DESIGN OF MICROSTRIP PATCH ANTENNA FOR 5G WIRELESS COMMUNICATION APPLICATIONS

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ABSTRACT

The purpose of this paper is to design and simulate a microstrip planar antenna for the future-fifth generation (5G) wireless applications. The antenna structure is built on a low loss RO3003 substrate of 3.0 relative permittivity and fed by a 50 Ohms microstrip line. The proposed antenna provided a high gain of 5.51 dB at 28 GHz (gigahertz) bands, with a minimum reflection coefficient of -24.3 dB, a very wide bandwidth of 2.5 GHz and the radiation pattern was mostly omnidirectional. The thickness of the substrate has been changed, the resonant frequency can be at 20/28 GHz or 20/38 GHz depending on the value of thickness, which both are the proposed bands for 5G. In this paper, all simulations have been using industry-standard software CST Microwave Studio.

Keywords: Microstrip planar antenna, 5G wireless applications, 28 GHz, 38 GHz, omnidirectional pattern, reflection coefficient.

1. INTRODUCTION

Over the last few decades, the wireless industry has changed and grown, time and time again. This industry as a whole shifted from 1G for analog to digital phones 2G (SMS - Short Message Services and voicemail), then from 2G to 3G, 3.5G networks, which came with the mobile broadband internet connections that enabled the smartphone revolution, to 4G and 4G-LTE (Long Term Evolution) which had high data rate cellular network. Future fifth-generation wireless communication networks (5G) [1, 2] will make an important difference and will add more services and benefits to the world over 4G. The fifth-generation, or 5G, is the new technological standard for the next generation of wireless networks.

Some requirements were given in the literature [1] for the main technical objectives for 5G systems: extremely high data rates per device (multiple tens Gbps), high data rates per area and massive amounts of connected devices; ultra-low latency (less than a microsecond), especially for multimedia, interactive 3D video/Virtual Reality (VR) applications and ultra-reliable to support various critical applications, such as vehicle-to-vehicle (V2V) communications, industrial control, healthcare, etc. Thus, the interference among transmitters should be minimized. Besides, the 5G technologies will make it most powerful and in huge demand in the future that it has never achieved before. However, the major difference between 4G and 5G techniques in the eyes of users is increasing data rate and less power consumption with better coverage. The 5G communications may take the wireless signals to a higher frequency range of 30 to 300 gigahertz (GHz), which means they will use millimeter-wave (mmWave) frequencies. But it will also give some challenges to the designer. Two of the major challenges are increasing the frequency of the higher band and the shorter data transmission range. Therefore, the performance of a 5G network can be increased more than 20 times than 4G-LTE.

There are a lot of candidate frequencies for 5G wireless technologies, where mmWave frequency spectrum around 28 GHz [3-6], 38 GHz [2, 3, 6, 7] and 60 GHz [8-14] is receiving important considerations. The purpose of a communication system is to transmit or receive information using electromagnetic waves. And this system uses antenna for radiating or receiving radio waves. In other words, the antenna is the transitional structure between free-space and a guiding device [15]. Microstrip antennas have received considerable attention starting in the 1970s, although the idea of a microstrip antenna was invented in 1953 [10] and a patent in 1955 [16]. These antennas can be used in many other governmental and commercial applications, such as mobile radio and wireless communications like in high-performance aircraft, spacecraft, satellite, and missile applications [15, 17, 18]. These antennas are low-profile, low-cost, small size, lightweight, and easy to fabricate. Major operational disadvantages of microstrip antennas are their low gain, low power, spurious feed radiation, and very narrow frequency bandwidth. These antennas have many different geometrical shapes such as rectangular, square, triangular, trapezoidal, circular, elliptical, and annular ring [11, 15]. Besides, the microstrip patch antennas can be made to conform to planar and non-planar surfaces.

MmWave microstrip patch antennas are a promising alternative to the future wireless technologies 5G. Several designs have already been carried out on this field achieving good performance in mmWave frequency band [3, 4, 6, 9, 12, 14, 19-21]. The geometry of a microstrip antenna consists of a dielectric substrate of certain thickness h_s, having a complete metallization on one of its surfaces and of a metal ''patch'' on the other side. The substrate is usually thin ($h_s \ll \lambda$). A dielectric substrate has a low dielectric constant which is desirable for good performance, larger bandwidth, better radiation, and better antenna efficiency. The metal patch on the front surface can have various shapes, although a rectangular shape is commonly used [4, 14, 22]. Four most popular configurations can be used to feed microstrip antennas: the microstrip line, coaxial probe, aperture coupling, and proximity coupling [14, 15]. The key point of the present paper is to propose a microstrip patch antenna to achieve a high gain and a wide impedance bandwidth for the 28 GHz application. On the other hand, the thickness of the substrate of microstrip patch antennas has been changed to investigate the effect of dimensions on microstrip patch antennas resonance frequency. The proposed antenna had a simple architecture and an almost omnidirectional radiation pattern and low fabrication cost.

