Design of a Compact Multi-Band Circularly-Polarized Microstrip Antenna

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***Abstract*-A multi-band circularly-polarized microstrip antenna is designed in this paper. The antenna is made up of two patches. Both the patches are placed on one substrate. The centre patch with four T-shaped slits is aimed to obtain dual-band operation. The outer patch with two square slits can work at another band. The antenna is excited with two feeding points to satisfy the port isolation. The antenna is compact and easy to fabricate. Simulated and measured results show that the antenna can generate circular polarized in three bands and can satisfy satellite communication.**

***Key words*-microstrip antenna, multi-band, circularly-polarized.**

I. INTRODUCTION

With the development of RF technology, satellite communication systems have been widely used in recent years [1]. For these systems, circular polarized antennas are needed due to their insensitivity to ionospheric polarization rotation[2]. In order to increase communication capacity and simplify the system structure, the antenna needs to receive and radiate signals at the same time. So, multi-band circularly-polarized antennas become more and more important. As satellite terminal antennas, small size and high isolation are needed. Microstrip antenna has been widely used due to its small size, lightweight, low profile, low cost and easy to conform. There are many literatures[3-5] in dual-band circularly-polarized microstrip antenna, but seldom in three band circularly-polarized microstirp antenna.

In literature[6], four T-shaped slits and four L-shaped slot are used to generate dual-band operation. In this paper, a three-band circularly-polarized is designed. The antenna only has one layer. And the patches are feed by two probes independently. The antenna is compact and easy to fabricate. The simulated and measured results show that the antenna has good electrical properties.

II. ANTENNA STRUCTURE

The structure of the proposed antenna is shown in Fig. 1. The antenna has only one layer. But the patches are made up of two parts. The centre part is a square patch with four T-shaped slits inserted at the radiating edges of the patch. This patch can generate dual-band operation, and works at 1.3GHz and 3GHz. The other part surrounding the centre patch is a square ring with two square slits, and works at 1.98GHz. The patches are placed on substrate with a dielectric constant of $\varepsilon_r = 4.4$ with thickness of h=1.5mm. The antenna has two feeding points. The centre patch and the outer patch are feed by probes separately. So, high isolation can be achieved.

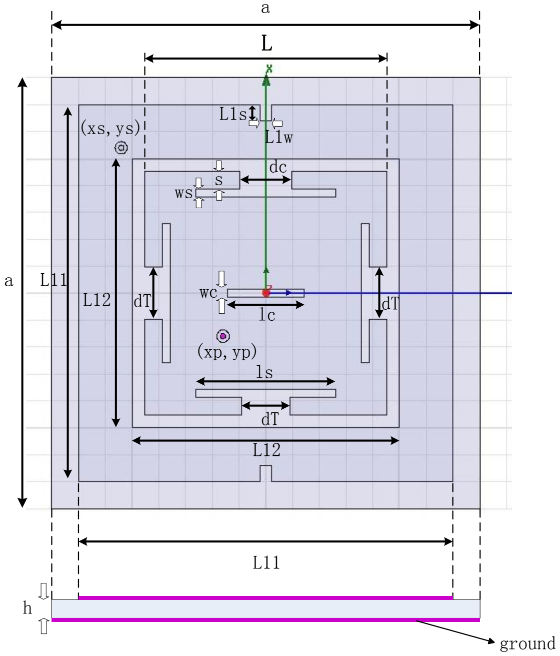


Figure 1. Configuration of the proposed antenna

The centre patch is a square patch with four T-shaped slits. So it can be regarded as a regular patch and the size can be calculated approximately by the following equations[7] :

$$f = \frac{c}{2w_e\sqrt{\varepsilon_e}} = \frac{c}{2(w+2\Delta l)\sqrt{\varepsilon_e}} \ ,$$

where f is the resonant frequency,

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{10h}{w}\right)^{-1/2} ,$$

$$\Delta l = 0.412h\frac{(\varepsilon_e+0.3)(w/h+0.264)}{(\varepsilon_e-0.258)(w/h+0.8)}$$

