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Optimization Design and Parameter Determination for Vivaldi UWB Antenna

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1. Introduction

The Vivaldi antenna is invented by Gibson [1] in 1979. It is traveling-wave antenna that is important to planar antenna, as shown in Fig.1.It consists of the narrower slotline transition to the wider slotline, which varies by exponential rule. And the electromagnetic wave is radiated out from the horn opening. Different frequency wave is radiated and received at the different part, but electrical length of the different wavelength corresponding radiate part is constant. So it has the wider bandwidth in the theory, and there is the same beam width in the frequency range [2].The properties of Vivaldi antenna are high gain, linear polarization and better time-domain characteristics. It is a very potential planar antenna for UWB communication applications.

One of the important parts of the Vivaldi UWB antenna is feeding structure which is a microstrip-slotline transition [3], as shown in Fig.2. Some parameters and variances must be considered in the design for the Vivaldi UWB antenna, which is difficult to select the best parameters and variances to Vivaldi UWB antenna. There are three parts: 1) magnitudes of strip-stub 2) sizes for slotline circle cavity 3) gradual rates of antenna. In this paper, the effect to the Vivaldi antenna performance by the parameters is discussed, which is the better technology support for Vivaldi UWB antenna design.

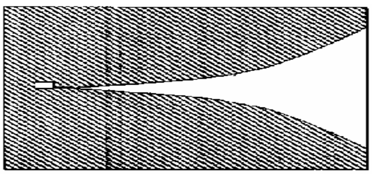

Fig.1 Original Vivaldi Antenna

Fig.2 Typical feeding structure of Vivaldi Antenna

2. Optimization design and parameter determination

2.1 The effect to bandwidth by magnitudes of strip-stub

The strip-stub is designed as a sector for the bandwidth enhancement of the Vivaldi antenna [4-5]. The flare angle of the sector θ and the initial angle of the sector A_0 affect directly the bandwidth of the Vivaldi antenna. Select the parameters of A_0=60^0, θ=40^0, A_0=70^0, θ=30^0, A_0=9^0, θ=88^0 to analysis with the other parameters are invariant using FDTD. The flare angle can affect the bandwidth. When it

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becomes smaller, high and low frequency are all affected. And when it becomes bigger, high frequency is greater affected, as shown in Fig.3.So when the strip-stub is designed, A_0=9^0, θ=88^{0}must be selected.

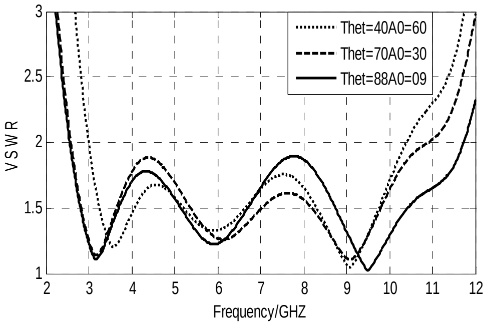


Fig.3 *VSWR* of the Different Flare Angle

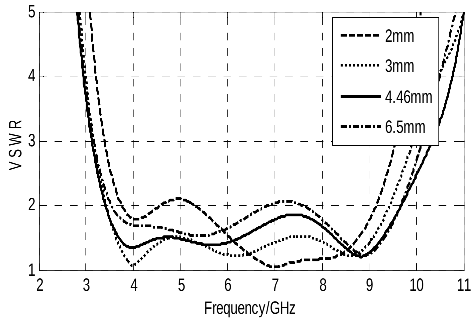


Fig.4 *VSWR* of the Different Slotline Cavity

2.2 The effect of the slotline circle cavity on bandwidth property

The end of the slotline feeding structure is designed as a circle cavity, which can realize the short circuit under the wider frequency range. Change the radius of the slotline circle cavity [6] with other parameters is constant from *R*=2*mm*,3*mm*, 4.46*mm* to 6.5*mm*.The four *VSWR* figures are obtained by optimum simulation using FDTD, as shown in Fig.4. When it becomes bigger, high frequency f_H is greater affected, and low frequency f_L is smaller affected. So the best *R*=4.46*mm* is selected in this design.

2.3 The effect the gradual rate of antenna on directivity property

The opening of the antenna *H* and the length of antenna *L* are designed by the theory and empirical equation [7]. So the gradual rate α is important to the performance of the antenna. Change the gradual rate α from α=0*mm*$^{-1}$,α=0.03*mm*$^{-1}$ to α=0.05*mm*$^{-1}$.The four performance figures are obtained by optimum simulation using FDTD, as shown Fig.5 and other performances are in Table.1.

There are two points obtained from the Fig.5 and the Table.1.

(1)With the gradual rate growing, the bandwidth of *VSWR* is increasing. And the low frequency f_L is affected by the gradual rate. When α equals to 0*mm*$^{-1}$, there are some frequencies' *VSWR* beyond 2.5 during 3~12GHz.Then the designed gradual rate must have lower limit value.

(2) With the gradual rate changing, the efficiency to antenna becomes smaller. But with the gradual rate growing, the gain and main lobe of the antenna is reducing, and then beam angle of the antenna is increasing.