This paper is outlined as follows. In section 2, the antenna dimensions and design are described. Simulation results and discussions are presented in Section 3. Finally, some conclusions are discussed in Section 4.

2. ANTENNA GEOMETRY AND DESIGN

In general, the dimensions of the microstrip antenna are calculated by using the microstrip antenna's equations as given in many references [15, 23]. In this paper, the optimization of the antenna dimensions is required to achieve some goals. Figure 1 shows the geometry of the designed antenna, it includes a top view and a side view. The proposed antenna is used the 50 Ohms microstrip line feeding technique because the microstrip feed line is also a conducting strip, usually of much smaller width compared to the patch. The microstrip-line feed is easy to fabricate, simple to match by controlling the inset position and rather simple to model [15].

The antenna is designed on a high-frequency ceramic-filled PTFE (Polytetrafluoroethylene) composite dielectric substrate by Rogers RO3003 with a dielectric constant of 3.0, loss-tangent of 0.001, and thickness of 0.5 mm. RO3003 high-frequency circuit materials are ceramic-filled PTFE composites intended for use in a commercial microwave and RF (radio frequency) applications. RO3003 substrate is the favorite for mmWave [24]. It is very suitable for UHF (ultra-high frequencies) because of its low dielectric loss and its low dispersion. Then, the proposed microstrip patch antenna can take a variety of substrate thickness.

It is typically composed of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The designed antenna's patch is made of copper material. The detailed physical dimensions for each part of the proposed antenna configuration are given in Table 1. Where h_p is patch thickness, h_s is substrate thickness. Finally, the resulting antenna was simple to design, fabricate and had a low profile.

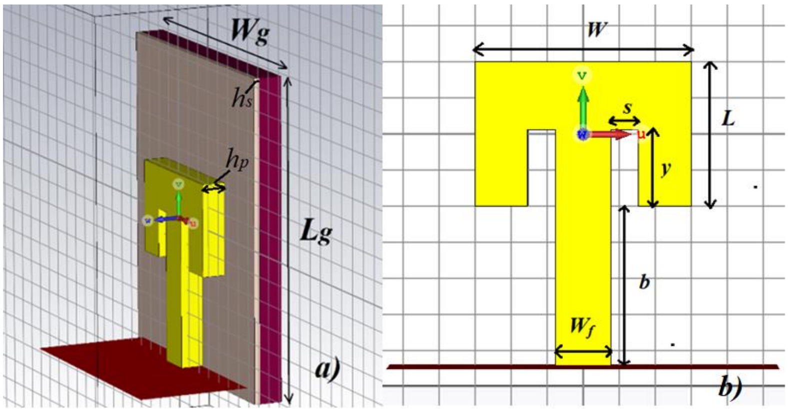

Figure 1. The geometrical structure of the proposed antenna: side view (a) and top view (b).

Table 1. Antenna structural parameters

Name	Unit (mm)	Name	Unit (mm)
W_g	6	W_f	0.77
L_g	7	y	1.06
h_s	0.5	W	3
s	0.385	L	2
h_p	0.5	b	3.264

3. RESULTS AND DISCUSSION

In this paper, the proposed antenna is designed and simulated using Computer Simulation Technology (CST) Microwave Studio (CST Suite 2018). The major simulation results (i.e. reflection coefficient, gain, bandwidth, radiation patterns) of the designed antenna are given in this section.

First, the results of the proposed antenna, its dimensions are in Table 1 and substrate thickness has valued $h_s = 0.5$ *mm*, are discussed.

