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Broadband 5G Millimeter Wave Microstrip Antenna Design

Meng Li
School of Communication Engineering,
Chengdu University of Information Technology ,
Chengdu, China

Abstract: This paper presents an ultra-wideband microstrip antenna that can be used in the 5G millimeter wave band. Compared with similar literature, by rational use of the meandering technique, can effectively guarantee bandwidth. The size of the antenna is 18 mm × 28 mm × 0.514 mm. The return loss of the antenna reached 16.84% (26.93-31.89 GHz), which is higher than 15.7% of the similar literature and has a wider bandwidth. And the gain of the antenna is 9.21dBi, which is higher than 8.38dBi of the similar literature. Meet the efficiency requirements of 5G millimeter wave mobile communication systems.

Keywords: Broadband, 5G millimeter wave, Microstrip antenna, Size, Mobile communication

1. INTRODUCTION

Due to its thin profile, easy to conformal, low cost, and multi-polarization and multi-band operation, the microstrip antenna is widely used in various military and civilian communications and other fields[1]. However, the inherent narrow band and relative size of the microstrip antenna is 1/2 wavelength, which are it main shortcomings and the main factors restricting its development[2]. Therefore, expanding the frequency band of the microstrip antenna has become an important research field in wireless communication technology[3]. Researchers have proposed various structures to try to increase the bandwidth of microstrip antennas[4]. For example, a wide-band microstrip antenna with an H-shaped slot, a bidirectional antenna with a L-shaped slot, a millimeter-wave direction with a H-shaped slot coupled with a circularly polarized microstrip antenna , three-feed circular polarization Microstrip antenna, improved quasi-Yagi antenna, etc[5][6]. In 2015, Han Dongfang and others designed an antenna for 5G mobile communication. The working frequency band covers 27.3GHz-32.95GHz, the relative bandwidth is 15.7%, and the gain is the maximum gain of 8.38dBi in this band. In this paper, the improved structure of the antenna is studied, and the inverted "W" shape structure is added on the basis of the antenna. The return loss of the antenna in the band 26.93-31.89 GHz is less than -10 dB, which increases the relative bandwidth while increasing the radiation gain of the antenna, so that the gain reaches 9.20 dBi.

2. ANTENNA STRUCTURE DESIGN

Figure 1 shows the general shape of a broadband 5G millimeter wave microstrip antenna. The antenna consists of a ground plane, a radiating patch, a dielectric substrate, and a microstrip feed. The substrate material is Rogers RT / Duroid 5880（h = 0.17mm, =2.2, tan = 0.0009） Radiation antenna patch etched on top of the dielectric board, The patch adopts a symmetrical structure, and adopts a meandering technique to design the microstrip antenna into a petal shape and is dug with a 'W' shaped groove. The remaining sides of the groove are composed of a plurality of circular arcs, and current flows through the curved microstrip surface to increase the effective length of the antenna increases the resonance frequency point, and when a plurality of resonance frequency points are close, it can expand the bandwidth , and achieve the antenna is miniaturized. And there are 3 pairs of rectangular grooves on both sides of the patch to change the current on the surface of the patch to adjust the radiation characteristics. And the feeding with the progressive semicircular structure can effectively improve the radiation performance of the antenna. Only the radius is optimized, and the impedance matching of the antenna can be obtained, which reduces the design difficulty of the antenna. Similarly, the sides of the substrate are replaced by curved corners to facilitate the miniaturization of the antenna.

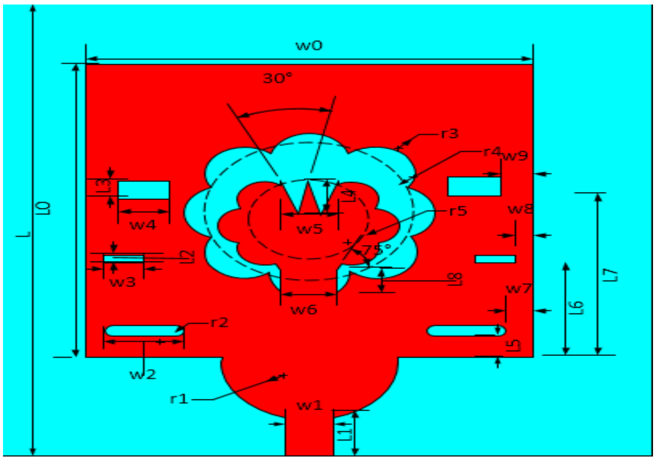
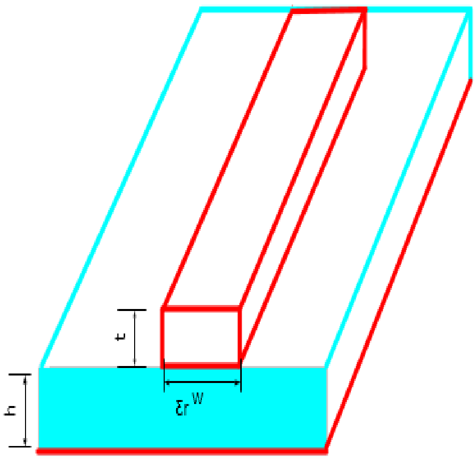


