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An Improved Design of Horn Antenna

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Abstract. A kind of horn antenna with square waveguide and cone aperture working in Ku band (12.25~12.75GHz) was designed in this paper. The traditional cone antenna with square waveguide and square-cone aperture has good performance in the practice. The horn antenna with cone aperture designed in this paper has the equivalent size with the traditional one. Through simulating with HFSS, the horn antenna designed in this paper has the similar gain with the traditional one, but its return loss is lower than the traditional one. It means that the performance of the improved horn antenna is better than the traditional one. The idea in this paper offered a good reference for the practice.

Keywords: antenna, horn, cone-shaped, Ku band

1 Introduction

Recently, as the development of the communication industry, antenna has become the key part of the communication terminal [1-5]. The performance of antenna is critical to the communication quality. The miniaturization of the antenna and the improvement of the gain have been taken as the hot points in recent years [6-10], however, there is less research in reducing the return loss of the antenna, especially Ku band communication antenna. The return loss has the closely connection with the efficiency of the antenna. The antenna has the lower return loss, which represents that it has better performance. So, the lower return loss is taken as the object, the structure of the antenna is changed. HFSS designed horn antenna with square waveguide and cone aperture, which has better performance than the traditional antenna.

The structure of the antenna designed in this paper is shown in Fig. 1.

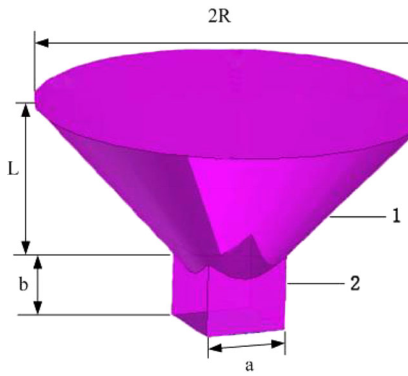

Fig. 1. Structure of the horn antenna with cone aperture

There are two parts in the structure of the antenna: square waveguide and cone aperture. Thereinto, R is the radius of the cone aperture, L is the length of the cone aperture, a is the side of the square

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waveguide, and b is the length of the square waveguide. In this paper, a is 15mm, b is 15mm, R is 35.35mm, L is 25mm.

2 Antenna Design

First, the traditional horn antenna with square waveguide and square cone aperture is designed, and the size of every part are obtained. The side of the waveguide is designed based on the principle of that the modes of the electromagnetic wave in the waveguide are the least. The size of the square cone aperture is designed based on the relation between the gain and the dimension. Then, do the simulation using HFSS.

Second, design the horn antenna with square waveguide and square cone aperture which has the equivalent dimensions with the traditional horn antenna, and do the simulation using HFSS. The design methods of the two kind of horn antenna are given as below.

2.1 The Design of the Traditional Cone Aperture Horn Antenna

In the design process of the horn antenna, the electromagnetic modes in the waveguide should be the least. In that case, the materials of the antenna can be the least, and the signal distortion caused by dispersion should be reduced. Fig. 2 is the structure of the traditional horn antenna.

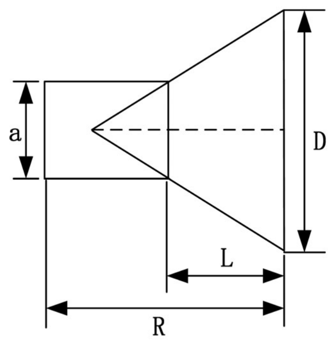

Fig. 2. Structure of the traditional horn antenna

The frequency range of Ku band is 12.25~12.75GHz. Based on the formula below:

$$\lambda = v/f \,. \quad \textbf{(1)}$$

The range of the wavelength is 23.53~24.49mm. Based on the empirical formula, the side of the square waveguide is $a = 0.7\lambda$. So, the range of the side is 12.25~16.5mm.

Because the electromagnetic wave with different frequency has different speed, which can cause dispersion problem and signal distortion. So, the lesser the electromagnetic wave modes in the waveguide, the better the performance of the antenna. The cutoff wavelength formula is shown below:

$$\lambda_c = \frac{2a}{\sqrt{m^2 + n^2}} \,. \quad \textbf{(2)}$$

When side a=15mm, the cutoff wavelengths under the electromagnetic wave modes in the waveguide is shown in Fig. 3.

To ensure the biggest gain in Ku band, the antenna's size can refer to the design process of sector pyramidal horn antenna's design. The structure of sector pyramidal horn antenna is shown in Fig. 4.

