DESIGN OF A SINGLE MICROSTRIP ANTENNA FOR THE FUTURE 5G MOBILE COMMUNICATION NETWORKS

THIẾT KẾ ANTEN VI DẢI ĐƠN CHO HỆ THỐNG DI ĐỘNG THẾ HỆ 5G TƯƠNG LAI

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Abstract: *Future fifth-generation (5G) of cellular systems will use millimeter-wave frequencies and it is expected to offer an extremely wide spectrum and multi-Gigabit-per-second (Gbps) data rates to mobile communications. Hence, mobile devices applied for fifth generation such as antennas seem to be a challenging task. In this article, a single microstrip antenna for the future 5G mobile networks is designed using Rogers RT5880 substrate with dielectric constant of 2.2, which has a simple rectangle shape with small size. The designed structure is proved to achieve large bandwidth and to improved reflection coefficient. Furthermore, simulated results on VSWR, surface current and 3D radiation patterns are presented. Design and simulations in this work are carried out using Computer Simulation Technology (CST) Microwave Studio (CST Suite 2018). This antenna can be considered a good candidate for applications in 5G.*

Keyword: *Antenna design; bandwidth; microstrip antenna; substrate.*

Classification number: *2.2*

Tóm tắt: *Các hệ thống di động thế hệ thứ năm (5G) trong tương lai sẽ sử dụng tần số sóng milimet, dự kiến sẽ cung cấp phổ cực rộng và tốc độ đa Gigabit mỗi giây (Gbps) cho thông tin di động. Do đó, cải tiến các thiết bị như anten phù hợp cho thế hệ mới được coi như một thử thách lớn. Trong bài báo này sẽ trình bày về anten vi dải đơn cho thế hệ 5G tương lai với kích thước nhỏ và có dạng hình chữ nhật. Anten được đặt trên tấm nền làm từ chất liệu Rogers RT5880 với hằng số điện môi tương đối là 2.2. Thiết kế này đạt được băng thông rộng và cải thiện hệ số phản xạ. Ngoài ra, trong bài báo còn đưa ra các kết quả mô phỏng của anten như VSWR, dòng điện mặt và giản đồ bức xạ 3D. Bên cạnh đó cách thiết kế và mô phỏng đã sử dụng chương trình Computer Simulation Technology (CST) Microwave Studio (CST Suite 2018) cũng được trình bày. Anten đề xuất này được coi là một thiết kế khả quan cho các ứng dụng 5G.*

Từ khóa: *Thiết kế anten; băng thông; anten vi dải; tấm nền.*

Chỉ số phân loại: *2.2*

1. Introduction

The new generation of mobile network technologies is characterized by new frequencies and larger bandwidth. The bandwidth of the first-generation wireless technology (1G) up to 30 kHz, 2G up to 200 kHz, 3G up to 20 MHz and 4G up to 100 MHz. The upcoming 5G will be five times than the present 4G. It will have a high data rate, large bandwidth, and high capacity. The future of mobile networks is entering into millimeter-wave communication. The spectrum of 5G applications is 20-90GHz [1, 2]. The 5G technology arose from the need for gigabit wireless communications, the Internet of Things (IoT) technologies connecting everything from self-driving vehicles, robots, and jet-engine diagnostics, better spectral efficiency, low consumption of battery, greater connectivity, flexibility, low latency, low cost of infrastructure deployment. The most prominent frequency bands for 5G communication are 28 and 38 GHz bands.

An antenna is a device between radio waves propagating through space and electric currents moving in metal conductors, it use with a transmitter or receiver. Antennas are essential components of all radio equipment [3]. Therefore, the designs of antennas are the most critical point for mobile and other 5G communication systems. These antennas have to improve characteristics such as antenna size, bandwidth, gain, power loss. In the last decades many researchers proposed different antennas and antenna arrays for 5G networks [4 - 9].

