

Miniaturization of S-band circularly polarized microstrip antenna

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Abstract. A S-band miniaturized circularly polarized microstrip antenna is designed and fabricated. The curved current technique is utilized, and the effective path length of current is increased by loading the U-shaped slot on the radiating patch. Thus the antenna resonant frequency can be tuned and the antenna can be significantly miniaturized. The experimental samples of the antenna are fabricated and tested. The measured results show that the two resonant frequencies of the miniaturized S-band circularly polarized microstrip antenna are 2.17GHz and 2.25GHz, with an impedance bandwidth ($S_{11} < -10$ dB) of 152 MHz (from 2.132 GHz to 2.284 GHz). The measured gain is about 0dB. The measured results are basically consistent with the simulation results.

1 Introduction

The frequency range of the S-band is 2 to 4 GHz. Satellite communications, radar, and Bluetooth, Zigbee (wireless communication technology that enables short-range, low-power consumption), wireless routers, and wireless mice, which are widely used in everyday life, all operate in this frequency range. Miniaturized microstrip antennas have the advantages of small physical size, easy fabrication and installation, which is conducive to concealed work, cost reduction, system integration and increased wind strength. It is a key direction of microstrip antenna research. The miniaturization of microstrip antennas can be considered as reducing the size of the antenna under the premise of keeping the antenna resonance frequency unchanged. Equivalently, it can also be considered that the resonant frequency of the antenna is reduced under the condition of ensuring that the overall size of the antenna is unchanged.

At present, according to the relevant literature, the main ways to achieve miniaturization of microstrip antennas are: using high dielectric constant substrates [1, 2], curved flow techniques [3, 4], short-circuit pin loading techniques [5, 6], or using artificial electromagnetic metamaterials (such as artificial electromagnetic bandgap structures [7-10], left-handed dielectrics [11]), fractal theory, etc. In general, not only a single miniaturization technology can be used, but also a combination of multiple miniaturization techniques can be used to achieve miniaturization of microstrip antennas.

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In this paper, the miniaturization of an S-band circularly polarized microstrip antenna is studied. By etching the U-shaped slot on the surface of the radiation patch of the antenna, the current on the surface of the patch is guided to a zigzag detour, the propagation path of the current is changed, the effective path length of the current is increased, the electrical length of the antenna is increased, and the resonance frequency of the antenna is reduced under the condition of ensuring that the geometric size of the radiation patch is unchanged.

2 Structure of the antenna

The antenna is mainly composed of a ground plane, dielectric plate, and radiation patch, and its overall structure is shown in Fig. 1. The radiation patch of the antenna is L_0 in length and W_0 in width. The specific design is to create a U-shaped slot inside the radiation patch, and the current bypasses the U-shaped slot when it flows to achieve the effect of increasing the current path. The U-shaped slot is w_i in thickness, L_1 in length, and W_1 in width, and is located at L_g and W_g from the radiation patch. The ground plane of the antenna has a defective ground structure. The proposed antenna is fabricated on an easily available FR4 substrate with a thickness of 1.6 mm ($\epsilon_r = 4.4$, $\tan \delta = 0.02$).

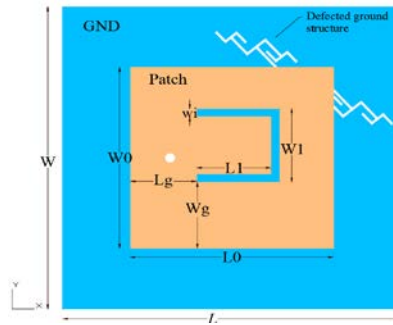


Fig. 1. The overall structure of the antenna.

3 Parameter analysis

The antenna is simulated and analysed by Ansoft HFSS electromagnetic software, and the parameters of the antenna are investigated. The current path on the radiation patch is changed by etching the U-shaped slot, and the resonant frequency of the antenna is affected. In this part, the influence curves of the main parameters of the U-shaped slot on its performance are analysed. This U-shaped slot has the key parameters of L_g , W_g , length L_1 , width W_1 . When one parameter is studied, the other parameters remain unchanged and are kept constant.

