IOP Conf. Series: Materials Science and Engineering 466 (2018) 012068 doi:10.1088/1757-899X/466/1/012068

Analyses on Related Properties of a Ridged Horn Antenna

Lei Xie and Wei He*

School of Physics and Electronic Information, Yunnan Normal University, Kunming, China

*Email: he99wei@aliyun.com

Abstract. The ridged horn antenna is used as a kind of broadband antenna, and its application in radar engineering has become more and more extensive. And it has better standing wave and radiation characteristics in a wide frequency band. This paper analyzed the related properties of ridge waveguide and horn ridge according to the antenna structure, and gives a design method of broadband double-ridge horn antenna. According to actual needs, a dual-ridge horn antenna with a frequency range of 20GHz-26GHz was designed. And electromagnetic simulation of the antenna using HFSS was given. The results showed that the gain reaches 18 dB at 24 GHz, and the main flap of the three-dimensional gain pattern is not cracked.

1. Introduction

With the development of electromagnetic theory and antenna technology, the demand for broadband antennas in various RF target simulation systems, electronic countermeasure systems, and electronic reconnaissance systems is increasing. Broadband antennas have been widely used in many high-speed wireless transmission equipment, such as high sensitivity radar, radio frequency interference machine, electromagnetic compatibility test system. Ultra-wideband antennas can be classified into monopole and dipole antennas, reflector antennas, horn antennas, spiral antennas, patch antennas, logarithmic period antennas, etc. according to their shapes, and they all have different adaptation occasions [1].

Horn antenna is a common broadband antenna, and its advantages as follow [2]: First, it's easy to obtain better antenna performance by adjusting antenna structure parameters; Second, It has superior directivity and high antenna gain; Third, it has low VSWR, wider bandwidth, and lower weight; Further, the theoretical calculation value of the horn antenna is easily achieved in practical applications. However, the operating frequency of a common horn antenna is not only affected by the size of the transmission waveguide but also limited by the gain requirement of the horn. In order to increase the bandwidth of the horn antenna and reduce the main mode cutoff frequency and its impedance characteristics, the ridge is usually used to improve the transmission characteristics of the horn antenna [3]. In this paper, a double-ridged horn antenna is proposed, and the radiation characteristics of the horn are analyzed by HFSS (High Frequency Structure Simulation). The dual-ridged horn antenna has excellent radiation characteristics in the operating frequency range of 20 GHz to 26 GHz.

2. Double Ridge Horn Antenna Structure

The ordinary horn antenna can be regarded as extending outward from the waveguide. From the broadband characteristics of the ridge waveguide, the ridge structure is added to the waveguide segment and the horn segment of the horn antenna. Thereby it can obtain a double-ridge horn antenna with a widened band. The structure of the double-ridged horn antenna is shown in Figure 1. The structure can be divided into a coaxial feed joint, a waveguide section, a horn section, and a double ridge [4].

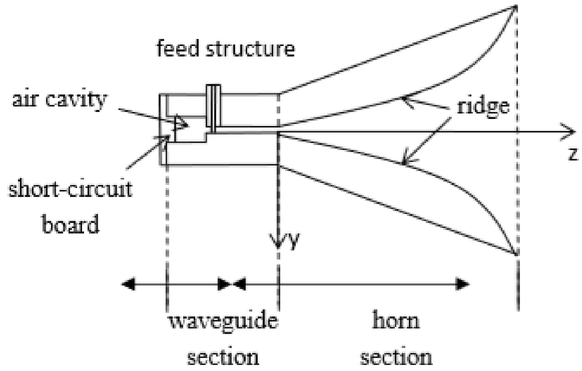

Figure 1. Cross-section of double-ridged horn antenna

The structure of the waveguide section is complicated. And the straight waveguide section is from the short-circuit board to the feed. Its function is to filter out the TE20 mode excited in the waveguide. The length of this segment has a direct influence on the performance of the whole antenna. The distance from the feed probe to the short-circuit version is less than half of the working wavelength. From the feeding section to the neck of the horn, it is a ridge waveguide section. The ridged waveguide is mainly used to reduce the cutoff frequency of the main mode transmission to achieve wideband characteristics. The cross-sectional dimension of the ridge waveguide portion is gradually increased from the feeding portion to the neck of the horn, and the ridge spacing is also linearly increased [5]. This section is approximated as a ridged horn.