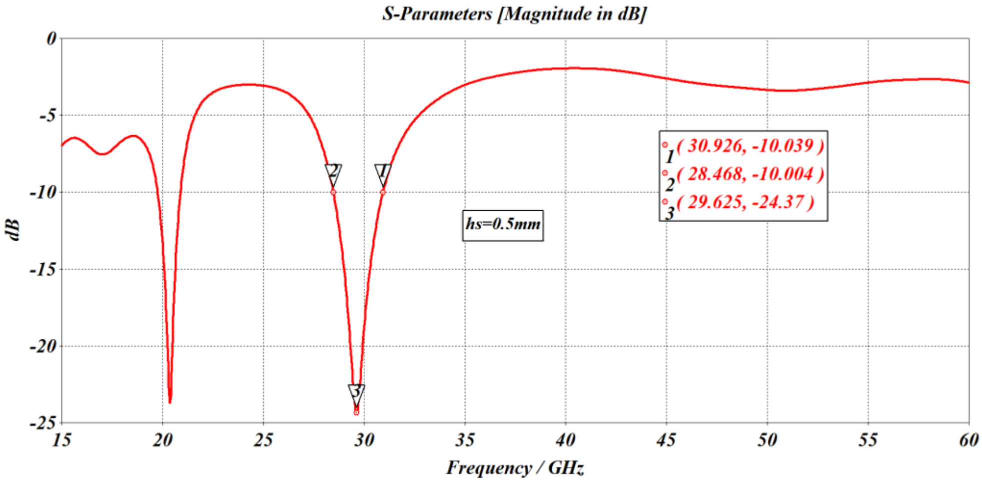

Figure 2. The plot of S_{11} parameters for the proposed antenna at 28 GHz bands.

One important antenna parameter is the reflection coefficient (or S_{11}) defining the bandwidth and the impedance matching characteristic. The simulated results of the S_{11} parameters for the proposed antenna are shown in Figure 2. Figure 2 reveals that the antenna can cover the mmWave bands (K and Ka) of 20/28 GHz for S_{11} less than -10 dB because the base value of -10 dB is taken as the base value for mobile communication. The single patch resonated at 29.6 GHz with a reflection coefficient of -24.37 dB with a bandwidth of 2.5 GHz and at 20.3 GHz with a reflection coefficient of -23.7 dB and a bandwidth of around 1 GHz. On the other hand, the antenna resonated at 29.6 GHz belonged to the proposed band 28 GHz for the future 5G application.

The simulated radiation pattern of the designed patch at 29.6 GHz is shown in Figure 3. The antenna achieved a high gain of 5.51 dB and has almost omnidirectional patterns.

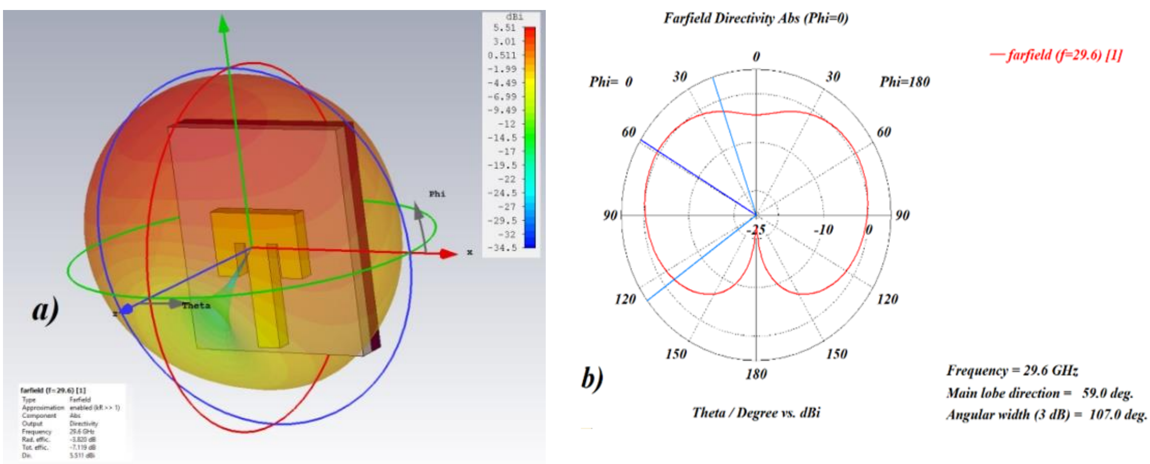

Figure 3. 3D directivity patterns (a) and 2D directivity patterns (b) of the proposed antenna at 29.6GHz.

Table 2. Comparison between the proposed antenna and other references at frequency bands 28 GHz

References	Size (mm^3)	Resonant frequency (GHz)	Gain (dB)	S_{11} (dB)	Bandwidth
[3]	20×5.5×0.254	28	5.2	-25	0.45 GHz
		38	5.9	-29	2.20 GHz
[20]	19×19 ×0.708	10.1	5.51	-27.5	278 MHz
		28	8.03	-24.5	1 GHz
[4]	14.71×7.9×0.254	27.91	6.69	-12.59	582 MHz
[9]	10×7.9×0.5	28.1	7.5	-17.17	1.6 GHz
This paper	7×6×0.5	29.6	5.51	-24.3	2.5 GHz
		20.3	3.57	-23.7	1 GHz

Table 2 presents a comparison between the proposed antenna and other references in terms of the overall size and simulated values of resonant frequencies, gain, return loss as well as bandwidth.

