Design of Tanh-profile Corrugated Feedhorn in Quasi-optical System

Ying Liu[1], Yuan Yao[1], Hai Wang[1], Junsheng Yu[1], Cheng Yang[1], Xiaodong Chen[2], and Xiaoming Liu[1]
[1]School of Electronic Engineering, Beijing University of Posts and Telecommunications,
No.10 Xitucheng Road, Beijing, China
[2]School of Electronic Engineering and Computer Science, Queen Mary, University of London, London, UK

***Abstract* - A novel tanh-profile corrugated feedhorn application in quasi-optical system is proposed in this paper. The simulation results of the corrugated feedhorn are carried out via CHAMP. The simulated bandwidth is from 300GHz to 350GHz and the center frequency is 324GHz. The proposed tanh-profile corrugated feedhorn application can achieve very low return loss, sidelobe and cross polarization levels around -40dB, -35.1 dB and -45dB respectively.**

***Index Terms* — Corrugated feedhorn, quasi-optical system, tanh-profile**

I. INTRODUCTION

Nowadays, an increasing number of applications such as security imaging, radar, radio astronomy and feed in a quasi-optical system need stable radiation patterns with low return loss, low sidelobe and cross polarization levels in a wide bandwidth [1]. Corrugated horns have demonstrated their feasibility as one of the best solutions due to their promising performance.

The properties of corrugated horn have been explored in detail, and many results which give detailed description of the electromagnetic features of corrugated horn antennas [2]-[4] have been generated.

Reference [5] presented a compact dual profile horn which consists of a profiled section followed by an exponential taper, but it can only achieve sidelobe and cross polarization levels both around -30 dB, which is insufficient for some high performance applications.

This paper introduces a sample way to design a tanh-profile corrugated horn and gives the design process in detail. The designed tanh-profile horn is simulated from 300GHz up to 350GHz, and the central frequency is 324GHz. After optimization, we present the tanh-profile horn with nearly -40 dB return loss, -35.1dB sidelobe and -45dB cross polarization levels at the central frequency.

II. THEORETICAL ANALYSIS AND HORN DESIGN

A. Theoretical Analysis

TE11 mode is the fundamental mode of the circular waveguide which can excite the right amount of TM11 (amplitude and phase) when it passes through the mode converter by means of a proper corrugation in the horn aperture, and a tanh-profile taper with determined length drives the mode mixture to the correct phasing at the aperture. While the mixture mode is TE11 mode superimposed with TM11 mode which is also called HE11 mode. Actually, the mode converter which combines the first six corrugations in this design provides a smooth transition from TE11 to HE11 mode.

In general, over a period of several wavelengths, the depth of the first corrugation is chosen to be about half a wavelength and then tapers down to quarter wavelength deep corrugations. Since the depth and shape of the corrugations determine the cross polarization radiation characteristics, their geometry is selected to give the minimum level of cross polarization at the center frequency 324GHz.

After modeled a number of profiles, we have designed a suitable tanh-profile corrugated feedhorn which can provide better side-lobe and cross-polar performance.

B. Horn Design

The structure of the proposed tanh-profile corrugated feed horn is illustrated as presented in the Fig. 1.

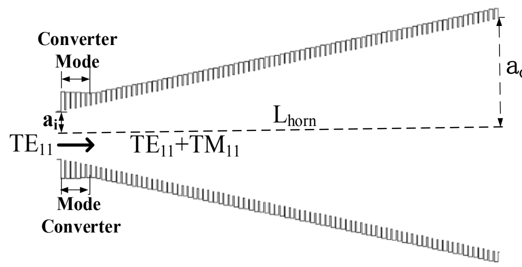


Fig. 1. Tanh-profile corrugated feed horn.

The design processes are summarized as follows:

Step 1: Define the radius along the tanh-profile. The tanh profile a(z) is given by equation (1):

$$a(z) = a_i + \left(a_o - a_i\right) \cdot \left[\frac{(1-A)z}{L_{horn}} + \frac{A}{2}\left(\tanh\left(\frac{B\pi z}{2L_{horn}} - \pi \right) + 1 \right) \right] \quad (1)$$

Where a_i is the throat radius, a_o is the aperture radius, after optimization, a_i and a_o are set to be 0.5158mm and 3.8542mm, respectively. A and B are adjustable parameters, both A and B are adjusted to excite the correct HE_{11} amplitude and phase at the aperture, whilst limiting the excitation of order higher modes. After optimization, A is 0.4123 and B is 0.7134 in this design. The parameter L_{horn} is the length of the horn which is set to be 9.9502*mm*. z is a local coordinate along the horn axis, with z being 0 and L at the input and output radius.

Step2: Define the slot depth of the mode converter. The *j*th slot depth is defined by equation (2)

$$d_j=\left\{\sigma-\frac{j-1}{N_{mc}}\left(\sigma-\frac{1}{4}\exp\left[\frac{1}{2.114\left(k_c a_j\right)^{1.134}}\right]\right)\right\}\lambda_c \qquad (2)$$

Where N_{mc} is the number of slots in mode converter which is 6 in this design. And σ is a percentage factor for the first slot depth of the mode converter which is 0.45 in this design. k_c equals to $2\pi/\lambda_c$.