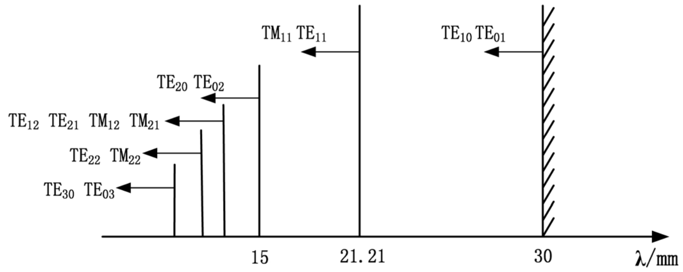

Fig. 3. The cutoff wavelengths under different modes when a=15mm

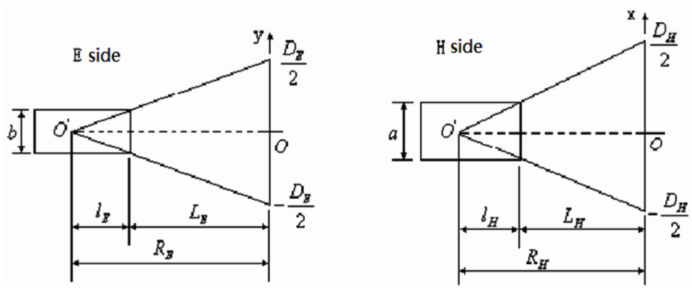

Fig. 4. The structure of the pyramidal horn

The size of the antenna is shown below when the antenna gets the biggest gain.

$$\begin{cases} R_{Hop} = \dfrac{D_H{}^2}{3\lambda} \\ R_{Eop} = \dfrac{D_E{}^2}{2\lambda} \end{cases} \tag{3}$$

$$\begin{cases} l_H = R_H(1 - \dfrac{a}{D_H}) \\ l_E = R_E(1 - \dfrac{b}{D_E}) \end{cases} \tag{4}$$

Verify that: $l_E = l_H, \dfrac{R_H}{R_E} = \dfrac{D_H(D_E - b)}{D_E(D_H - a)}$. The principle is that: R_H and R_E can only be bigger.

The relationship between E plane sectoral horn's gain and size is shown in Fig. 5.

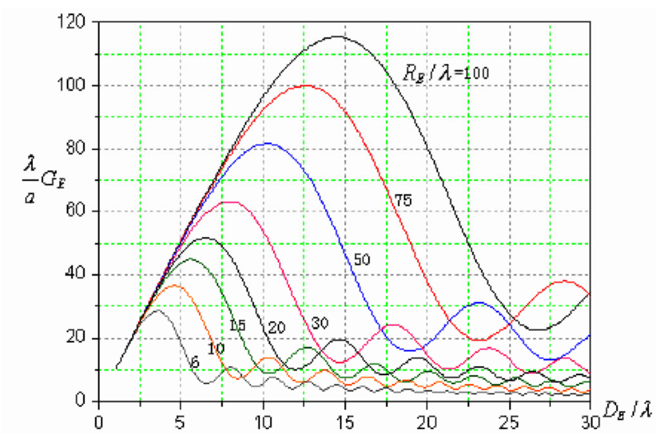

Fig. 5. the relationship between E plane sectoral horn's gain and size

The relationship between H plane sectoral horn's gain and size is shown in Fig. 6.

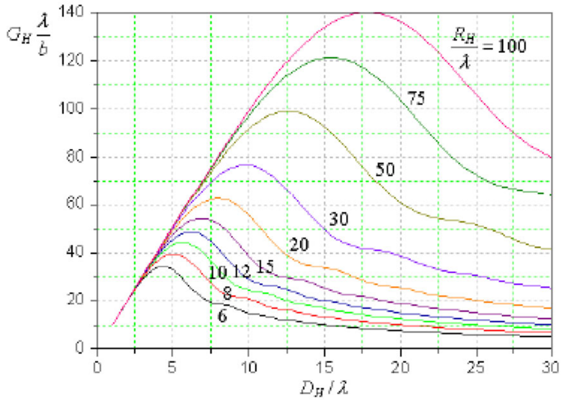

Fig. 6. The relationship between H plane sectoral horn's gain and size

Based on the design principles above, the side of the square waveguide can be 15mm, the length of the waveguide is 15mm, the side of the square cone aperture is 50mm, and the length of the square cone is 25mm. The model established above can be simulated in the HFSS. The structure of the square waveguide square cone aperture horn antenna is shown in Fig. 7.

