# Design of Ridge-Loaded Slow Wave System in Terahertz Band

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**Abstract:** *In this paper, a ridge-loaded waveguide structure working at terahertz band is established, and the high frequency characteristics are calculated by HFSS. Based on the ridge-loaded structure, a multi-section slow wave system is designed, and the MTSS is used to calculate the beam-wave interaction. The results show that the slow wave system designed in this paper has a great improvement in performance.*

**Keywords:** High efficiency; Ridge-loaded folded waveguide structure; multi-section slow wave system; Terahertz

## Introduction

The folded waveguide TWT can work in millimeter wave band, terahertz band and some short centimeter band.It has a good application prospect in the field of broadband communication and military electronic system. As a kind of all metal slow wave structure, folded waveguide has the following characteristics: good bandwidth performance, large power capacity, simple input-output coupling structure, good heat dissipation performance, easy processing, etc [1,2,3]. In this paper, based on the ridge-loaded folded waveguide high frequency structure, a high efficiency slow wave system is designed. By adding sever at some reasonable positions in the system, the slow wave system can be reasonably divided into several sections. The sever can effectively suppress the oscillation, reduce its impact on the performance of TWT, and improve the output power and electron efficiency of the system.

## Influence of ridge loaded folded waveguide parameters on high frequency characteristics

The ridge-loaded folded waveguide structure is shown in Figure 1. ***a***, ***b*** and ***h*** are the outer dimensions of the ridge-loaded folded waveguide, ***r*** is the electron beam channel, ***a1*** is the width of the ridge-loaded region, ***b1*** is the narrow edge of the ridge-loaded region. ***h1*** is the height of the ridge-loaded region.

### *A. Effect of **a1** on high frequency characteristics*

The influence of ***a1*** on dispersion and coupling impedance is shown in Figure 2. When ***a1*** = 0, it means that there is no ridge loading, which is the conventional folded waveguide. It can be seen from Figure 2. (a) and (b) that with the increase of ***a1***, the normalized phase velocity increases gradually, the dispersion curve gradually becomes flat, and the coupling impedance increases slowly. According to $fc = c/2a$ , ***a*** determines the cut-off frequency of the fundamental mode, so the cut-off frequency has the similar tendency.

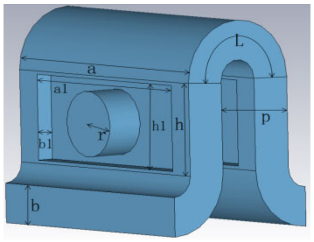
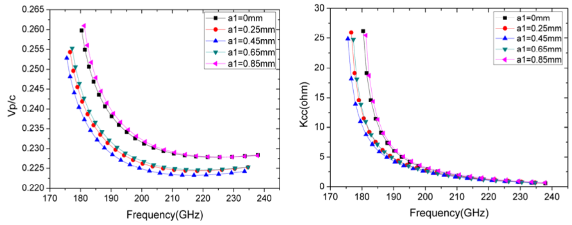


**Figure 1.** Ridge-loaded folded waveguide structure

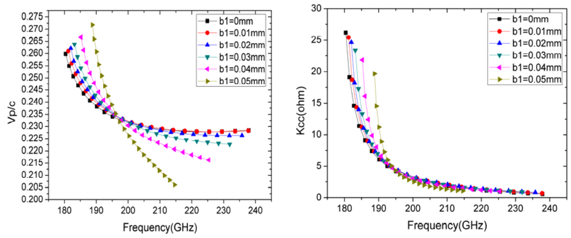


(a) (b)

**Figure 2.** (a) Effect of ***a1*** on the dispersion (b) Effect of ***a1*** on the coupling impedance

After research, the dispersion curves are basically coincident, the dispersion flatness is similar. The dispersion curve is basically unchanged and the coupling impedance curve is basically the same with each other with the increasing of ***h1.***

### *B. Effect of **b1** on high frequency characteristics*



(a) (b)

**Figure 3.** (a) Effect of ***b1*** on the dispersion (b) Effect of ***b1*** on the coupling impedance

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From Figure 3. (a) and (b), it can be seen that the dispersion curve gradually becomes flatter, the cut-off frequency gradually moves to the low frequency band, and the coupling impedance increases gradually with the decreasing of ***b1***. ***b*** is a value closely related to the coupling impedance. The value of ***b*** is determined by maximizing the coupling impedance. The value of ***b1*** also has an impact on the coupling impedance.