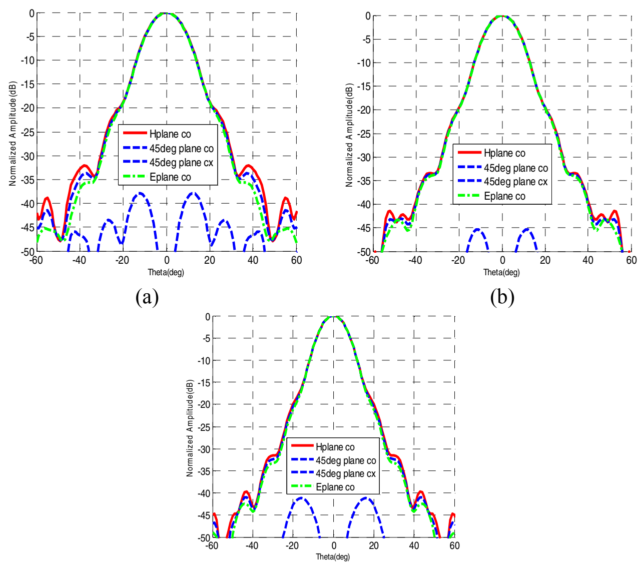
Step3: Define the depth of other slots except mode converter. It is more complex and defined by equation (3)

$$d_j=\frac{\lambda_c}{4}\exp\left[\frac{1}{2.114\left(k_c a_j\right)^{1.134}}\right]-\left(\frac{j-N_{mc}-1}{N-N_{mc}-1}\right)\left\{\frac{\lambda_c}{4}\exp\left[\frac{1}{2.114\left(k_c a_o\right)^{1.134}}\right]-\frac{\lambda_o}{4}\exp\left[\frac{1}{2.114\left(k_o a_o\right)^{1.134}}\right]\right\} \qquad (3)$$

Where N is the total number of slots, λ_0 is the free-space wavelength. Those parameters are defined by those equations and we get more appropriate values after optimization.

III. Simulation Results

The designed corrugated horn is modeled and simulated via CHAMP electromagnetic simulation software which is a general software tool allows a fast and accurate design and analysis any rotationally symmetric antenna with a feed horn. The designed horn shows very good performances in terms of low side-lobe and cross-polarization levels at 300GHz, 324GHz and 350GHz as it can be seen in Fig.2 while Fig.3 gives its return loss performance.



(a) (b) (c)

Fig. 2. The amplitude results in different pattern cut at the frequency of (a) 300GHz, (b) 324GHz and (c) 350GHz

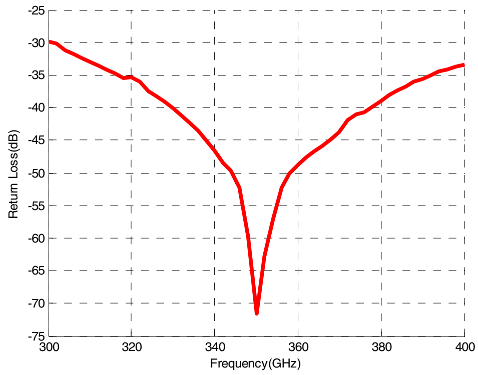


Fig. 3. The return loss of the tanh-profile corrugated horn

From the simulated results shown in Fig.2 we can see that the sidelobe levels are suppressed to some extent, and their levels are different having -33.8dB, -35.1dB, -32.8dB in 300GHz, 324GHz and 350GHz respectively, and the cross-polarization levels are -38.4dB, -45dB, -42.9dB respectively. As Fig.3 shows, the simulated tanh-profile gives very low return loss from 300GHz to 350GHz. It reaches -40dB at the central frequency and -72dB at 350GHz.

IV. Conclusion

A tanh-profile corrugated feedhorn working at the frequency from 300GHz to 350GHz has been successfully presented in this paper. The design processes are also presented in detail. The CHAMP simulated results show that the sidelobe levels can reach nearly -35.1dB, the cross-polarization level is -45dB and the return loss is nearly -40dB at the center frequency of 324 GHz.

Acknowledgment

This work is supported by the National Natural Science Foundation of China under Grant No. 61201026 and Beijing Higher Education Young Elite Teacher Project (Grant no. YETP0438).

References

[1] Granet, C, “A smooth-walled spline-profile horn as an alternative to the corrugated horn for wide band millimeter-wave applications” *IEEE Trans. Antennas Propagat*, vol. 52, pp. 848-854, 2004

[2] P. J. B. Clarricoats, “Corrugated horns for microwave Antennas”, Antennas and Propagation Society Newsletter, IEEE, vol. 27, 1984.

[3] A. D. Olver, P. J. B. Clarricoats, A. A. Kishk, and L. Shafa“Horns and Feeds”. *IEEE Press,* 1994.

[4] Davidson,D.B,”Computational Electromagnetics for RF and Microwave Engineering” *Aerospace and Electronic Systems Magazine, IEEE.* vol.20 , pp. 27 - 28, 2005

[5] L. Lucci, R. Nesti, G. Pelosi, and S. Selleri,”Design of an improved profiled corrugated circular horn at 320 GHz,” *Waves &Apps,* vol. 18, pp. 387－396, 2004.