A design of modified Vivaldi antenna

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Keywords: Vivaldi antenna, high gain, groove

Abstract. Conventional Vivaldi antenna has the advantages of ultra wideband, but its backward radiation is too large and the the gain of the main radiation direct is low [1]. On the basis of the original Vivaldi antenna, this paper designed a Vivaldi antenna element with a groove, its working frequency is from 400 MHz to 900 MHz. Grooves can change the current distribution on the antenna surface, so as to influence the gain of the antenna element, and can make the pattern more evenly. The test and simulation results show that the pattern of the modified Vivaldi antenna is more smooth than the traditional Vivaldi antenna, and the antenna gain is improved in the whole operating range.

1. Introduction

The Vivaldi antenna is a kind of exponential tapered slot antenna that is put forward by the British Philips laboratory of Gibson in 1979 [2][13]. The slot of Vivaldi antenna varies according to the index law. It is a kind of antenna which is nonperiodic and continuous, so it has a very wide frequency band. Although the Vivaldi is a kind of antenna with ultra-wideband, but its orientation is relatively poor, and the gain decreased sharply in the working frequency band of the low-end and high-end[6]. Therefore, how to improve the radiation performance of Vivaldi antenna is a focus of research for many scholars. The Vivaldi antenna is a planar antenna with simple structure and can be integrated with other modules using printing technique, so it is used in various measurement and receiving system to probe electromagnetic wave signal with wide frequency band.

The exponential curve of typical Vivaldi antenna is shown in Fig. 1 , which is determined by the opening rate of R and P 1 (x1, Y1), P 2 (X2, Y2) [3].
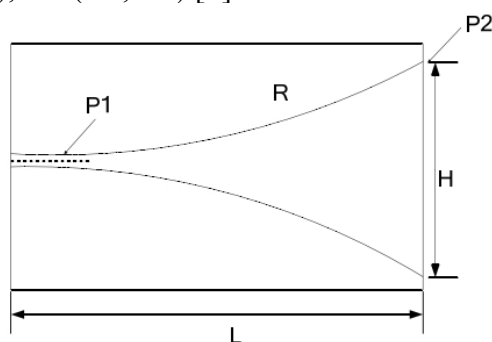

Fig. 1 The exponential curve of typical Vivaldi antenna

In the figure, H is the size of the antenna mouth,which is half of the wavelength. y_2-y_1 is the length of the tapered part of the antenna. When the opening rate is zero, it is a linear tapered slot antenna. In accordance with the requirements of the theoretical calculation

$$\lambda_{g\,max} = \frac{c}{f_{min}\sqrt{\varepsilon_r}}$$

(1)

In the formula (1), c is the speed of light in vacuum, f_{min} is the lowest frequency, ε_r is dielectric constant[4][13].

The width of the most narrow slot is about 2% of the maximum cut-off frequency. For the same opening size. the size of the angle is inversely proportional to the length of the antenna. When the opening angle of antenna becomes smaller, it can improve the low frequency impedance bandwidth. Conversely, when the open angle of antenna becomes larger, that can improve the antenna frequency

impedance bandwidth, and then opening of P1 becomes smaller, the performance of low frequency segment will decline[8][11][14].

2. The design of traditional form of Vivaldi antenna

Through the above analysis, we can find the design for tapered slot antenna can be mainly concentrated in two aspects, namely the design of feed structure and slot shape[7]. The feed structure affects the matching characteristics of the whole antenna impedance, while shape of slot line control the antenna radiation characteristics[9][10].