It is noticeable from this comparison, at the related bands the proposed antenna size is reduced of 47% compared to [9], 64% compared to [4], 89% compared to [20], 61% compared to [3]. From Table 2, at 28 GHz bands, it can be seen that its S_{11} parameter is higher than in comparison with [4, 9] and almost the same as in [3, 20] and bandwidth is broader when compared with other antennas. The designed antenna has a higher gain with [3] but a lower gain in comparison with [4, 9, 20]. Therefore, the proposed antenna has better results than other references at frequency bands 28 GHz.

Impedance matching is a very important parameter for any antenna. Maximum matching means max power transfer or low reflection coefficient. It is found that patch antenna characteristics are affected by antenna dimensions [21]. In this work, four different substrate thickness h_s are simulated and compared. The result of the S_{11} parameter, VSWR of the antenna obtained are shown in Figure 4 and Figure 5.

The results in Figure 4 show when the thickness is lower ($h_s = 0.09$ *mm; 0.1 mm; 0.125 mm*) the S_{11} parameters are decreased (*-25.1 dB, -26.3 dB, -28.8 dB*, respectively) at resonant frequency bands 38GHz when the thickness is upper (herein, $h_s = 0.5$ *mm)* the S_{11} parameters had value around -24.2 dB at resonant frequency bands 28 GHz. The acceptable value of VSWR for wireless application should be less than 2 and as seen in Figure 5, the VSWR of this patch antenna is around 1.1 for all these cases. Therefore, the designed antenna can be working at frequency bands 28 GHz or 38 GHz if only to change its substrate thickness. Figure 6 shows the simulated radiation patterns of proposed 5G antenna at frequency 38 GHz, the antenna achieved a high gain of 6.01 dB.

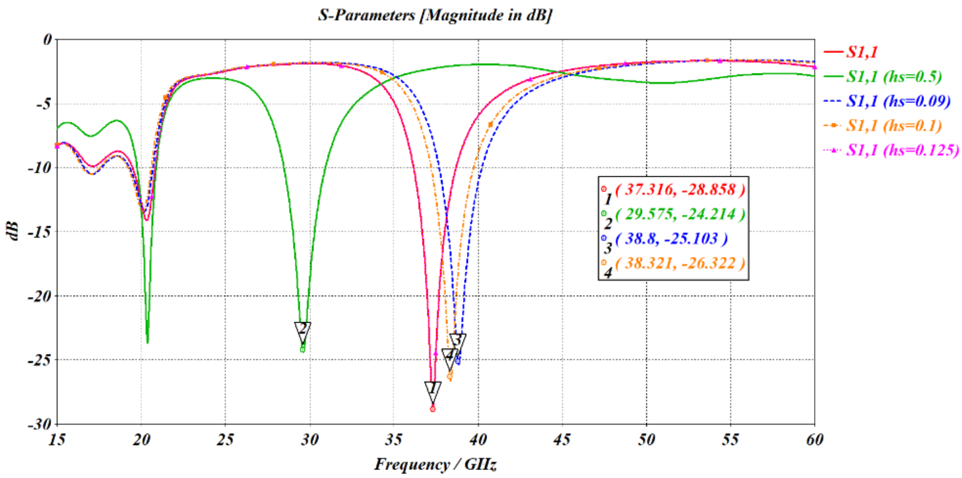

Figure 4. Simulated S-parameters of different substrate's thickness h_s.