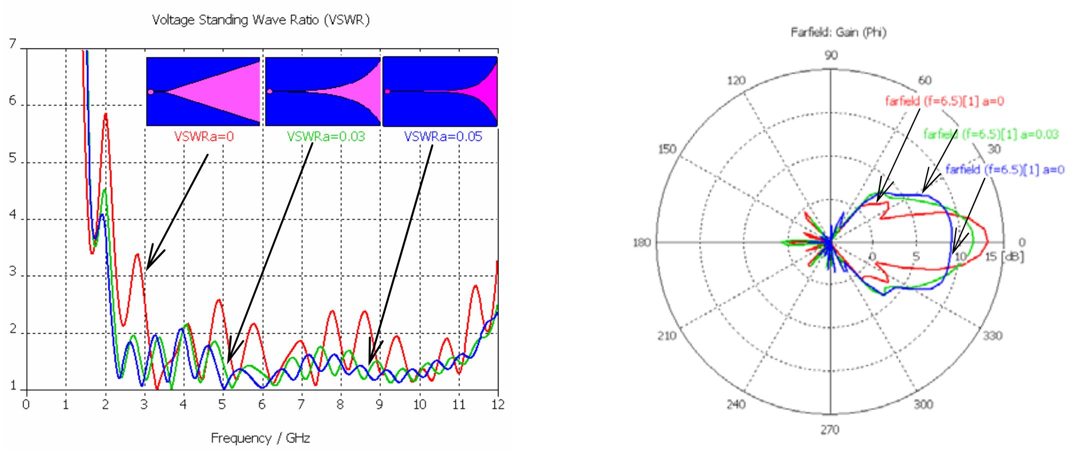


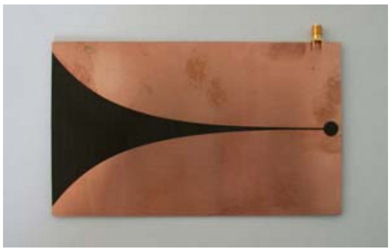
Fig.5 Effect to Bandwidth by Sizes of Slotline Cavity (Left: VSWR, Light: Directional Diagram)

Table 1 Electrical Parameters of Different Gradual Rate to Vivaldi Antenna

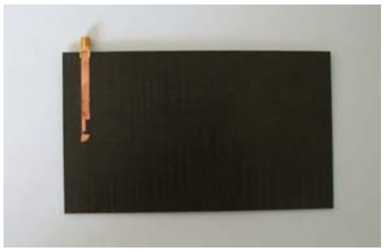
Gradual Rate \ Index	Efficiency (%)	Gain (dB)	Main Lobe (dB)	Sub Lobe (dB)	3 dB Beam Angle(degree)
$\alpha=0mm^{-1}$	98.32	13.09	13.1	-9.8	22.8
$\alpha=0.03mm^{-1}$	98.06	11.45	11.4	-7.7	36.6
$\alpha=0.05mm^{-1}$	98.08	8.975	9.1	-9.8	60.2

3. Fabrication and measurement

Select the Teflon for $\varepsilon_r=2.2$, $t=1.5mm$ to make the model antenna according to the sizes of designing from previous sections, as shown Fig.6. The measurement and simulation of $|S_{11}|$ is shown as Fig.7.



(a)



(b)

Fig.6 Model Antenna Photo
(a) Front View (b) Rear View

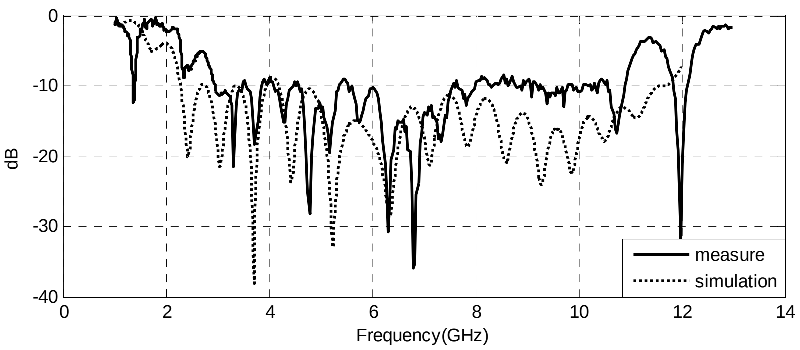


Fig.7 Measurement and simulation scheme of $|S_{11}|$

From Fig.7, Bandwidth equals to 7.945GHz ($BW=f_H- f_L$=10.91-2.965=7.945GHz) and relative bandwidth is 114.5 %($BWr=2\frac{f_H-f_L}{f_H+f_L}=\frac{7.945}{6.938}=114.5\%$), which wholly meet the necessary of WUB antenna's bandwidth specified by FCC.

4. Conclusions

Some parameters must be considered in the design for the Vivaldi UWB antenna to obtain good radiation performance. In this paper, the magnitudes of strip-stub, the sizes for slotline circle cavity and the gradual rate of antenna are included in these parameters. A Vivaldi UWB antenna which covers 3.1GHz～10.6GHz frequency band has been designed through parameter optimization using

FDTD. The relations between parameters and radiation characteristics such as bandwidth and directivity are discussed according the tested results of the prototype antenna. The measure results uniform to the emulation results during the low frequency (2*GHz*~6*GHz*).But in order to the error of minor sized processing, the high frequency performance isn't perfectly.

Acknowledgments

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