A Design of Miniaturized Dual-band Antenna

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***Abstract*：Based on the principle and cavity mode theory of microstrip antenna, this article introduces the theoretical approaches of slotting in the non-radiative side to get the dual characteristics. We have designed a dual-band microstrip antenna with a U-shaped slot, which can make the high-frequency be 5.25GHz and the low-frequency be 1.75GHz by changing the length and width of the slot.**

I. INTRODUCTION

In recent years, with the development of communication system and radio system, the technology for antenna's miniaturization and multi-frequency becomes more and more important. Because of its low profile, small volume and light weight, mcirostrip antennas have been widely used in many fields [1].

To make the antenna miniaturization, we can increase the dielectric constant of the dielectric substrate[2], slot on the surface and short loading[3]. We can also make antenna achieve multi-band by using a variety of different resonant modes (such as radiation patch TM_{10} or TM_{01} mode), the antenna operates in the mode, which can be achieved in dual or multi- frequency band antenna; patch is loaded by a single method or open grooves, changing the patch field distribution of natural modes, and thus interfere with the mode the excitation of the resonant frequency, so that the antenna can operate in dual-band or multi –band; single layer substrate used in a structure covering the plurality of the radiation patch .

According to modes theory, the first three modes of the microstrip patch have the same polarization plane, they are TM_{10} TM_{20}, TM_{30}, which apply the theory for the realization of the dual frequency and multiple frequency. In these models, TM_{10} is a typical pattern in practical application, TM_{20} mode resonant frequency is twice as high as the TM_{10} mode, and TM_{30} mode resonant frequency is three times higher than the TM10 mode. But in the actual application, the last two resonant modes are not often used. This is because on the surface of the patch, the current distribution is not uniform in TM_{20} mode, which the antenna radiation pattern can produce zero [4]. The antenna radiation direction plan will produce larger side lobe in TM_{30} mode. To take advantage of the above three models to implement dual-band characteristics, usually adopted method is slotted on the patch. Loading cracks in the patch surface can change the path current movements on the surface of the patch, which can change the current distribution. Through the gap on the patch loading position is different, can be roughly divided into the slot method: slot at the edge of the radiation and the radiation in slot.

II. ANTENNA DESIGN

Slotting at the radiation patch edge is used widely to achieve dual-band antenna [5]. This method is simple and convenient. It can not only make the antenna gain double frequency characteristic, but also the process is simple. Compared with slotting at the edge of the radiation, slot near the radiation side, which will make the current distribution small. The related antenna radiation characteristics, such as antenna pattern, cross polarization performance will be better. This design loads the u-shaped slot in the radiation boundary, by changing the slot length and width can easily adjust the antenna of high frequency resonance point and low frequency resonance points, meet the antenna need.

2.1 U-shape slot antenna

The U-shape antenna structure is shown in Fig.1. According to the figure, the size of the patch is L×W, the width of the slot is w, the length of the slot is Ls and the slot is 1mm far away from the edge of patch. The thickness of the dielectric substrate is h. The dielectric constant is ε_r. The coaxial feed point from the center axis of the patch is m.

This design of miniaturized multi-band antenna should make the high frequency be 5.25GHz and the low frequency is 1.75GHz.

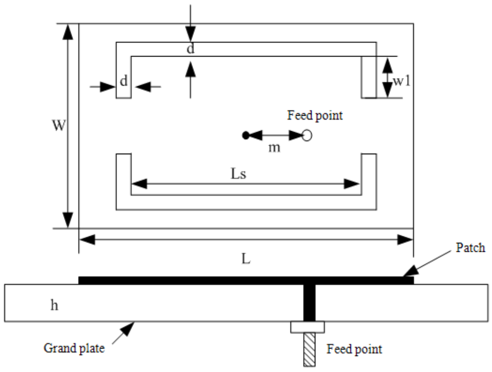


Fig.1. U-shape slot microstrip antenna structure.

According to the above theory, choosing high dielectric constant and thick dielectric substrate can get miniaturization antenna, so this design uses rogers4350 as the substrate and is thickness is 1.524mm. to get a good frequency impedance matching, we uses coaxial feed.

After calculation, the size of the antenna is: L=32mm, W=28mm, m=5mm. Changing the length Ls、width w can affect the ratio of high frequency and low frequency. Detailed discussions of the analysis are as follows.

(1) Length Ls

Change the length Ls while the other parameters maintain the same size, S11 parameters of the antenna is shown in Fig. 2.