Microstrip is a type of electrical transmission lines and that is used to transmit electromagnetic wave or microwave-frequency signals from one point to another point. The transmission-line technology can be combined with ordinary printed-circuit techniques to permit construction of monolithic phased-array modules containing not only the transmission line components, but also phase shifters, couplers, control circuitry, radiating elements, and solid-state transmitting and receiving amplifiers [10]. A microstrip patch antenna consists of a thin (thickness very small compared to the free space wavelength) metallic patch above a large metallic ground plane [3, 10]. The patch is supported by a dielectric sheet, known as a substrate. The patch is usually etched on the dielectric substrate using printed circuit board technology. The patch can be square, circular, elliptical, rectangular, triangular or any other configuration. The performance of the patch depends on its size and shape. Microstrip antenna is easy to feed using coaxial cable and microstrip lines. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper)

Several works were done on single and dual-band microstrip patch antenna for 5G communication at 28 GHz and 28/38 GHz [4, 5, 7-9] but a single band antenna still not exist at a single band of 38 GHz for 5G applications. Therefore, a single microstrip patch antenna is designed and simulated in this paper, which is resonated at 39.3 GHz (of 38 GHz band). The designed antenna has a simple rectangle shape, providing good performance.

The rest of the present study is structured as follows: Section 2 describes and designs the antenna. Simulation results and discussions are presented in Section 3. Finally, conclusions are outlined in Section 4.

2. Antenna geometry and design

The first practical step in the process of designing a microstrip patch antennas is substrate selection. Substrate parameters such as thickness and dielectric constant greatly influence on the impedance bandwidth of the antenna. To increase bandwidth, increase the substrate height and/or decrease the substrate permittivity (hence this will also affect the resonant frequency and the impedance matching). It is designed on a low cost Roger5880 substrate with a dielectric constant of 2.2, loss-tangent of 0.001, and thickness of 0.5mm. Dimensions of this antenna are calculated using the well-known microstrip patch antenna formulas [3] as follows: The procedure assumes that the specified information includes the dielectric constant of the substrate (ϵ_r), the resonant frequency (f_r), and the height of the substrate h.

Specify: ϵ_r; $f_r(in\ Hz)$; h

Determine: *Wp, Lp;*

$$W_p = \frac{1}{2f_r\sqrt{\mu_o\epsilon_o}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{v_o}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \qquad (1)$$

where v_0 is the free-space velocity of light.

Determine the effective dielectric constant ϵ_{reff} of the microstrip antenna using

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{W_p}\right]^{-1/2} \qquad (2)$$

Once W_p is found in (1), determine the extension of the length ΔL using a very popular and practical approximate relation for the normalized extension of the length [11]:

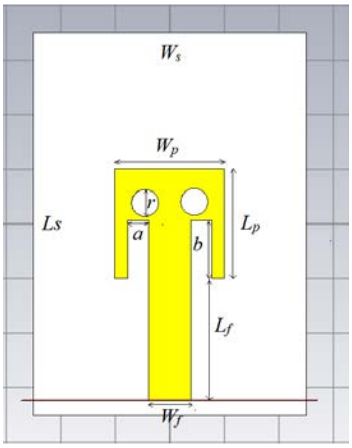
$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_r+0.3)(\frac{W_p}{h}+0.264)}{(\epsilon_r-0.258)(\frac{W_p}{h}+0.8)} \qquad (3)$$

The actual length of the patch can now be determined by solving:

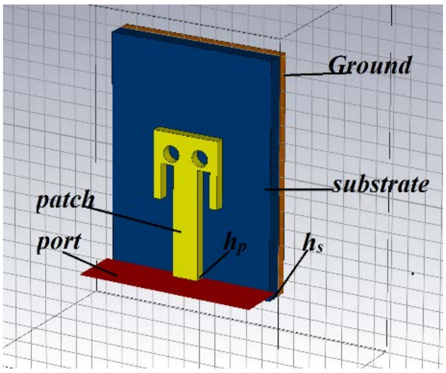
$$L = \frac{1}{2f_r\sqrt{\mu_o\epsilon_o\sqrt{\epsilon_{reff}}}} - 2\Delta L \qquad (4)$$

By using above equations and optimized by a software tool from CST Microwave studio the antenna dimensions are selected. An optimization method is a procedure which is executed iteratively by comparing various dimentions (W, L, h_t, h_p) till an optimum solution (such as lower S11 parameter, higher directivity) is found. The designed printed type antenna is constructed on a substrate of area dimensions 7×5 mm^2, fed by a 50 Ω microstrip line of 0.77mm wide and 3.264mm long. The ground plane is placed on the back of the substrate layer.