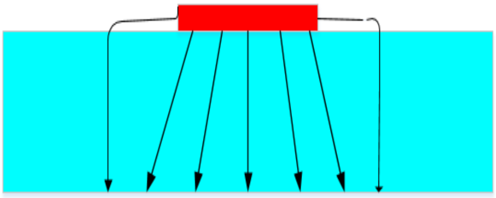
Figure.1. Shape of a broadband 5G millimeter wave microstrip antenna

3. THE MICROSTRIP SIZE

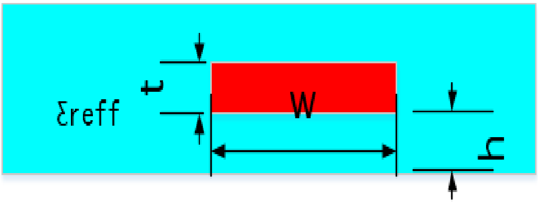
3.1 General microstrip antenna



（a） Microstrip lne



(b) Electric field lnes



(c) Effective dielectric constant

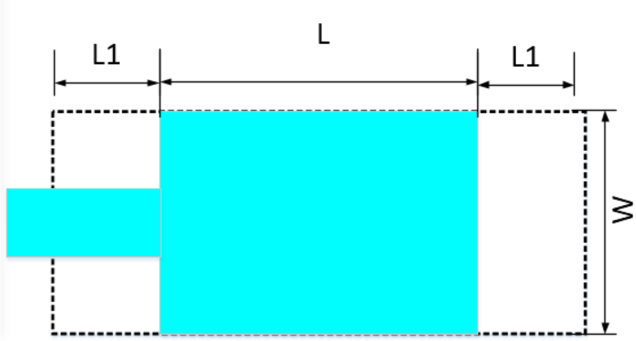
Figure.2.General microstrip antenna

The microstrip line has a width W, a thickness t, a medium height h, and a dielectric constant. At the lateral edge of the microstrip line, a portion of the power line is in the air, and most of the power line is in the medium. As shown in Figure (b). Therefore, the microstrip line transmits a quasi-TEM mode. When W/h>>1 and >>1, the power line will mainly concentrate on the dielectric substrate, and the edge effect of the microstrip line is weakened, and the microstrip line is flat. Waveguide conversion, usually introducing an effective dielectric constant to describe the edge effect of the transverse field of the microstrip,As shown in (c), the microstrip line maintains the same electrical characteristics (propagation constant and characteristic impedance) at this time. There is 1< $\varepsilon_{reff} < \varepsilon_r$,when there is air above the medium, And when ε_r >>1, ε_{reff} will be close to ε_r and will approach when ε_r >>1. ε_{reff} is also a function of frequency, and has a static value when the frequency is not high.

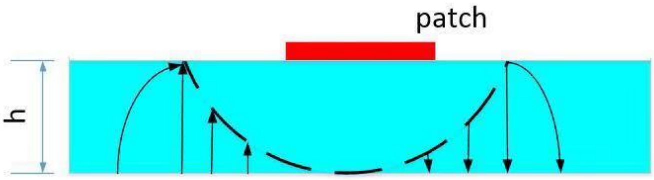
$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{w}]^{-1/2}$$

$$\frac{w}{h} > 1$$

Due to the longitudinal edge effect, the electrical dimensions of the microstrip patch are larger than the actual physical size, as shown in Figure 3.



（a） Top view



（b） side view

Figure.3.Edge effect

At both ends of the patch length direction, due to the fringe field effect, the two ends each extend in length L1, so for the main mode TM mode, the effective length:

$$L_{reff}=L+2*L1$$

When the edge effect is not considered, the resonant frequency of the microstrip patch is:

$$(f_r)_{010}=\frac{1}{2*L\sqrt{\varepsilon_r}\sqrt{\mu_0\varepsilon_0}}=\frac{C_0}{2*L\sqrt{\varepsilon_r}}$$

C_0 is the free space speed of light.

When considering the edge effect, the microstrip patch resonant frequency is:

$$(f_{reff})_{010}=\frac{1}{2L_{reff}\sqrt{\varepsilon_r}\sqrt{\mu_0\varepsilon_0}}=\frac{1}{2(L+2L1)\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}}$$

$q=\frac{(f_{rc})_{010}}{(f_r)_{010}}$ is called the edge factor. When the height of the medium increases, the edge effect is enhanced, the effective length is lengthened, the distance of the radiation groove is closer, and the resonant frequency of the patch is lowered.