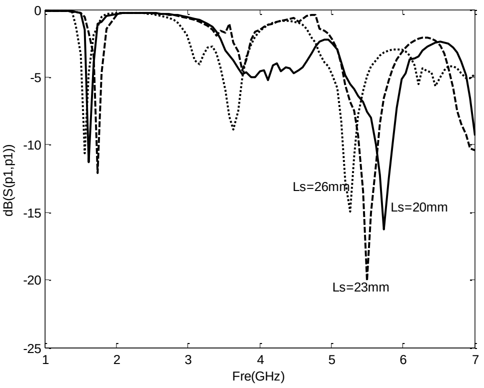


Fig.2. S11 parameters with different Ls.

As can be seen from the figure 2, changing Ls affects the S11 parameters of the antenna. The high frequency changes a lot but the low frequency variation is not obvious. The current of the patch surface will not produce high frequency response if Ls is too short, which cannot form dual-frequency.

(2) Width d

Change the width d while the other parameters maintain the same size, S11 parameters of the antenna is shown in Fig.3.

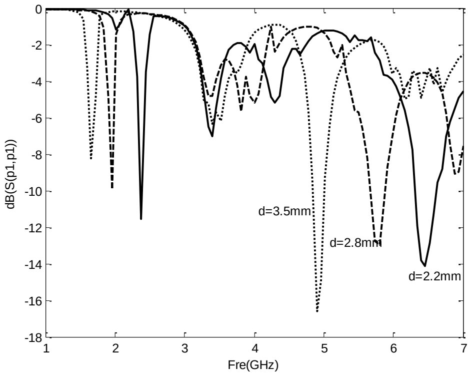


Fig.3. S11 parameters with different d.

As can be seen from the Fig.3, the high frequency and low frequency vary a lot by changing w. With the increasing d, the high and low frequency becomes small, which is because d affects the Antenna impedance characteristics.

Considering the effect of the slot length and width to the antenna, we can optimize the design parameters of the antenna during simulation, which can obtain the desired high and low bands.

After simulation and optimization in the HFSS, the size of the antenna is: L=32mm， W=26mm， m=5mm， L=24， w=3mm， w1=5.5mm。

During the HFSS simulation environment, S11 simulation results of the antenna is shown in Fig.4.

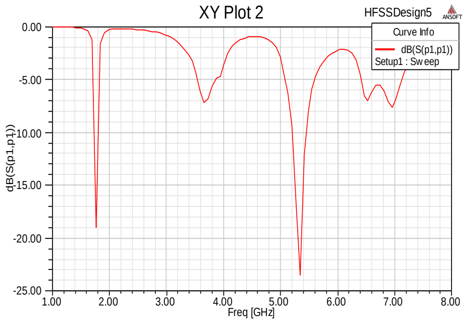


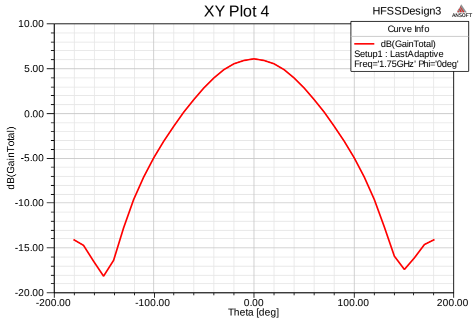
Fig.4. S11 parameters of the antenna.

Antenna radiation pattern is shown in Fig.5.

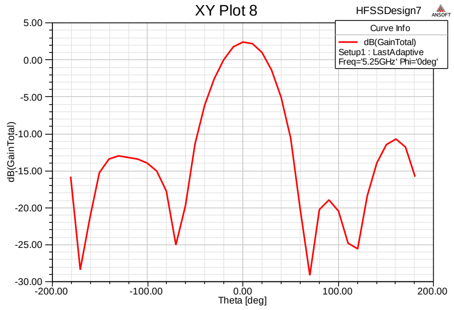
It can be seen from the radiation pattern that the high-frequency 5.25GHz gain can reach about 3dB while the low frequency 1.75GHz gain is 6dB.It also can be seen that the antenna at high frequency 5.25GHz exits secondary lobes.

2.2 *Antenna measured results*

Based on the simulation, we use the CAD drawing to draw the antenna size and work out this U -shaped slot antenna microstrip antenna.



Center frequency is 1.75GHz.



Center frequency is 5.25GHz.

Fig.5. Antenna radiation pattern.

