩽VSWR⩽2 [13]. This ratio is always considered as real and positive real number. Higher the value of VSWR greater the mismatch. Hence, the proposed microstrip rectangular patch antenna has a value of 1.14 at 31 GHz and of 1.24 at 34.2 GHz and 1.46 at 38.4 GHz as shown in the figure.3.

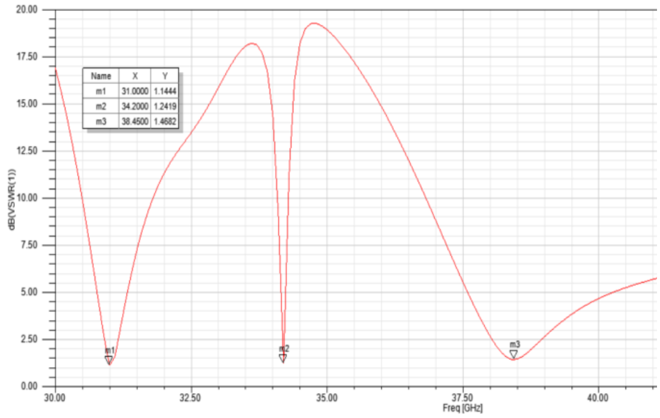

Fig.2: Voltage Standing Wave Ratio

C. Gain

The efficiency and the directional capability of antenna can be represented or analysed by gain of antenna and it is expressed in decibels.

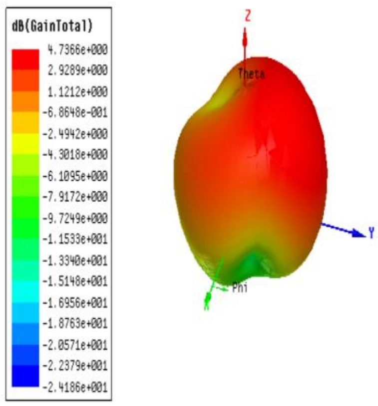

Fig.3: 3d Polar Gain Total Plot In Db Of Proposed Antenna Design At 31 Ghz

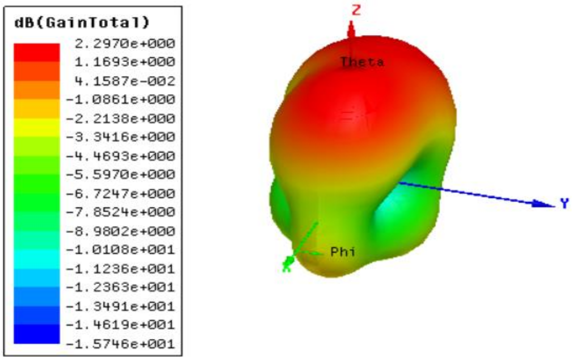

Fig.4: 3d Polar Gain Total Plot In Db Of Proposed Antenna Design At 34.2 Ghz

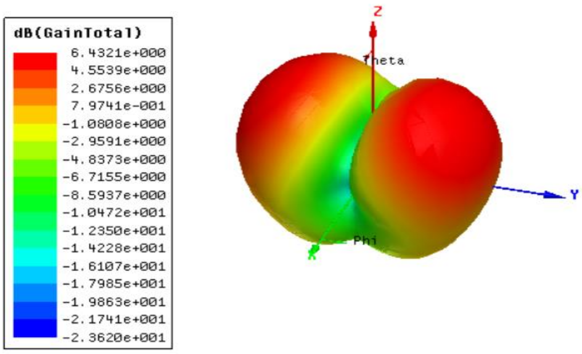

Fig.5: 3d Polar Gain Total Plot In Db Of Proposed Antenna Design At 38.4 Ghz

3D polar gaintotal plot in dB of Proposed Antenna Design with optimized dimensions using RT5880 substrate

From the fig.3 the gain achieved is 4.73 dB at 31 GHz and from fig.4 the gain is 4.15 dB at 34.2 GHz and is 6.432 Db at 38.4 GHz. From the figures 3 to 5 the maximum gain achieved is 6.4321 dB at 38.4 GHz in fig.5.

D. Radiation pattern

Radiation pattern graphically represents the field strength variation of the radio waves. The figures show 2D radiation pattern of high gain. High gain is very much required for 5G wireless system because this radiation patterns indicates the quantity of power radiated by antenna.

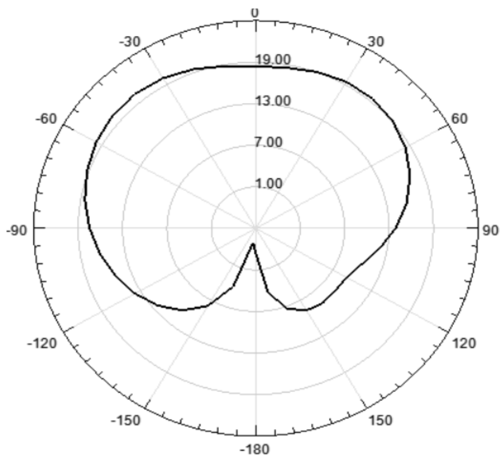

Fig.5: Plot Of 2d Radiation Pattern With Phi=0 Deg At 31 Ghz

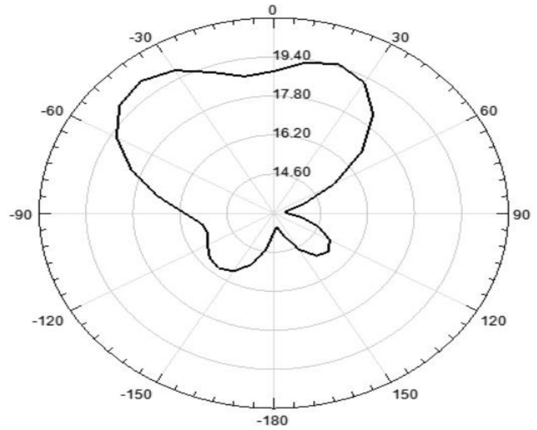

Fig.6: Plot Of 2d Radiation Pattern With Phi=0 Deg At 34.2 Ghz

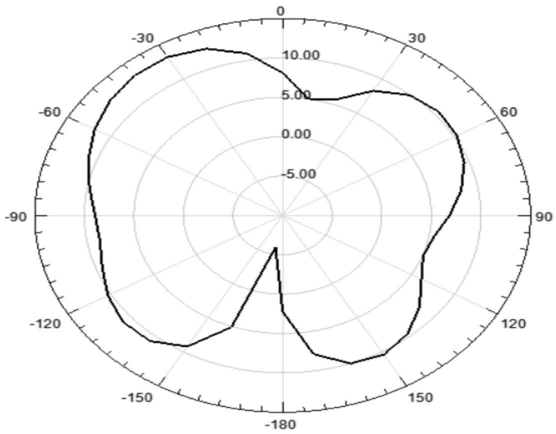

Fig.7: Plot Of 2d Radiation Pattern With Phi=0 Deg At 38.4 Ghz

IV. Conclusion and Future Scope

Our proposed microstrip rectangular patch antenna is designed and successfully implemented using HFSS software. The proposed design operates at three frequencies

by inserting slots in the rectangular patch. The proposed design of Microstrip patch antenna has higher gain for good signal strength, also one can download and upload other 4K/8K ultra-high definition content and other 5G applications for better and good return loss, voltage standing wave ratio. The future scope is, proposed antenna can radiate at multiple frequencies by making slots in patch and adjusting their positions and can obtain greater bandwidth, better return loss and higher gain by configuring antenna with array elements.

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