3.2 Radiation patch design steps for microstrip patch antennas

Ple Given a dielectric substrate (ε_r , h) and frequency f_r , find W、L.

Step 1: to make the microstrip patch a good radiator, requires:

$$W=\frac{1}{2*f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}=\frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$ Step

2: Calculate ε_{reff} according to the above analysis formula.

Step 3: Calculate L1 by the same reason.

Step 4: Calculate the actual patch length L:

$$L=\frac{1}{2*f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}}-2L1$$

The antenna is designed and optimized using HFSS. The optimized antenna size is as follows:

Table 1. Antenna parameter table (unit:mm)

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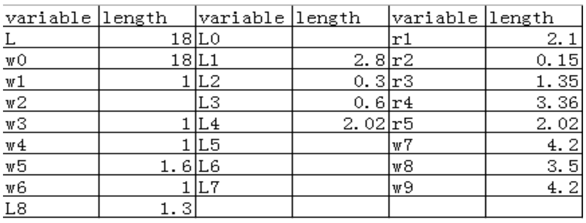


variable	length	variable	length	variable	length
L	18	L0		r1	2.1
w0	18	L1	2.8	r2	0.15
w1	1	L2	0.3	r3	1.35
w2		L3	0.6	r4	3.36
w3	1	L4	2.02	r5	2.02
w4	1	L5		w7	4.2
w5	1.6	L6		w8	3.5
w6	1	L7		w9	4.2
L8	1.3				

4. ELECTROMAHNETIC SUMULATION AND RESULT ANALYSIS OF ANTENNA

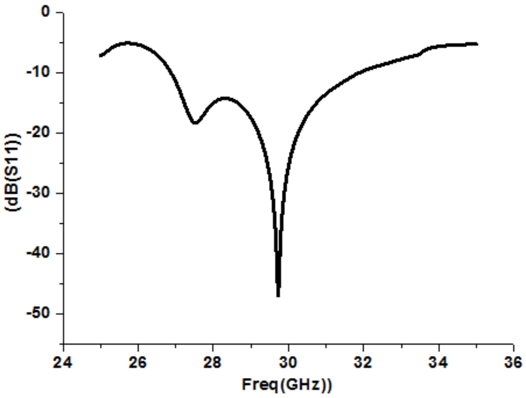
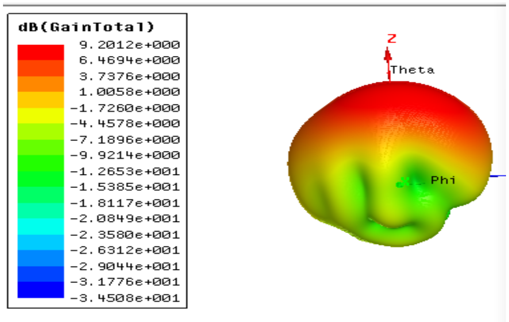


Figure.4. Echo Loss of Antenna

As can be seen from Figure x and Figure y, we achieved a wide bandwidth (16.84%) in the 5G FR2 band from 27.3GHz to 32.95GHz, which is higher than the similar literature and meets the requirements of the millimeter band. The maximum measurement gain of the antenna is 9.21 dBi, which is higher than the gain in the general literature. The size is only 18 mm × 28 mm × 0.514 mm, and the miniaturization of the broadband is also realized.



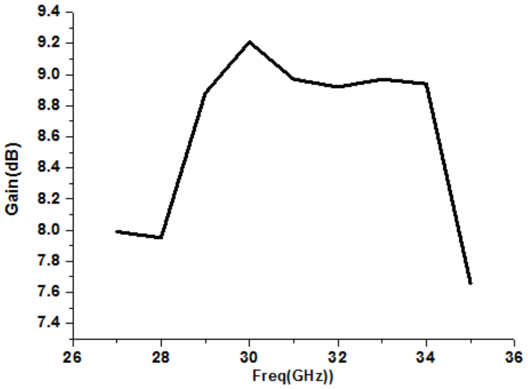


Figure.5. Gain of Antenna

5. CONCLUSION

This paper proposes a microstrip antenna with a wider bandwidth, working with the 5G millimeter wave band, which achieves 16.84% bandwidth by changing the antenna layout and semi-circular progressive feed. The antenna size is 18 mm × 28 mm × 0.514 mm. The slot structure in the antenna extends the bandwidth of the antenna by extending the length of the current propagation. The antenna achieves higher gain in the same literature and has a wider bandwidth, and can be used in a 5G mobile communication system and other wireless communication systems in a frequency band, and has high engineering practical value.

6. REFERENCES

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