This antenna is printed on a substrate rogers4350, the relative dielectric constant of the board was 3.55 , the thickness is 1.524mm, scale is 40mm * 50mm, at the same time, using the probe of 1mm diameter of SMA coaxial feed，its Physical antenna is shown in Fig.6.

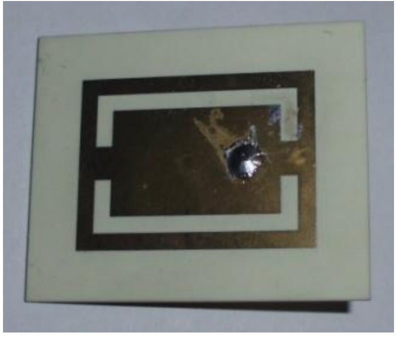


Fig.6. Physical Antenna.

After analyzing by the network analyzer, the physical dual-band antenna S-parameters is shown in Fig.7.

As can be seen from Fig.7, the antenna reflection parameters of the test curve and the curve obtained software simulation is consistent. After testing, the direction of the antenna 5.25GHz diagram is shown in Fig.8.

Fig.8 shows that the measured results and simulation results are basically consistent. It can be seen from the figure, only a slight deviation of the measured and simulation, the actual measured gain is slightly lower than the simulation results.

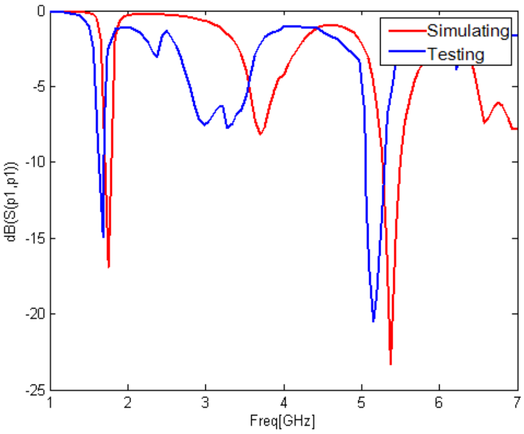


Fig.7. S-parameters of the antenna diagram comparison chart.

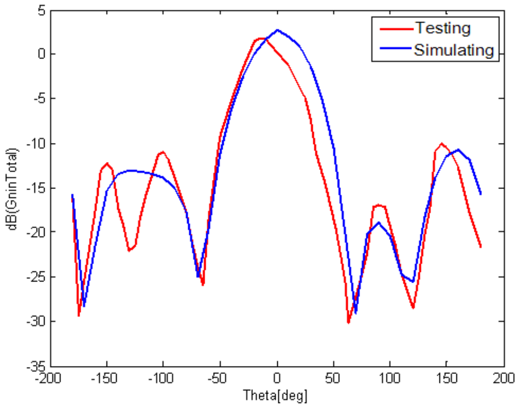


Fig.8. Measured antenna pattern.

The paper designed to achieve the dual-band antenna though, but from the simulated and measured results can be seen very narrow bandwidth of the antenna, with the current requirements of ultra- wideband characteristics compared, there is a large gap between the need for further optimization and improvement. In addition, the size of the antenna could be improved, so that the antenna can truly achieve miniaturization, ease of integration in the circuit board.

III. CONCLUSIONS

This paper introduces some theoretical basis and technical methods to figure out the miniaturization and dual-frequency of the antenna in detail. Based on this theory, a dual-band structure with a slot along the non-radiation side has been investigated. According to the theory, we have designed a dual-band microstrip antenna with a U-shaped slot, which can make the high-frequency be 5.25GHz and the low-frequency be 1.75GHz by changing the length and width of the slot.

REFERENCES

[1] Lin Changlu. *Modern Antenna Design* [M]. People Post Press,1990.

[2] Lo. T Ketal. Miniature aperture-coupled microstrip antenna of very high permittivity[J]. *Electron, Letts*, 1997, Vol.33, pp. 9-10.

[3] Chow Y. L, Wail K. L. Miniaturizing patch antenna by adding a shorting pin near the feed probe a folded monopole equivalent[J].*IEEE Antennas and Propagation Society International Symposium*, 2002,4, pp.6-9.

[4] Chen W. H. Dual-band reconfigurable antenna for wireless communication [J]. *Microwave and Optical Technology Letters*. 2004.3,40(6), pp.50-55.

[5] Zi Dong Liu, Hall P S．Wake，Dual-fequency planar inverrted-F antenna[J]. *IEEE Antennas and Propagation*, 1997, 45(10), pp.1451-1458.