First, we should selecte the dielectric material, the dielectric constant is 2.2, the thickness is 31.2mm, the center frequency is 650MHz. The structure disgram of slot antenna is shown in Fig. 2. The relevant parameters are shown in Table 1.
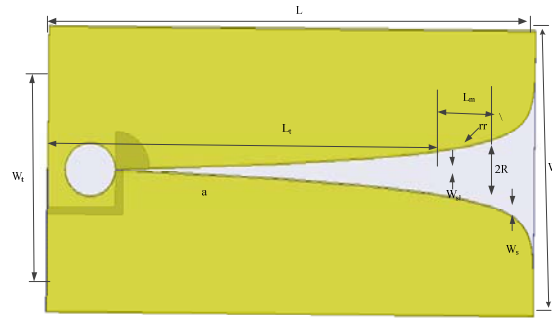

Fig. 2The structure diagram of traditional Vivaldi antenna

Table 1 Relevant parameters of traditional Vivaldi antenna

L	W	H	F_{W2}	F_{L3}
560mm	400mm	5mm	8mm	36mm
R	rr	F_{L1}	W_S	R_2
20mm	37.5mm	83mm	5.55mm	0.031

Through the simulation analysis of HFSS software, we can get the return loss of the original Vivaldi antenna at 400MHz~900MHz, which is less than -10dB at each frequency point of the working frequency band. As shown in Fig. 3, the bandwidth of the antenna meets the requirements of the system. Now we investigate the antenna pattern in frequency of 400MHz, 650MHz, 900MHz, through the HFSS simulation, the results are shown in Fig. 4, Fig. 5 and Fig. 6 .
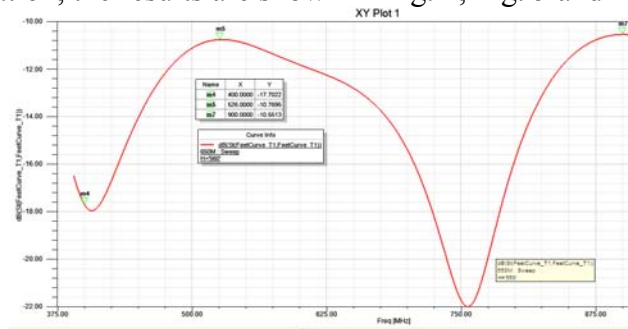

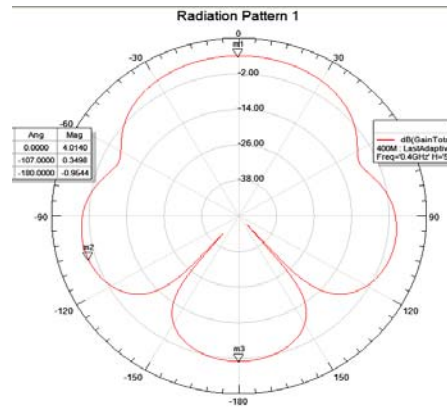Fig. 3 Return loss of conventional Vivaldi antenna element at 400~900MHz

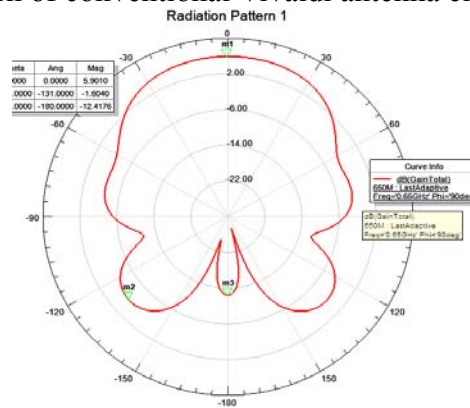Fig. 4 The pattern of conventional Vivaldi antenna element in 400MHz

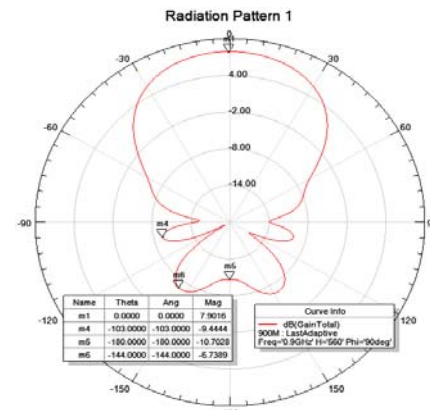Fig. 5 The pattern of conventional antenna element in 650MHz

Fig. 6 The pattern of conventional antenna element in 900 MHz

By analysis, the side lobe of traditional Vivaldi antenna unit at the frequency of 400MHz is large, the gain is about 4dB. The gain is about 5.9dB at 650MHz, and about 7.9dB at the high frequency of 900MHz.