The effect of the U-shaped slot position parameter L_g on antenna S11 is shown in Fig.2. The performance of the antenna is not up to level for S-band when the position parameter L_g is 6mm and 10 mm. At $L_g = 8$ mm, the antenna produces two resonant frequencies and has a good impedance bandwidth. Fig. 3 investigates the influence of the position parameter W_g of the proposed antenna on S-parameters. At $W_g = 9$ mm, the reflection coefficient S11 value at the antenna resonance frequency is the best, the impedance bandwidth is wider, and the impedance match is better.

The performance of the antenna is also affected by the width W_1 of the U-shaped slot. The simulated result of antenna S11 with the variation of W_1 is shown in Fig. 4, the resonant frequency of the antenna gradually decreases with the increase of W_1 . When $W_1 = 10$ mm, the resonant frequency is further reduced, the impedance matching of the

antenna is significantly improved, the working frequency band is widened, and the performance is better. Fig.5 gives the simulated result of antenna S11 with the variation of L1. As L1 increases, the current path is extended and the resonant frequency is decreased. Finally, at L1 = 9mm, the S11 value at the antenna resonant frequency drops below -30dB, and the performance is good.

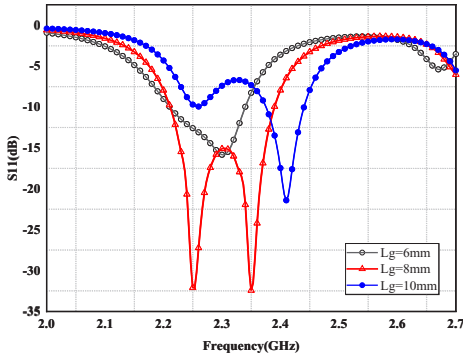


Fig. 2. Simulated S11 with varying L_g .

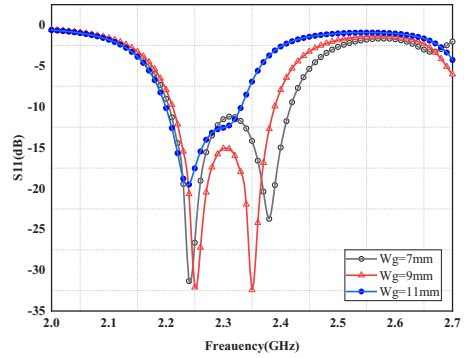


Fig. 3. Simulated S11 with varying W_g .

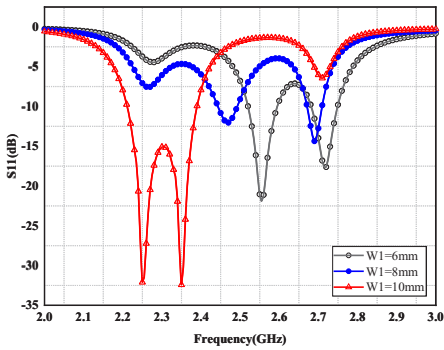


Fig. 4. Simulated S11 with varying W_1 .

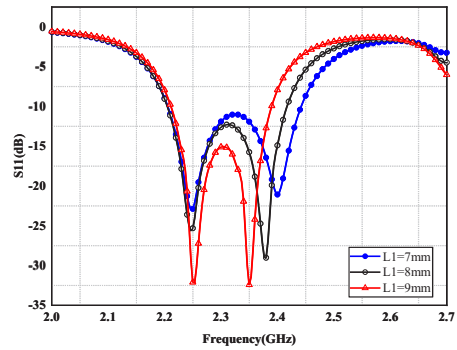


Fig. 5. Simulated S11 with varying L_1 .

All dimensions of the antenna patch are simulated and swept, and the finalized dimensions of the antenna are as follows (unit: mm): L=41, W=41, h=1.6, L0=24.6, W0=24.6, Lg=8, Wg=9, L1=9, W1=10, wi=1.1

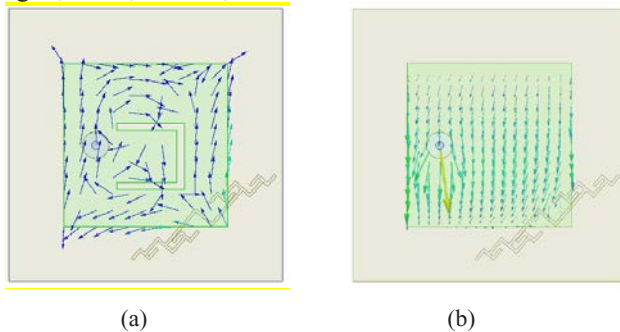


Fig. 6. Antenna current distribution (a) U-shaped slot patch (b) Common patch.

