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A Slotted Planar Antenna for 5G Applications

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Abstract: This paper presents a slotted planar microstrip patch antenna for the 5th generation communication. The planar microstrip patch antenna is designed with a square patch and two longitude slots at 3.5 GHz, using FR4 substrate and feds by a coplanar waveguide structure (CPW). The proposed antenna was simulated, analysed, and optimized using computer simulation technology (CST) software. Simulation results show a good return loss of greater than10 dB and impedance bandwidth of about 650MHz, which meet the requirements of future 5G applications. In this work, the geometry of the presented antenna and its related parameters are presented and discussed.

Keywords: Planar Antenna,5th Generation ,Coplanar Waveguide (CPW), CST.

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1. INTRODUCTION

Nowadays, 5G technology is suggested to provide huge communications and capacity to accommodate such communications. A cell's bandwidth and resolution are increased in the 5G technology, when compared to 4G,The security features are enhanced, and then the energy efficiency is increased as compared with 4G. the frequency ranges between (3 to 5 GHz) for initial trial and implementation of 5G infrastructure. Table 1 depicts the different mid band 5G frequency bands associated with the operational nation or country [1]. The cellular network's capacity must be substantially enhanced. To accommodate such massive communications, it is predicted that the 5G network will need to have 1000 times the capacity of the current system [2],[3] and [4]. Another issue is the size of the antenna when coupled with other antenna arrays[5].Since 5G technology demands compact devices. Planar technology was suggested for the installation of the antenna array since it is a low-loss transmission line with a wider bandwidth [6]. Many researchers used a variety of approaches to feed the printed monopoles, one of which was a coplanar waveguide (CPW)[7]. Because of the benefits of enhancing radiation efficiency and bandwidth, coplanar waveguide (CPW) antennas are frequently employed [8].

In this paper, a planar microstrip patch antenna with slots at 3.5 GHz for 5G frequency has been designed and analysed. Section 2 discusses the antenna design processes, including planar antenna design. Section 3 shows the simulation and performance of the proposed antenna. Finally, in section 4, the findings of this research are summarized.

Table 1. List of different mid band 5G frequency bands For Various Countries.

Country/Region	Frequency Bands (GHz)
USA	3.10 - 3.55 and 3.70 - 4.20
China	3.30 - 3.60, 4.40 - 4.50 and 4.80 - 4.99
Europe	3.40 - 3.80
Japan	3.60 - 4.20 and 4.40 - 4.90
Korea	3.40 - 3.70

2. ANTENNA DESIGN

In order to several advantages, the microstrip feed line remains the most preferred technique for establishing microwave transmission in planar technology. However, this method has significant disadvantages, the most significant of which is the limited bandwidth offered. Coplanar waveguide (CPW) antennas are frequently used because they improve radiation efficiency and bandwidth while minimizing radiation loss and substrate dielectric losses. Because of its lower leakage and lower dispersion, this CPW antenna feeding technology outperforms the microstrip feed line. However, traditional shapes such as round and rectangular are most used. Other configurations are used, which are difficult to analyse and need very massive numerical calculations [8]. but mostly conventional shape likes circular and rectangular are used [9]. There are some other configurations used, which are complex for analysis, and it requires very large numerical calculations. In its most common form, a planar microstrip antenna, its most common form comprises a radiating patch on top of a dielectric substrate material with a ground plane on the bottom. Fig 1 depicts the proposed slotted antenna's geometry. The antenna comprises a patch with a crossing slot linked to a feed line that is printed on a thin FR4 substrate with a relative permittivity of 4.3 and a thickness of 1.6 mm. The ground plane handles most of the substrate's backside and includes a tiny hole for impedance matching. Using a microstrip construction, the parameters of the planar antenna should be considered. The patch antenna's width (W) may be computed by [8, 9]:

$$\mathrm{w} = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where w is the patch width, f_r is the antenna resonant frequency, and ε_r is the substrate of the dielectric constant. The effective dielectric constant may be calculated using the following formula [10] :

$$\pounds_{\mathrm{eff}} = \frac{\pounds_r+1}{2} - \frac{\pounds_{r-1}}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right)$$

$$\mathrm{L}\ \mathrm{L}_{\mathrm{eff}} = \frac{c}{2f_r\ \sqrt{e_{\mathrm{eff}}}} \qquad (2)$$

Where L is the length of the patch antenna , and $\mathrm{L}_{\mathrm{eff}}$ effective length of the antenna, h is the height of the substrate, and the extension length may be calculated as follows [11, 12]:

$$\frac{\Delta L}{h} = 0.421\frac{(\pounds_{\mathrm{eff}}+0.3)\left(\frac{w}{h}+0.264\right)}{(\pounds_{\mathrm{eff}}-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (3)$$