3. The design of modified Vivaldi antenna

Based on the original Vivaldi antenna, this paper improves the Vivaldi antenna element with a groove, the length of which is 180mm, the width is 10mm, the open angle is 60°. The structure diagram is shown in

Fig. 7, the relevant parameters are shown in Table 2. Groove can change the current distribution on the antenna surface, so as to influence the gain of the antenna element, and make the directional diagram more uniform. It won't have the disadvantages of high Side lobe level and narrow Scanning range.

Fig. 7 Diagram illustrating of modified Vivaldi antenna element

Table 2 Related parameters of modified Vivaldi antenna element

L	W	H_1	L_t	R_2	R
562mm	360mm	5mm	400mm	0.055	20mm
F_{L1}	F_{W1}	F_{L2}	F_{W2}	L1	L2
79mm	5.5mm	36mm	4mm	10mm	200mm

The current on the surface of grooves of modified Vivaldi antenna will lead to the increase of side lobe and the decrease of the gain of the end radiation direction. Most researchers believe that the structure of the groove can suppress the current on the surface, which can improve the radiation characteristics of the antenna[7]. Through the simulation of HFSS, we can find that the return loss of the modified Vivaldi antenna in each frequency point from 400MHz~900MHz band is less than -10dB, which is shown in Fig. 8.

With the join of grooves, the pattern of Vivaldi antenna element in 400MHz is more rounded, the scanning angle is larger than the original antenna, the gain in the range of -30° to 30° can reach 4dB, sidelobe level is significantly reduced, as shown in Fig. 9. Similarly, the scanning range from -30° to 30° can reach 6.2dB in 650MHz, the sidelobe level reduced to -1.1dB, as shown in Fig. 10. The scanning range from -30° to 30° can reach 8.1dB in 900 MHz, the sidelobe level is reduced to -3.6dB, as shown in Fig. 11.

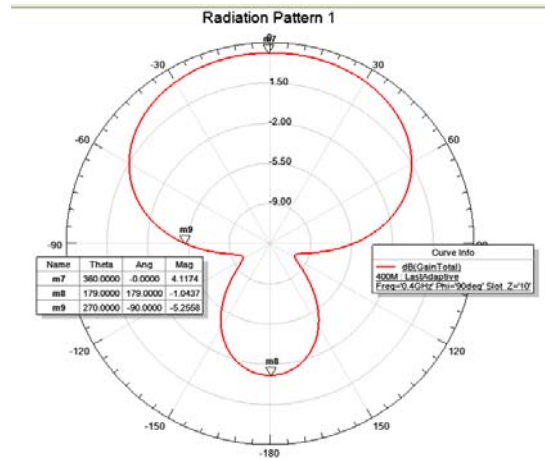Fig. 8 Return loss of modified Vivaldi antenna element in the frequency from 400~900MHz

Fig. 9 The direction pattern of modified Vivaldi antenna element in 400MHz
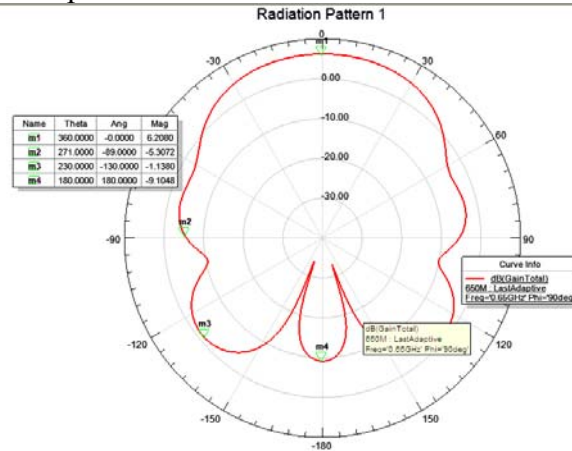