$$w_e = w + 2\Delta l \ .$$

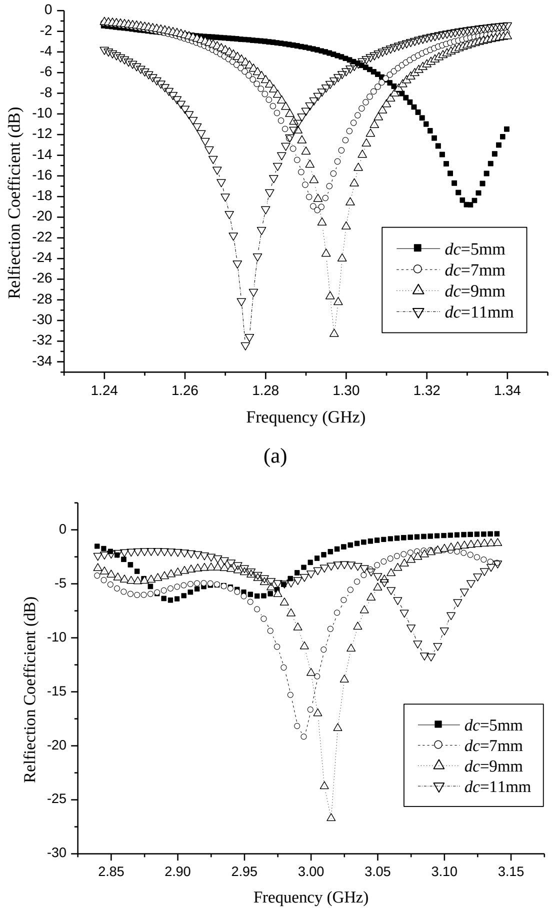
The size calculated by the equations is not the exact and final characteristics. The proposed antenna has been simulated using HFSS software. The final physical characteristic of the antenna is given in Table 1.

PARAMETERS			
	VALUE(mm)		VALUE(mm)
L11	69	L12	49.5
L1w	2	L1s	3.1
a	85	h	1.6
L	45.2	ls	26
dc	9	dT	9.8
ws	1.6	s	3.2
wc	1.6	lc	14.2
xp,yp	8,8	xs,ys	27,27

Table 1: Physical characteristics of the antenna

III. PARAMETRIC STUDY

In this section, the effect on reflection coefficient of parameters dc and dT is studied.

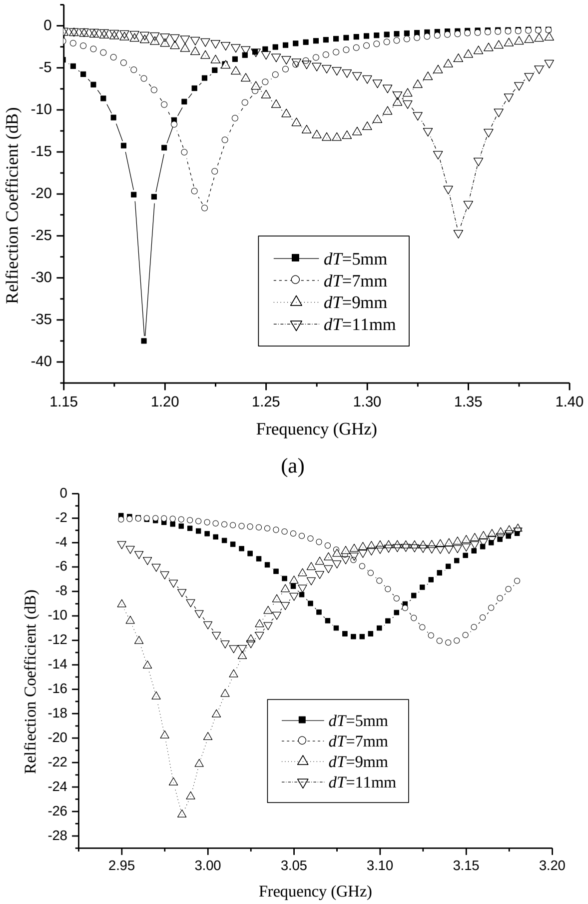


(a)

(b)

Figure 2. Simulated refletion coefficient versus dc of the antenna

In Fig.2, the reflection coefficient versus frequency for different values of dc is presented when dT is 9.8mm. In low frequency, the increase of “dc” causes a decrease of the reflection coefficient. While in high frequency, the increase of “dc” causes an increase of the reflection coefficient. When the antenna works at 1.3GHz and 3.0GHz, dc is around 9mm.