There is an air cavity between the ridge waveguide and the short circuit plate. The function of the reflection cavity is to suppress the TE_{20} electromagnetic wave of the mode in the waveguide. This can make the main mode (TE10 mode single mode transmission has a larger bandwidth) and play the role of widening the frequency band [6].

Horn segment: in order to effectively suppress the transmission of higher-order modes generated during impedance conversion, the length of the horn is at least half the wavelength of the lowest operating frequency. The calibre size of the horn is determined by the phase difference between the gain and the aperture surface. Good matching effect when the horn segment impedance is as follows.

$$\begin{cases} Z = Z_\infty e^{kz} & 0 \le z \le L/2 \\ Z = 377 + Z_\infty\left(1 + e^{k(L-z)}\right) & L/2 \le z \le L \end{cases} \tag{1}$$

$$Z_{L/2} = \frac{Z_0 + Z_L}{2} \tag{2}$$

Where L the length of the horn segment, and k is a constant(it can be determined by equation (2))

The shape curve of the ridge structure is generally changing by as follow:

$$y(z) = Ae^{kz} + Cz \tag{3}$$

3. Design Principle and Method

3.1. Ridge Waveguide Design

First to define the size of the waveguide, and the cross-sectional view is shown in Figure 2.

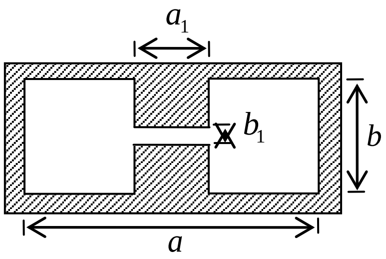

Figure 2. Ridge waveguide structure

A schematic cross section of the ridge waveguide portion is shown in Figure 2. The cross-section dimension of the waveguide is a×b, where the ridge width is a1, and the ridge spacing is b1. The design is mainly based on the ridge waveguide theory. The function of the ridge waveguide is to transmit the electromagnetic wave fed by the coaxial line, so that when entering the ridge horn, a stable electromagnetic wave can be formed. furthermore, its size is also related to the cutoff frequency of the antenna working.

According to the antenna frequency band requirements of 20GHz to 26GHz, the main mode cutoff wavelength is $\lambda' = 3.20cm$, and TE_{20} mode cutoff wavelength is $\lambda'' = 1.11cm$. From this, we can get the size of the waveguide. Finally, we chose the length of the wide side of the waveguide is $a = 1.2cm$,and the narrow side length is $b = 0.556cm$,and the ridge width is $a_1 = 0.3cm$, and the ridge spacing is $b_1 = 0.236cm$.

The excitation of the horn feed structure are used 50Ω feeder and N -type connector. We pass the coaxial feed through the center of the first ridge, and the center conductor feeds the second ridge across the gap of the ridge. Thereby a monopole radiator is formed. In the horn waveguide section, the ridge waveguide between the feed and the neck of the horn has a linear increase in cross-sectional area to avoid impedance mismatch due to structural abrupt changes[4]. Therefore, we use the italic structure for the ridge waveguide wall. The size of both sides of the ridge waveguide is linearly increased. The cross-sectional view is shown in Figure 3.

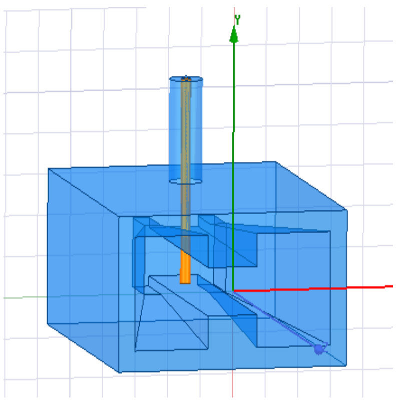

Figure 3. Feed ridge waveguide section

3.2. Horn Section Design

The shape of the ridge is designed according to the impedance matching principle of the transmission line, so that the impedance inside the horn can smoothly transition. The horn Is a standard gain antenna. The size of the horn can be calculated from the optimal pyramid horn design equation[7] by given gain, operating wavelength and waveguide size:

$$A^4 - aA^3 + \frac{3bG\lambda^2}{8\pi\varepsilon_{ap}}A = \frac{3G^2\lambda^2}{32\pi^2\varepsilon_{ap}^2} \qquad (4)$$