Figure.1 depicts the updated patch with two slots added to the original patch (b). The redesigned antenna's slots parameters (length and breadth) may be determined using:

$$\mathrm{L}_{\mathrm{slot}} = \frac{1}{2f_r\sqrt{\pounds_{\mathrm{eff}}}\sqrt{\pounds_o\mu_o}} - 2\Delta L \qquad (4)$$

$$\mathrm{W}_{\mathrm{slot}} = \frac{1}{2f_r\sqrt{\pounds_o\mu_o}}\sqrt{\frac{2}{\pounds_r+1}} \qquad (5)$$

The dimensions of the final patch design are presented in Table 2.

Table 2. Final antenna dimensions.

Parameters	Dimensions(mm)
Ws	40
Ls	30
W	33
L	11
Wslot	13
Lslot	2.5
Lgap	20.4
Wgap	2
Lfed	16.7
Wfed	2
Lgad	15
Wgad	17.7

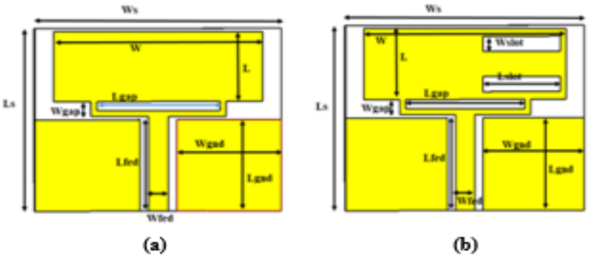

Figure 1. Planar microstrip antenna is presented. (a) general patch, (b) two-slot customized patch.

A parametric analysis was carried out in this paper to determine the influence by adding two slots to the original patch in Fig 1.(a) general patch (b) two-slot customized patch .It can be seen that raising the slot number causes an increase in return loss and an increase in gain and a broader bandwidth.

3. RESULT AND DISCUSSIONS

Figure 2 shows the S11 parameters of the planar antenna at (3.5GHz) for patch and without Sub Miniature Version A (SMA). Fig 3 depicts the planar antenna's S11 parameters. The modified planar antenna response compared to the general structural simulation. The value of 11.5 dB return loss with impedance bandwidth of 200 MHz is got, and the value is compared to the modified antenna with a return loss of 16.29 dB and bandwidth of 650 MHz at 3.5 GHz.).Fig 4 shows the 2D Radiation pattern performance at 3.5 GHz without (SMA), while Fig 5. shows the 2D Radiation pattern performance at 3.5 GHz with (SMA).

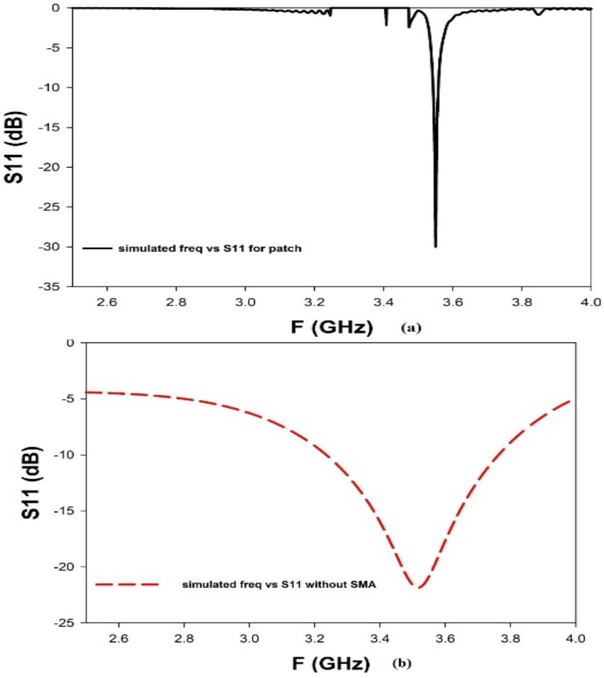

Figure 2. S11 of the planar antenna at (3.5GHz): (a)for patch (b)without (SMA).

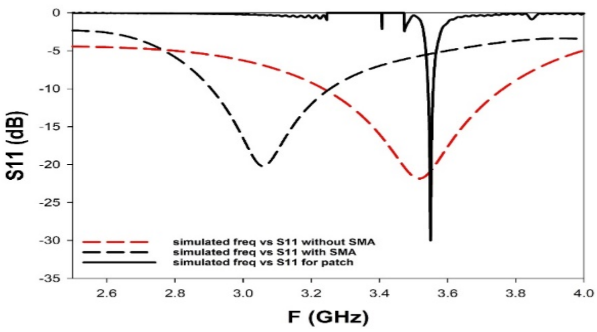

Figure 3. The planar antenna S-parameter changing because of the overall construction.