(a)

(b)

Figure 3. Simulated refletion coefficient versus dT of the antenna

In Fig.3, the reflection coefficient versus frequency for different values of dT is presented when dc is 9mm. We can note that in low frequency, the increase of “dT” causes a increase of the reflection coefficient. But in high frequency, there is no regularity with the change of “dT”. When the value of dT is from 9mm to 11mm, the antenna can works at 1.3GHz and 3.0GHz. From further optimization, the value of dT is decided to 9.8mm.

IV. EXPERIMENTAL RESULT

Simulation is based on the software of HFSS. The antenna is fabricated and measured at last. The photograph of the antenna is shown in Fig. 4.

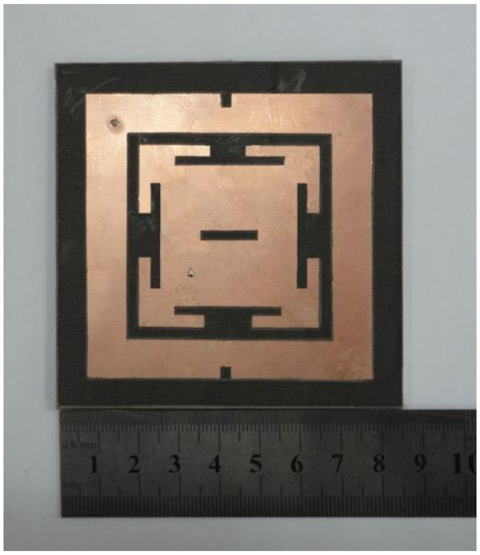
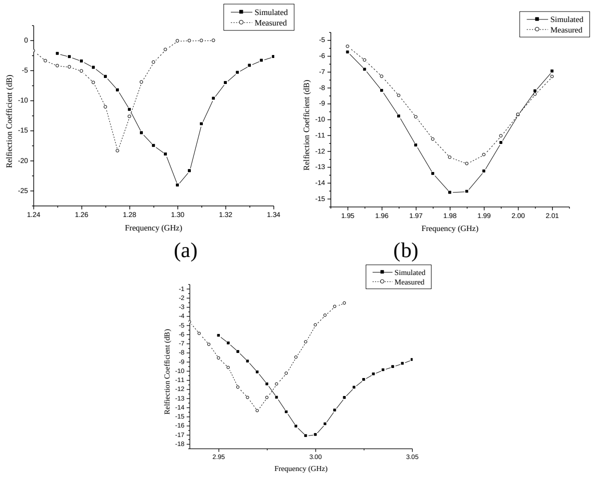


Figure 4. Photograph of the antenna

The simulated and measured results of reflection coefficient versus frequency are shown in Fig. 5. When the reflection coefficient is lower than -10dB, the simulated bandwidths of the antenna are 1.278GHz-1.315GHz, 1.965GHz-1.995GHz and 2.968GHz-3.032GHz. However, the measured results of reflection coefficient are 1.267GHz-1.283GHz, 1.972GHz-1.998GHz and 2.955GHz-2.985GHz. The difference between measured and simulated results in low frequency and high frequency is bigger. The measured bands are lower than the simulated. The reason is that there are many slits on the patch, and high machining precision is requirement. There are errors in fabricating.