For the best gain pyramid horn, we usually use 50% of the aperture as efficiency value:

$$G = 0.51\frac{4\pi}{\lambda^2}AB \quad (5)$$

The relationship between the diameter of the horn and the metal plate length radiating section is as follows:

$$A = \sqrt{3\lambda R_1} \quad (6)$$

$$B = \sqrt{2\lambda R_2} \quad (7)$$

each parameter of the bring $\varepsilon_{ap} = 0.51$ into formula (4) to find A. Bring the obtained A value into the formula (5) to find B. Finally, we can calculate the value of each parameter of the horn:$A = 5.608cm$,$B = 4.347cm$,$R_1 = 8.387cm$,$R_2 = 7.559cm$. Shape curve formula combined with ridge structure (3):$y(z) = Ae^{kz} + Cz$,$A = \frac{b_1}{2}$,$C = 0.015$. The ridge structure curve can be obtained after the data is brought in.

$$y(z) = 0.00118e^{43.490z} + 0.015z \quad (8)$$

4. Simulation of Double Ridge Horn Antenna

According to the design requirements of this paper, the double-ridged horn antenna shown in Figure 4. It was designed by HFSS. The width of the ridge waveguide is $a = 1.2cm$. The length of the narrow side is $b = 0.556cm$. Ridge width is $a_1 = 0.3cm$. Ridge spacing is $b_1 = 0.236cm$. The length of the horn is $5.608cm$. The width is $4.347cm$, and the length is $6.592cm$. The length of the waveguide is $1.563cm$.

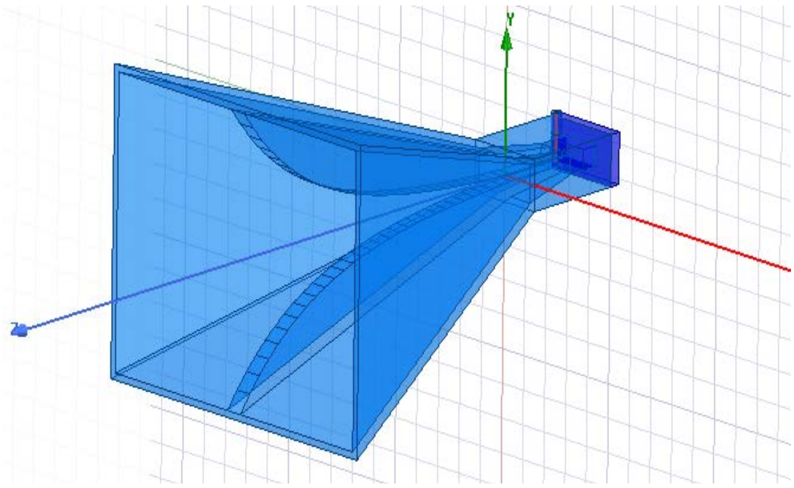

Figure 4. Double ridge horn antenna module

The gain of the E-plane and the H-plane of the dual-ridge horn antenna in the 24GHz is as shown in fig. 5. The gain directions of the E-plane and H-plane in the polar coordinate system are shown in Fig. 6.The three-dimensional gain pattern is shown in Figure 7.