The antenna adopts a U-shaped slot loading technique to extend the current path and realize miniaturization. The patch current distribution of the antenna loaded with U-shaped

slot and the common microstrip antenna are shown in Fig.6, the current distribution is simulated by the electromagnetic simulation software Ansoft HFSS. From the simulation results, the current on the surface of the ordinary microstrip antenna patch flows directly from the bottom of the patch to the top of the patch, and the flow path is short. However, in the process of the current flowing around the U-shaped slot, the flow path of the antenna is greatly increased, and the resonant frequency of the antenna is reduced, so the antenna is miniaturized.

4 Results and discussion

After parameter optimization, the S11 value of the miniaturized antenna is shown in Fig.7 and is compared with a common microstrip antenna of the same size. The result of the miniaturized antenna shows an impedance bandwidth (S11 < -10 dB) of 180 MHz (from 2.21 GHz to 2.39 GHz). The two resonant frequency points are 2.25 GHz and 2.35 GHz, and the corresponding S11 values are -32.02 dB and -31.71 dB respectively. The result of the common microstrip antenna shows an impedance bandwidth (S11 < -10 dB) of 190 MHz (from 2.75 GHz to 2.94 GHz) and the two resonant frequency points are 2.79GHz and 2.9GHz, respectively. The simulated AR bandwidth (axial ratio < 3 dB) of the miniaturized antenna is about 2.14% (from 2.31GHz to 2.36 GHz) with the center frequency of 2.3 GHz was achieved as shown in Fig.8. The antenna after miniaturization in this paper has a lower resonant frequency compared with the common microstrip antenna, the miniaturization is achieved without changing the patch size, but the bandwidth and gain of the antenna are reduced.

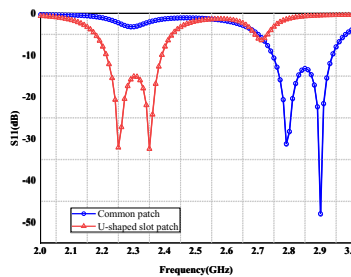


Fig. 7. Comparison of S11 value between U-shaped slot antenna and common patch antenna.

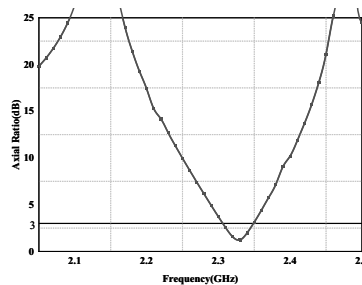


Fig. 8. Antenna axis ratio characteristic diagram.

To validate the proposed concepts, a prototype is fabricated and measured. Fig. 9 shows the photograph of the fabricated proposed miniaturized antenna. The S-parameters of the antenna is tested using a vector network analyser. Fig. 10(a) shows the measured and simulated S-parameters for the proposed miniaturized antenna. The antenna simulated result shows that the two resonant frequency points are 2.16GHz and 2.25GHz, and the

corresponding S11 values are -20.58dB and -20.98dB, respectively. And the measured result shows an impedance bandwidth (S11 <-10 dB) of 152 MHz (from 2.132 GHz to 2.284 GHz). Comparing the measured results with the simulated results, it can be seen that the general trend of the two curves is consistent, but the measured resonant frequency point is slightly shifted to the left, and the corresponding S11 value is also increased. Fig.10(b) shows the gain result of the test, the maximum gain at 2.2GHz is about 0dB, while the maximum gain of the simulation result is 1.17dB. The reason for the increase of the S11 value corresponding to the resonant frequency point of the antenna, the narrowing of the bandwidth, and the weakening of the gain is likely to be the error in the actual processing, the influence of some impurities introduced during the welding SMA joint. Table 1 gives a comparison between the miniaturized antenna in this paper and other antenna in the literatures. The antenna in this paper is smaller in size compared with other antennas operating at similar frequencies, but the gain of the antenna is reduced while achieving miniaturization.