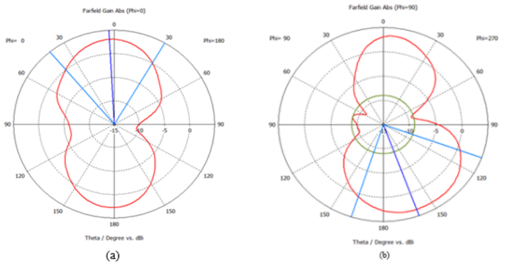

Figure 4. Performance of a 2D radiation pattern at (3.5GHz) without SMA (a) The E-Plane (b) and the H-Plane

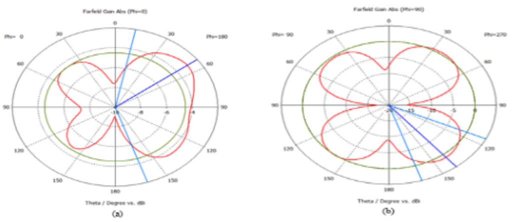

Figure 5. The planar antenna S-parameter changing because of the overall construction.

Figure 6 shows a 3D representation of simulated radiation pattern and gain at 3.5 GHz with and without (SMA). The design shows virtually omnidirectional behavior, which is desirable in applications. Figures 7 and 8 illustrate the current density and surface current for the designed antenna.

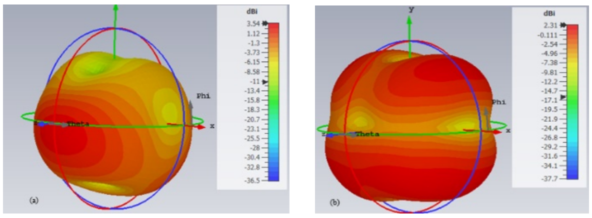

Figure 6. 3D simulation of radiation pattern and gain at 3.5 GHz (a) with SMA, (b) without SMA.

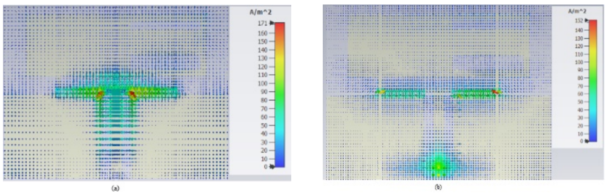

Figure 7. Simulated current density for the antenna (a) with SMA and (b)without SMA.

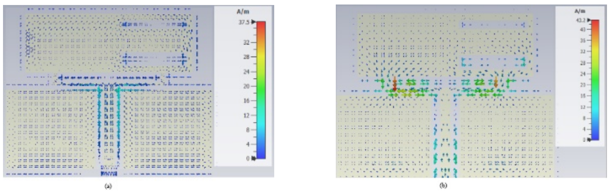

Figure 8. Surface current simulation of the antenna (a) with SMA(b) without SMA.

As shown in Table 3, the modified structure (with slots) demonstrated good return loss and bandwidth after adding slots to the basic structure, as well as high gain, directivity, and efficiency.

Table 3. The Planar Antenna With And Without Slots

Planar microstrip antenna	Without slots	With slots
Return Loss (dB)	11.5	16.29
Frequency (GHz)	3.5	3.5
Bandwidth (MHz)	200	650
Gain (dB)	3.51	3.54
Directivity (dB)	5.5	5.74
Efficiency (%)	80%	83%

Table 4 shows a comparison of the proposed antenna with prior works. When compared to previous antenna designs, the suggested one has a greater gain and a broader bandwidth.

Table 3. Comparison With Previous Work

References	Frequency (GHz)	Bandwidth (MHz)	Gain(dB)	Efficiency%	substrate
[13]	2.45	101	3.42	60	FR4
[14]	3.67	2800	2.1	90	FR4
[8]	2.4	50	----	----	FR4
[15]	2.24–2.48, 5.15–5.82	870	----	----	FR4
This work	3.5	650	3.54	83	FR4

3. CONCLUSION

A slotted planar microstrip patch antenna for 5G applications is presented in this paper. The antenna has been designed and optimized to cover the frequency range of 3.5 GHz for 5G mid band frequency applications. Once the primary achievements of the proposed antenna are compared to performing the existing antenna design, it is seen that the antenna provided in this work has a wider bandwidth 650 MHz, higher efficiency, and higher gain. The results of the proposed antenna are more suitable for mid band 5G applications.

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