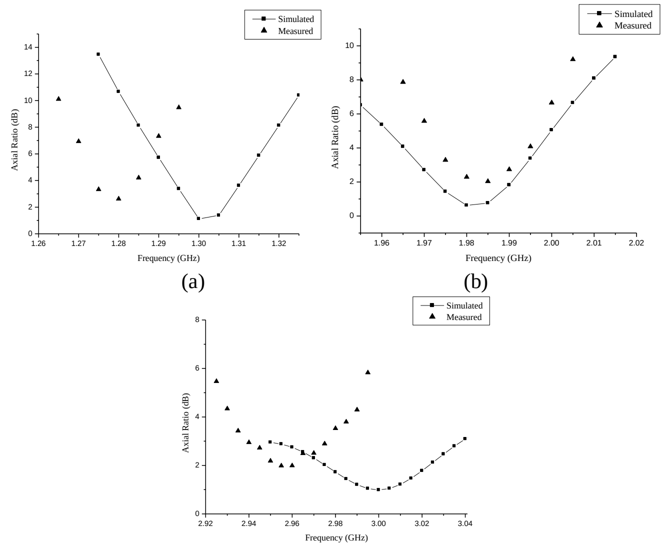


(a) (b)

(c)

Figure 5. Simulated and measured reflection coefficient versus frequency of the antenna

Fig. 6 gives out the simulated and measured results of axial ratio versus frequency of the antenna. From Fig. 6, we can conclude that when the axial ratio is lower than 3dB, the simulated bandwidths of axial ratio are 1.297GHz-1.308GHz, 1.967GHz-1.994GHz and 2.955GHz-3.035GHz. The measured bandwidths of axial ratio are 1.277GHz-1.283GHz, 1.975GHz-1.993GHz and 2.942GHz-2.977GHz. When the antenna works at 1.98GHz, the bandwidth of axial ratio is narrower than that at 1.3GHz and 3GHz.

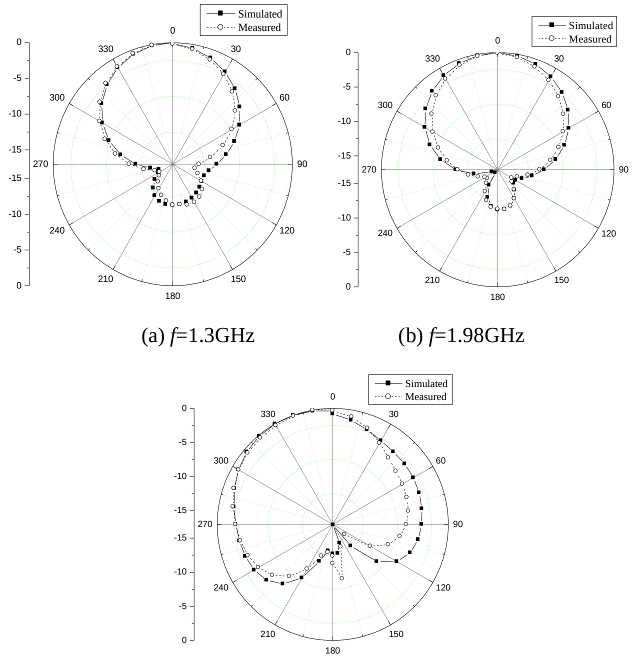


(a) (b)

(c)

Figure 6. Simulated and measured axial ratio versus frequency of the antenna

From Fig. 5 and Fig. 6, we can obtain that the bandwidth of the outer patch, including impendence bandwidth and axial ratio bandwidth， is not as wide as the centre patch. This is because that the bandwidth of the square ring is narrow, and not wider than the square patch.



(a) *f*=1.3GHz (b) *f*=1.98GHz

(c) *f*=3GHz

Figure 7. Simulated and measured normalized radiation patterns of the proposed antenna at xoz plane

The simulated and measured normalized radiation patterns at xoz plane are shown in Fig. 7. When the antenna works at 1.98GHz, the maximum radiation direction is +z direction. But the maximum radiation direction is a little offset +z direction when the antenna works at 1.3GHz and 3GHz. The square ring is a symmetrical structure. But the centre patch is not a symmetrical structure because the parameters of dc and dT are not equal.

V. CONCLUSION

In this paper, a multi-band circularly-polarized microstrip antenna is designed. The antenna is compact and easy to fabricate. Two patches are placed on one substrate. The centre patch is a square patch with four T-shaped slits, and the outer patch is a square ring with two square slots. The antenna can work 1.3GHz, 1.98GHz and 3GHz. Good circularly polarized operation can be generated. Simulated and measured results show that the antenna can generate circular polarized in three bands and can satisfy satellite communication.

ACKNOWLEDGMENT

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