Fig. 10 The direction pattern of modified Vivaldi antenna element in 650MHz
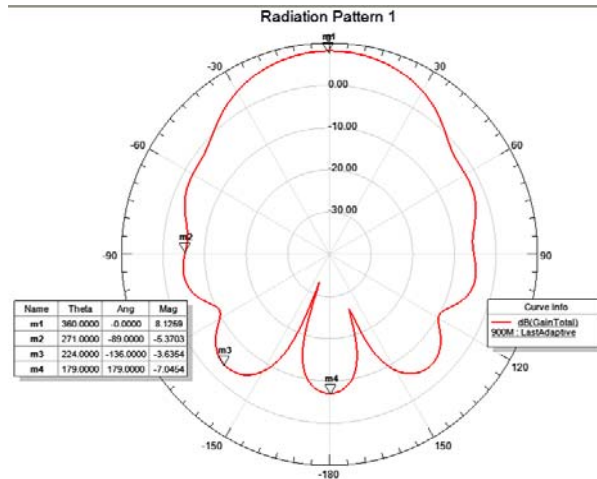

Fig. 11 The direction pattern of modified Vivaldi antenna element in 900MHz

In summary, the gain of Vivaldi antenna unit with the groove is higher than the conventional Vivaldi antenna unit, and the scanning range is larger than that of the conventional Vivaldi antenna unit, the sidelobe level is lower. Simulation results also prove that the performance of this kind of groove is more superior.

4. Manufacture and test of antenna unit

In order to verify the correctness of the theoretical analysis and simulation results, it is necessary to process and test the Vivaldi antenna array unit. For the purpose of convenient processing and testing, we processed and tested the Vivaldi antenna model with a ratio of 2:1, the physical picture of

the Vivaldi antenna array unit is shown in Fig. 12. The radiating element of the antenna is a thin copper plate, in order to reduce the weight of the antenna as much as possible, the thickness of the selected copper plate is only 0.1mm. The interior of the antenna is a light material, and the antenna is fed by a microstrip line, and the end of the antenna is connected with the coaxial connector.

Fig. 12 The physical picture of the Vivaldi antenna unit

We use the vector network analyzer to measure the antenna unit, The reflection coefficient of the antenna is shown in Fig. 13. It can be seen from the figure, the antenna model in the frequency range of 280MHz-1200MHz, the reflection coefficient is below -10dB. It can be seen that the measured bandwidth of slot antenna we designed to be far superior to the required bandwidth (400MHz-900MHz).
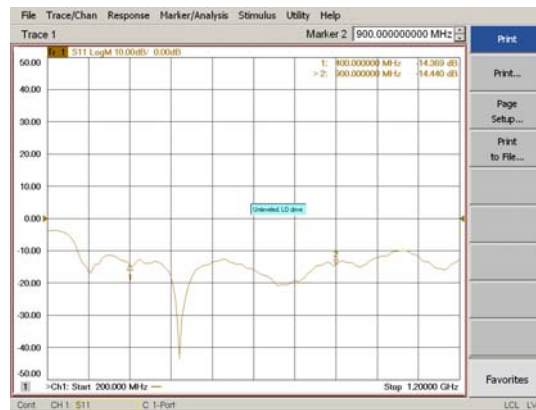

Fig. 13 The Vivaldi antenna array unit reflection coefficient test

5. Conclusion

In this paper, wo designed the structure of the Vivaldi antenna, and modified the performance of the antenna by adding groove technology. According to the simulation results, the woring frequency of the Vivaldi antenna is from 400MHz to 900MHz, the return loss are less than -10dB. At the low frequency, the gain of the modified Vivaldi antenna is about 4dB. At the high frequency, the gain of the modified Vivaldi antenna is about 7.9dB. Compared with the traditional Vivaldi antenna, the gain of the improved Vivaldi is higher, and the direction map is more smooth. In order to verify the validity of the simulation results, we processed the modified imp array element, and with the help of laboratory equipment, the test results show that the reflection coefficient of the antenna was below -10dB in the working freuency.

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