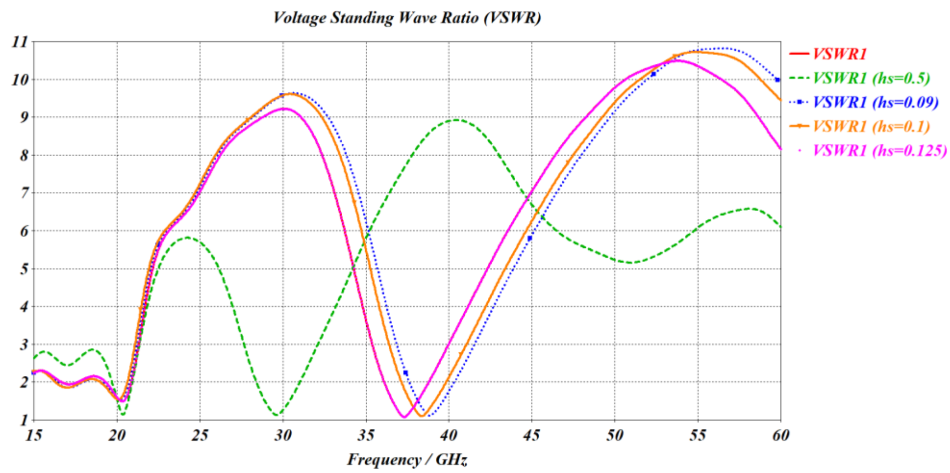

Figure 5. Simulated VSWR-parameters of different substrate's thickness h_s.

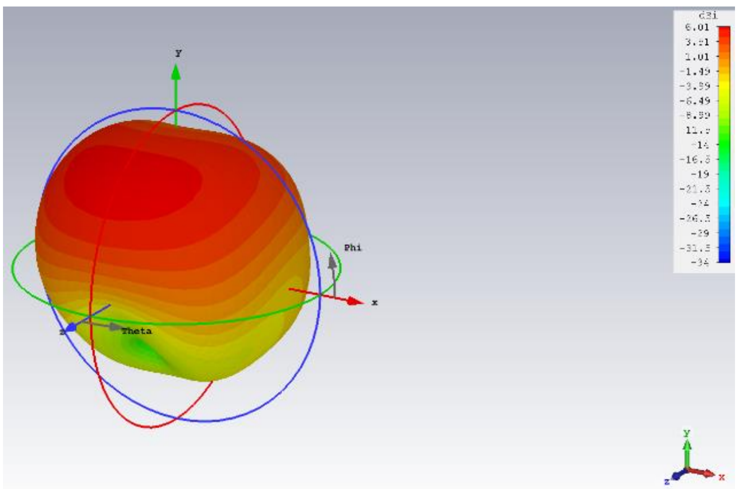

Figure 6. Simulated directivity patterns of proposed 5G antenna at frequency 38 GHz.

It is obvious in Figure 4 and 5 there is also good performance in terms of reflection coefficient and VSWR at resonant frequencies around 20.3 GHz, which is in K-bands, with S_{11} parameters of -14 dB or -23 dB and bandwidth of 1.4 GHz. Hence, the results can be considered using another application.

4. CONCLUSION

In this paper, a microstrip patch antenna has been proposed for 5G wireless communication. The single patch antenna resonated at 29.6 GHz with a reflection coefficient of -24.3 dB and a wide bandwidth of 2.5 GHz. The achieved gain of the designed antenna is 5.51 dB and its directivity pattern is almost omnidirectional. The designed antenna is a very low-profile structure with dimensions $7 \times 6 \times 0.5$ mm^3. Therefore, it can be easy to integrate into devices with space constraints. The simulated results, which have been taken with different thicknesses of the substrate, were given that the antenna resonated at 28 GHz bands or 38 GHz with a reflection coefficient around -25 dB. Besides, in all cases of the thickness of the substrate, the antenna also resonated at 20.3 GHz with a reflection coefficient of around (K-bands for other purposes applications) with good performance in the term S_{11} parameter and VSWR parameter. The proposed antenna is a good candidate for applications in 5G wireless technology.

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TÓM TẮT

THIẾT KẾ ANTEN VI DẢI PHẲNG ỨNG DỤNG TRONG HỆ THỐNG
TRUYỀN THÔNG KHÔNG DÂY THẾ HỆ 5G

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Bài báo trình bày về thiết kế và mô phỏng anten vi dải phẳng cho ứng dụng 5G trong tương lai. Cấu trúc của anten được đặt trên tấm nền được làm từ vật liệu RO3003 có hệ số điện môi tương đối bằng 3 và anten được cấp nguồn kiểu vi dải. Anten có độ lợi hướng 5.51 dB tại dải tần 28 GHz với hệ số phản xạ đạt cực tiểu -24.3 dB, băng thông rộng đạt 2.5 GHz và giản đồ hướng gần như đa hướng. Khi thay đổi độ dày của tấm nền, tần số cộng hưởng của anten có thể đạt 28 GHz hoặc 38 GHz. Kết quả mô phỏng của bài báo đã sử dụng phần mềm CST Microwave Studio.

Từ khóa: Anten vi dải phẳng, ứng dụng không dây 5G, 28 GHz, 38 GHz, đa hướng, hệ số phản xạ.