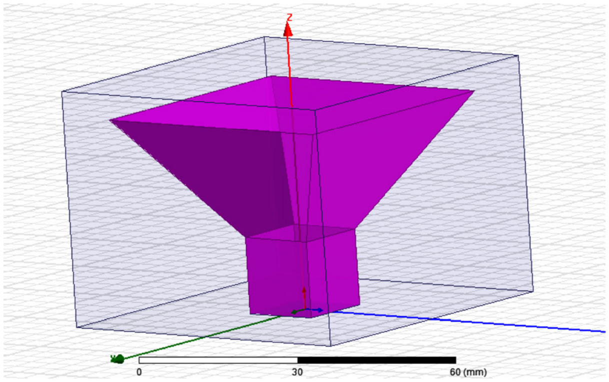

Fig. 7. The structure of the traditional horn antenna

The gain of the square waveguide square cone aperture horn antenna in 12.5GHz is shown in Fig. 8 and Fig. 9. The gain under different frequency is shown in Fig. 10. The gain of the traditional horn antenna in other article is shown in Fig. 11 [11]. The max value of the gain in Fig. 11 is lower than 10dB, which is lower than the 15.25dB in Fig. 8. It means the improved antenna's performance is better than the traditional one. The return loss of the horn cell is shown in Fig. 12. The return loss of the horn cell represents the matches of the antenna port. The lower the return loss is, the antenna's performance is better.