A geometrical configuration of the designed microstrip antenna with a rectangular patch is shown in figure 1. Table 1 shows the optimized dimensions of the designed antenna demonstrated in figure 1.



(a)



(b)

Figure 1. *Geometrical configuration of the designed microstrip antenna (a. Front view; b. Side- view).*

Table 1. Antenna structural dimensions.

Symbol	Unit (mm)	Symbol	Unit (mm)
W_g	5	W_f	0.77
L_g	7	b	1.06
h_s	0.5	W_p	2
a	0.385	L_p	2
h_p	0.3	L_f	3.264
r	0.25		

3. Simulation results and discussion.

The simulations of the designed antenna are performed using Computer Simulation Technology (CST) Microwave Studio (CST Suite 2018). The results are discussed in this section.

Firstly, the important parameter in any antenna is the reflection coefficient or S_{11} (S-parameter), which shows the input to output relation between ports and defines the bandwidth and the impedance matching [3, 12]. If S_{11} = 0 dB, then all the power is reflected from the antenna and nothing is radiated. If S_{11} = -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power [3]. Therefore, the S_{11} should be less than -10dB for an antenna to perform. The reflection coefficient (dB) of the designed antenna is shown in Figure 2. This figure reveals that the antenna can cover the 5G bands of 38 GHz for S_{11} less than −10 dB. This antenna resonated at 39.3GHz with a reflection coefficient of -23.86 dB and a bandwidth of 2.13 GHz from 38.3 GHz to 40.4GHz.

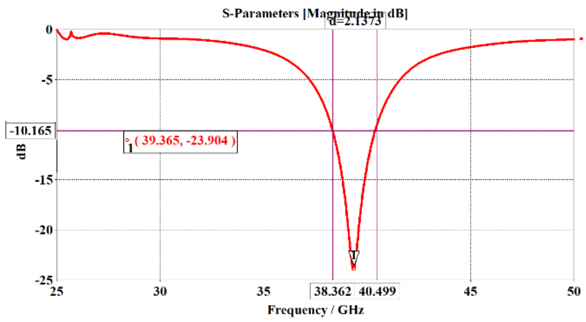


Figure 2. *The S_{11} curves of the designed antenna.*

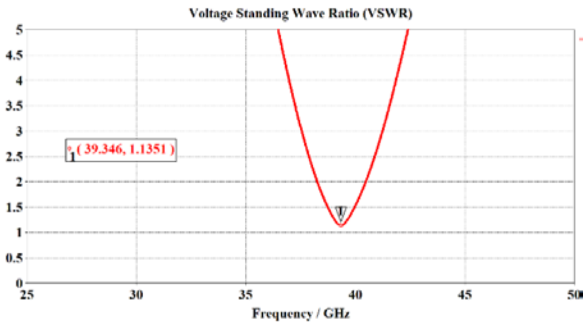
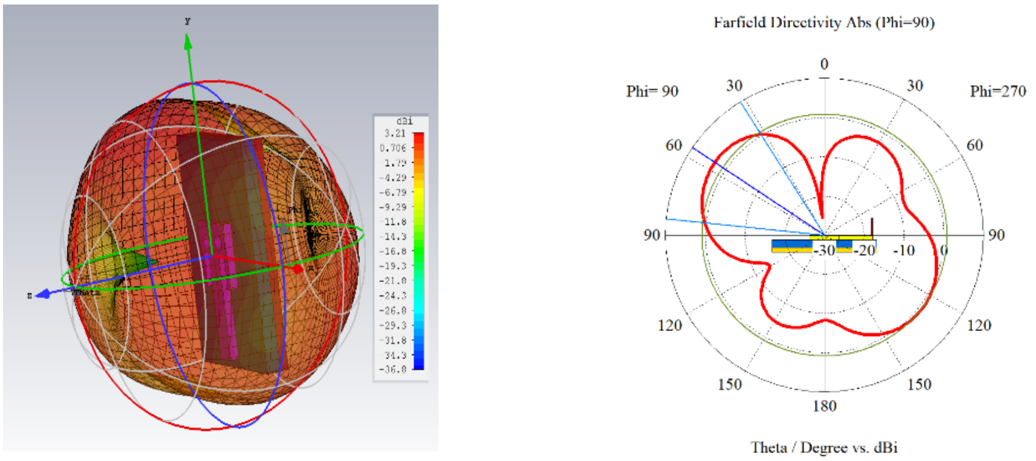