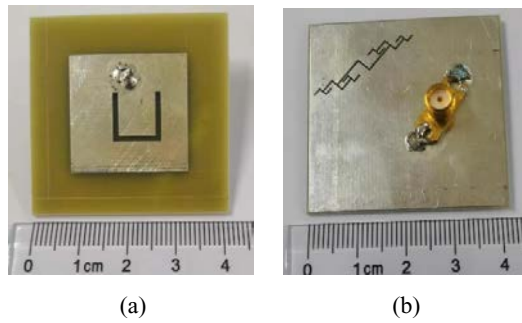


Fig. 9. Fabricated proposed antenna (a)Top view (b)Bottom view.

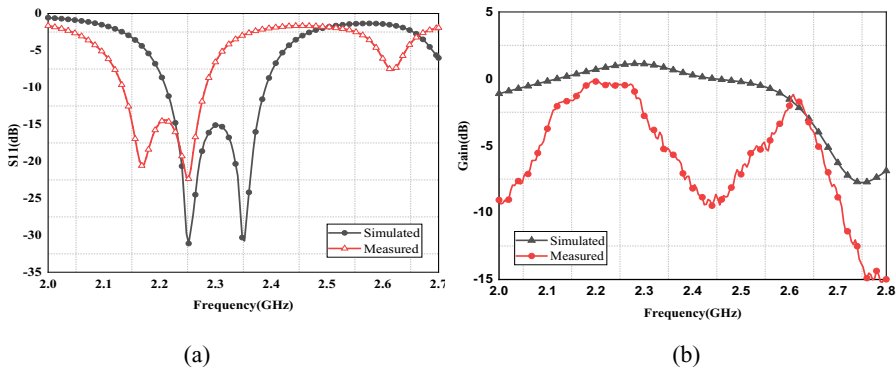


Fig. 10. Antenna measured results compared with simulated results (a)S11 (b)Gain.

Table 1. Comparison of the performance of the antennas.

Ref.	Size(mm)	Operating frequency (GHz)	Bandwidth (GHz)	Gain (dB)
[4]	117*97*8.33	1.92-2.15	0.23	8dB
[12]	50*50*6.2	1.88-2.12	/	0dB
[13]	61.22*61.22*1.57	2.45	0.177	/
This paper	40*40*1.6	2.21-2.39	0.18	0dB

5 Conclusion

In this paper, the miniaturization of S-band circular polarization microstrip antenna is mainly studied, and the curved flow technology, one of the classical microstrip antenna miniaturization technique, is mainly used. By etching the U-shaped slot on the surface of the radiation patch of the antenna, the current on the surface of the patch is guided to a zigzag detour, the propagation path of the current is changed, the effective path length of the current is increased, the electrical length of the antenna is increased, and the resonance frequency of the antenna is reduced under the condition of ensuring that the geometric size of the radiation patch is unchanged. Compared with the ordinary microstrip antenna with the same patch size, the two resonant frequency points of the miniaturized antenna are reduced to 2.16GHz and 2.25GHz, and the miniaturization effect is obvious.

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References

1. J. Long, D.F. Sievenpiper, IEEE AWPL, 14 (2015)
2. J.S. Kula, D. Psychoudakis, W.J. Liao, C.C. Chen, J.L. Volakis, J.W. Halloran, IEEE, 48 (2006)
3. Nasimuddin, Z.N. Chen, X. Qing, IEEE TAP, 60 (2012)
4. X.X. Qi, Y.Z. Chen, Shandong Industrial Technology, 23 (2018)
5. A.A. Salih, M.S. Sharawi, IEEE AWPL, 15 (2016)
6. Y.H. Li, Y.J. Zhang, Techniques of Automation and Applications, 37 (2018)
7. P.P. Bhavarthe, S.S. Rathod, K.T.V. Reddy, IEEE TAP, 67 (2019)
8. J. Zaid, M. Farahani, A .Kesavan, T. Denidni, IEEE, (2017)
9. H. Liu, J.A. GUO, M.X. Shi, Y. SUN, Information Technology and Informatization, 07 (2017)
10. Z.H. Cao, F. Xing, X. Lei, Z.M Wang, Journal of Microwaves,28(2012)
11. L.G. Wei, Shipboard Electronic Countermeasure,39(2016)
12. J. Li, A. Zhang, W.T. Joines, Q. H. Liu, IEEE ISAP,(2016)
13. N. Gurgel, I. Queiroz, H. Andrade, T. Silveira, IEEE, (2021)