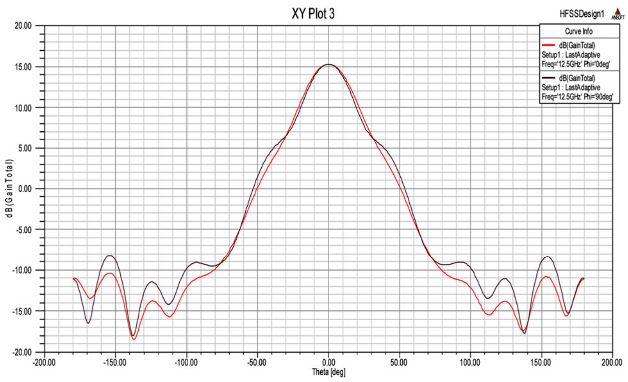

Fig. 8. The gain of the traditional horn antenna in 12.5GHz

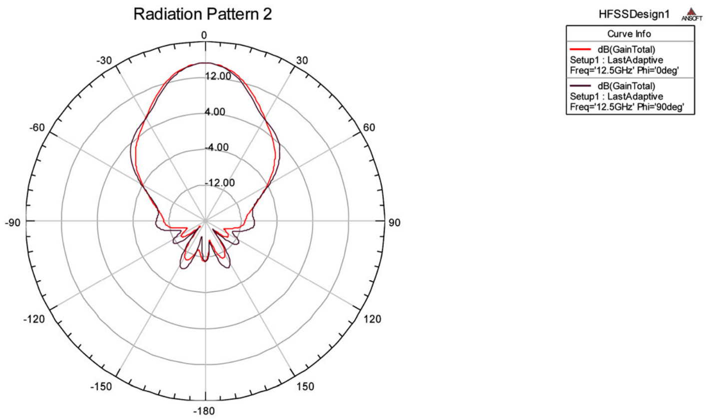

Fig. 9. The gain direction of the traditional horn antenna in 12.5GHz

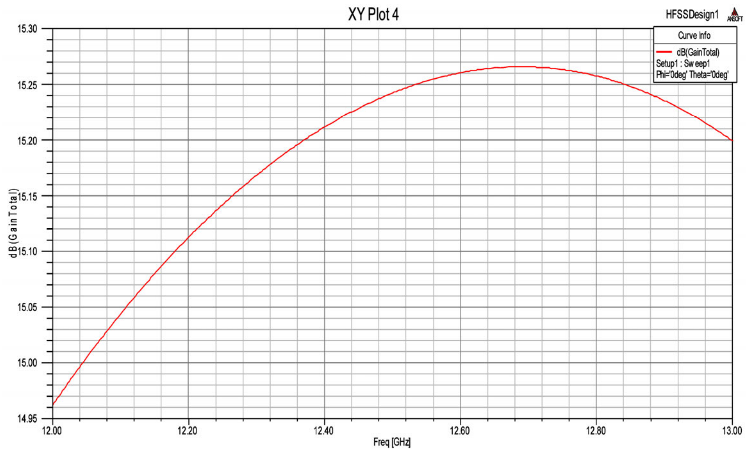

Fig. 10. The gain of the traditional horn antenna under different frequency

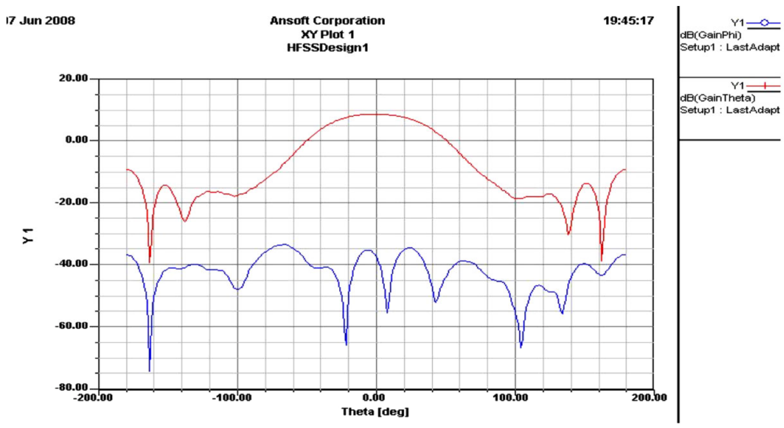

Fig. 11. The gain of the traditional horn antenna in other article

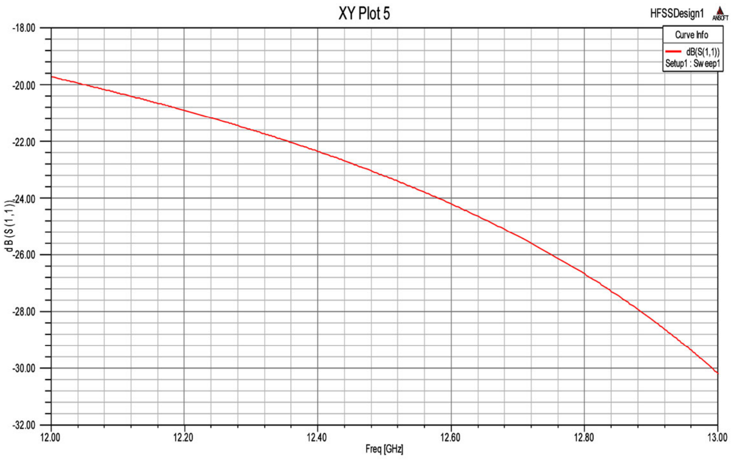

Fig. 12. The return loss of the traditional horn antenna

2.2 The Design of the Horn Antenna with Square Waveguide and Cone Aperture

Taking the equivalent dimensions of the traditional horn antenna as the square cone aperture horn antenna's dimensions. The side of the square waveguide is 15mm, the length of the square waveguide is 15mm, the radius of the cone aperture is 35.35mm, the length of the cone aperture is 25mm. Then, simulating the model above in the HFSS. The structure of the improved horn antenna is shown in Fig. 13.

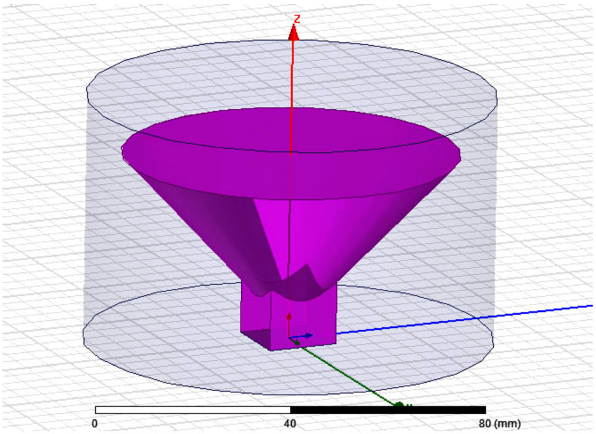

Fig. 13 The structure of the improved horn antenna

The gain of the improved horn antenna in 12.5GHz is shown in Fig.14 and Fig. 15. The gain under different frequency is shown in Fig. 16. The return loss of the horn cell is shown in Fig. 17.