Figure 3. *Plot of VSWR of the designed antenna.*

Voltage Standing Wave Ratio (VSWR) gives more information about the power reflection of an antenna. VSWR should be a real and positive number. Smaller the value of

VSWR, better the performance of the antenna. The acceptable level of VSWR for wireless application should be less than 2, which corresponds to S_{11} less than -10 dB and as seen in Figure 3, the VSWR of the designing antenna is 1.13 at 39.3GHz.

The directivity patterns of the designed patch are shown in Figure 4. The antenna achieved a directivity of 3.21 dB. This result is shown the main lobe magnitude had a value of 3.21 dB, main lobe direction 56.0 deg., angular width (3 dB) 52.1 deg. and the sidelobe level -2.4 dB when phi = 90°. It can be seen that the radiation pattern is asymmetric.



(a) *(b)*

Figure 4. *The simulated directivity patterns of the proposed antenna (a: 3D pattern; b: 2D pattern).*

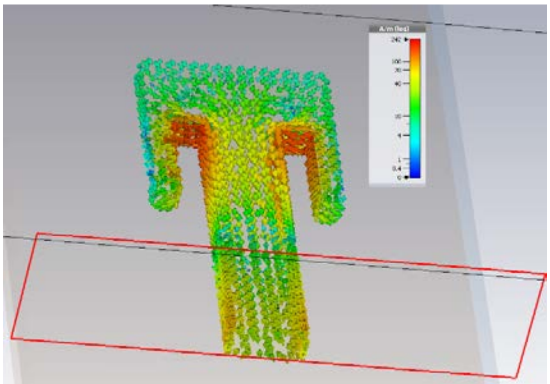


Figure 5. *Surface current distribution for the simulated antenna.*

Table 2. Comparison between the proposed antenna and other references.

Ref.	**Size (mm^3)**	**Material**	**Resonate Frequency (GHz)**	**Bandwidth**	**S11(dB)**
[4]	Patch: 3.4×4.127 Thickness of substrate: 0.25mm	Roger 5880ϵ_r =2.2, tanδ=0.001	24.4	530MHz	-14.7
			28	900MHz	-19.3
			38	480MHz	-18.7
[5]	10×10×0.762	Neltec NH9320 ϵ_r =3.2; tanδ=0.0024	30.5	1.5 GHz	-16
			41.5	N/A	-18
This paper	5×7×0.5	Roger5880 ϵ_r =2.2, tanδ=0.001	39.3	2.13 GHz	-23.86

As shown in Figure 5, at 39.3 GHz frequency current is mostly concentrated at the outer edges of feedline and both arms of this patch.

Comparative analysis of this 5G antenna with previous 5G antennas in other references.

Table 2 summarizes size, resonate frequency, bandwidth, and S_{11}- parameter of previous works and this antenna. It is shown that the designed antenna size is reduced by 22,8% compared to [5], patch size of the designed antenna is reduced by 28.5% compared to [5].

At the related band (38 GHz) it can be seen that its S_{11} parameter is lower than in comparison with [4, 5] and bandwidth is broader when compared with those antennas. Hence, this antenna had better results than other references (in Table 2) in terms of the S_{11}- parameter and bandwidth. It is worth noticing that thicknesses of this design and the design of [5] substrate are thicker than in [4] and this designed antenna and [4] are used the same material with a lower dielectric constant value than in [5].

The results prove that using a thicker substrate material with a lower dielectric constant in the design of microstrip antenna leads to better antenna performance, which agreed in the theory of microstrip antenna [3] and with results in [13]

4. Conclusion

In this article, a microstrip patch antenna is presented for 5G wireless communication. The designed antenna is a very low-profile structure. Therefore, it can be easily integrated into other devices with space constraints.

A good performance was given to make it a good candidate for 5G and other high-frequency applications. A further aim is to build an array with this element to improve the directivity for the application in the frequency range❑

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