### *C. Optimized ridge loaded folded waveguide structure*

By studying the influence of ridge loading region parameters on the high frequency characteristics, the principle of maximizing the coupling impedance and flattening the dispersion curve is adopted. The specific parameters of the optimized high frequency junction are as follows: ***a***=0.85mm, ***b***=0.12mm, ***h***=0.27mm, ***r***=0.1mm, ***a1***=0.85mm, ***b1***=0.01mm, ***h1***=0.27mm.

## Design of high efficiency slow wave system and calculation of beam-wave interaction

Based on the optimized ridge loaded folded waveguide structure, a high-efficiency slow wave system is designed in MTSS as shown in Figure 4. The total length of the whole system is 87 periods, and two 2mm-long sever is added at 15th period and 40th period respectively to suppress the oscillation. The whole system is divided into three sections.The length of each periodic structure in the whole slow wave system is the same.

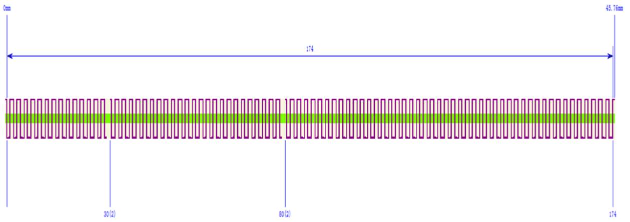
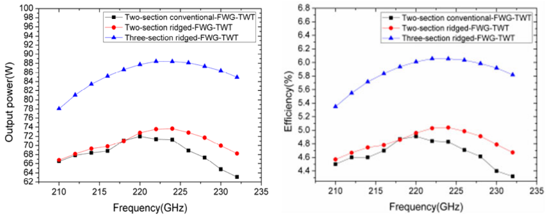


**Figure 4.** High efficiency slow wave system

Considering the loss, the copper is used as the background material, and its equivalent conductivity is set as 2.4*10^7 S/m. In the MTSS-BWIS module, we set the working voltage to 14600 V, electron current to 0.1A, the magnetic field strength to 1.09 Tesla, and its period to 2.4mm. At the same time, we also study the two-section conventional FWG slow wave system and the two-section ridge-loaded FWG slow wave system.



(a) (b)

**Figure 5.** (a) Output power (b) Electron efficiency

It can be seen from Figure 5. that the output power and electron efficiency of the three-section ridge-loaded folded waveguide slow wave system designed in this paper are greatly improved compared with the two-section conventional FWG slow wave system and two-section ridge-loaded FWG slow wave system. The output power is over 86W in 218~230GHz frequency range, and the electron efficiency is more than 6% in 220~226GHz frequency range.

It can be seen that the output power of the three-section ridge-loaded FWG slow wave system is 87.75w at the central working frequency of 220GHz, and the maximum electron efficiency is 6.01%.

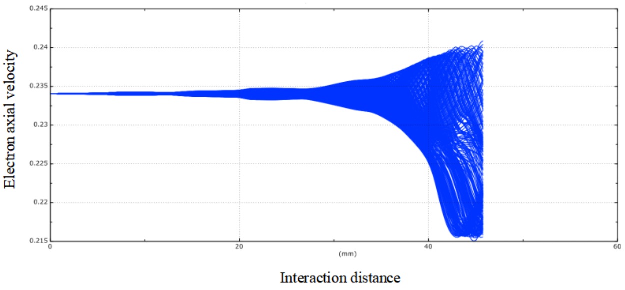


**Figure 6.** Distribution of electron axial velocity

Figure 6. shows the distribution of electrons axial velocity in the process of beam wave interaction . It can be seen that in the initial stage of interaction, most electrons conduct velocity modulation. With the beam wave interaction, the velocity of most electrons decreases gradually, releasing energy. At the end of interaction, the velocity of most electrons decreases a lot, outputting a lot of energy, so that the high-frequency signal can be amplified.

## Conclusions

In this paper, a high efficiency ridge-loaded folded waveguide slow wave system is designed. The output power is more than 86W in 218~230GHz frequency range, and the electron efficiency is greater than 6% in 220~226GHz frequency range. Compared with the other two kinds of folded waveguide slow wave system, its performance is greatly improved.

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