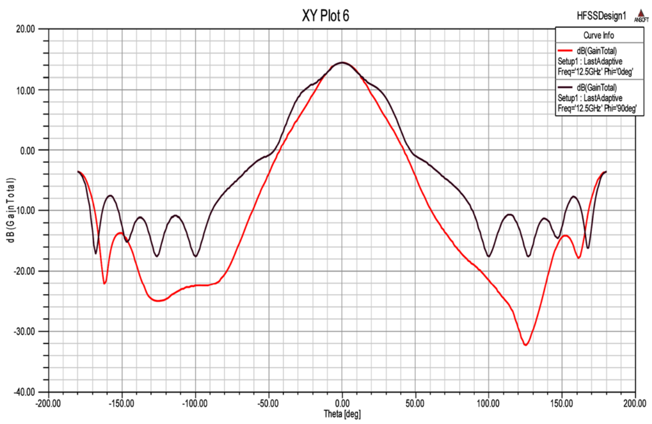

Fig. 14. The gain of the improved horn antenna in 12.5GHz

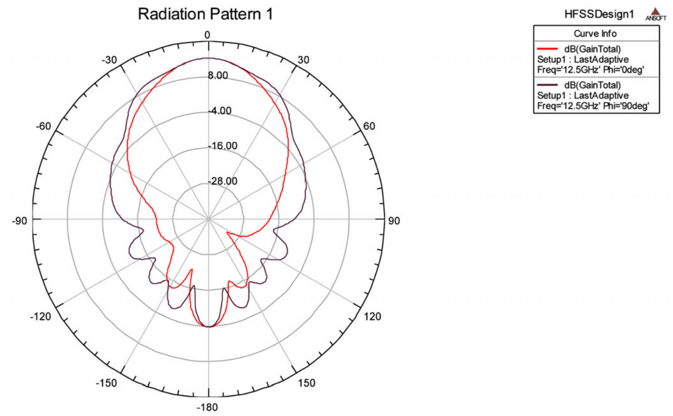

Fig. 15. The gain direction of the improved horn antenna in 12.5GHz

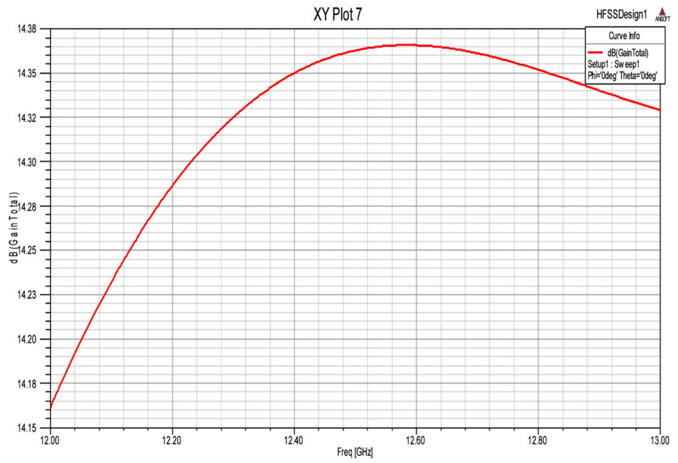

Fig. 16. The gain of the improved horn antenna under different frequency

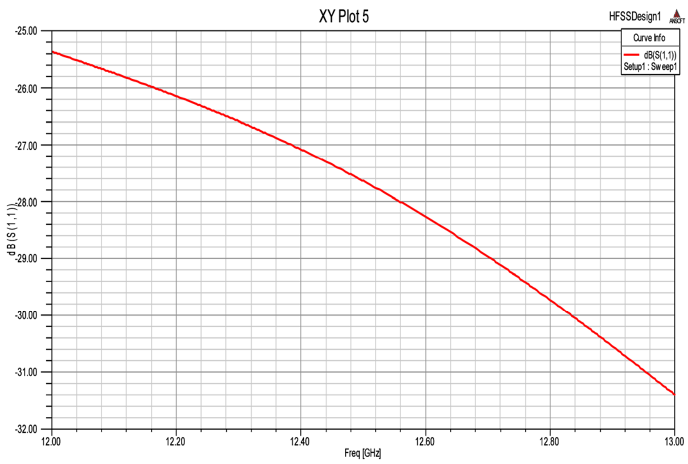

Fig. 17. The return loss of the improved horn antenna

3 Simulation Result and Analysis

The two group of simulation curves show that: the traditional horn antenna and the improved horn antenna have almost the same gain, but the return loss of the improved horn antenna is lower than the traditional one. What's more, the improved horn antenna has higher efficiency than the traditional one.

4 Conclusions

An improved horn antenna with square waveguide and square cone aperture is discussed in this paper. It has the equivalent dimensions with the traditional horn antenna. Through simulating, the results show that: they have almost the same gain, but the return loss of the improved horn antenna is lower than the traditional one. It represents that the structure of the improved horn antenna is better than the traditional one, and the performance of the improved horn antenna is better too. The design process offers good reference for the practice.

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