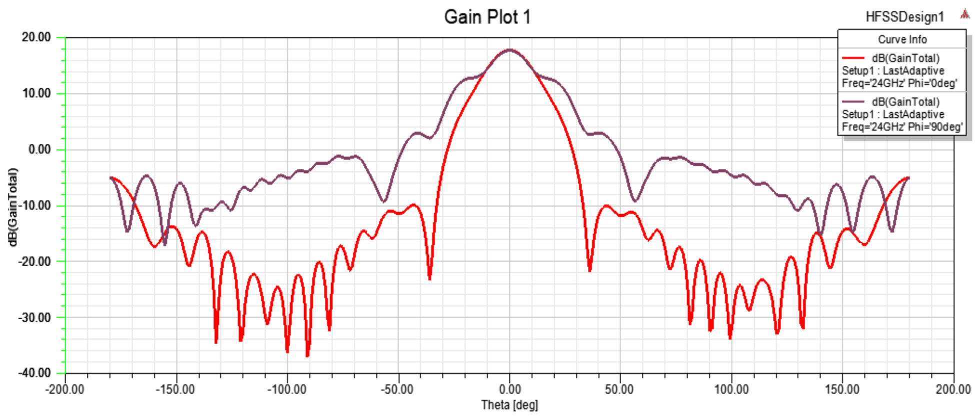

Figure 5. E-plane and H-plane gain pattern

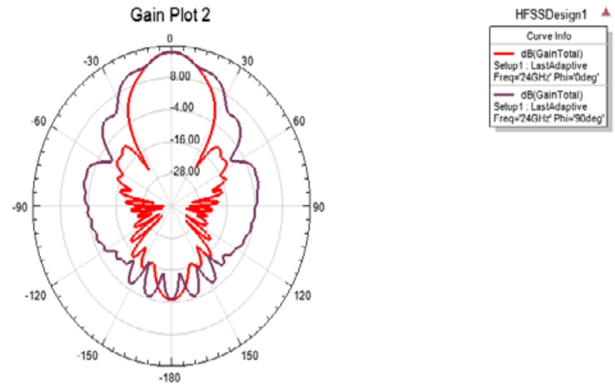

Figure 6. Gain pattern of E-plane and H-plane in polar coordinate system

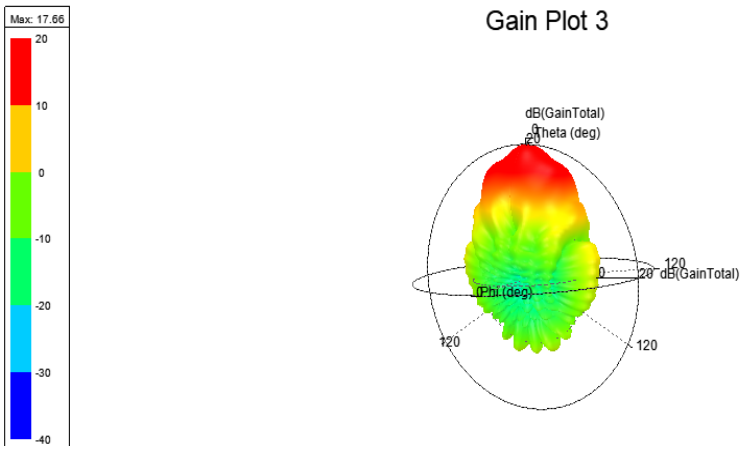

Figure 7. Three-dimensional gain pattern

5. Conclusion

This paper introduced and analyzed the composition of the double-ridged horn antenna and how it works. Combined with the actual design needs, a design method of a broadband double-ridge horn antenna is given. And using HFSS (Electromagnetic Simulation Software) we designed a 20GHz~26GHz broadband double-ridged horn antenna. The antenna gains 18dB at 24GHz, and the E-plane and H-plane gain directivity is good, and the main flap of the three-dimensional gain pattern is not cracked. Simulation and measurement results are ideal for higher practical requirements. It has certain reference value for designing such antennas in engineering.

6. Acknowledgements
This project was supported by National Natural Science programs (51267021) and College students' innovative entrepreneurial training programs (2015).

7. References
[1] Adamiuk G, Zwick T, Wiesbeck W. UWB Antennas for Communication Systems 2012 *J. Proceedings of the IEEE* **100(7), p** 2308-2321.
[2] Lai H, Franks R, Kong D. A Broad Band High Efficient Quad Ridged Horn 1987 *J. Antennas and Propagation Society International Symposium* **25** 676–679.
[3] Liu li, Theory Analysis and Simulation of Electrical Properties for Broadband Dual-Polarized Quadruple-Ridged Horn Antenna 2017 *J. System Simulation Technology* 4
[4] Shi ayuan 2017 The High-gain & Ultra-wide Band Double-ridged Horn Antenna. Xian: Xidian University, pp67
[5] Yang kang 2015 Design Method of Ultra-wideband Double-ridged Horn Antenna. Beijing: China Ship Research and Development Academy, pp456
[6] Zhao jianbei 2013 Research on Characteristics of Ultra Wideband TEM Ridged Horn Antenna. Harbin: Harbin Institute of Technology, pp234
[7] Warren L, Stutzman and Gary A, Thiele. Zhu shouzheng, Translation 2006 *Antenna Theory and Design* (Beijing: People Post Press) pp 291-292.