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# Q Factor and Insertion Loss Analysis of Half-height Pin Ridge Gap Waveguide

Fangfang Fan<sup>1</sup> Jian Yang<sup>2</sup> Zehong Yan<sup>1</sup> Ying Liu<sup>1</sup>

**Abstract** – The promising millimeter wave transmission structure, gap waveguide, has advantageous characteristic compared to conventional ones. As for the ridge gap waveguide (RGW) and groove gap waveguide (GGW), they usually can be fabricated by milling technology, the height and the gap between the pins always are the main factors for the cost. Recently, half-height pin, a new pin form, is proposed for the gap waveguide technology to effectively reduce the manufacture cost and difficulty. In this paper, the Q values and insertion loss of the RGW using half-height pins will be investigated carefully in terms of the structure of the ridge and pins.

## 1 INTRODUCTION

The promising millimeter wave transmission structure, gap waveguide[1], has advantageous characteristic compared to conventional waveguide and microstrip. It has the lower insertion loss than microstrip, and easier manufacture process than waveguide [2]. They usually can be fabricated by milling technology, the height and the gap between the pins always are the main factors for the cost and difficulty. Because the height of the pins usually should be set about a quarter of the wavelength, while for gap between the pins is less than one tenth of the wavelength, thus for the higher frequency, they will be very small for fabrication, which will result in much higher cost and manufacture stress. Recently, half-height pin [3], a new pin form as shown in Fig.1, is proposed for the gap waveguide technology to effectively reduce the manufacture cost and difficulty. In paper [4], the author has given the stop-band analysis and comparison about the full height pin and half-height pin form. It indicates that the new pin form has the similar stop-band characteristic, in addition, half-height pin has the bigger width of the pin compared to the full height pin which processes the same stop-band, that is to say, the new pin form not only has the superiority in the height, but also in the width.

In this paper, the Q value and insertion loss of the ridge gap waveguide (RGW) using half-height pins, since the same topic for full height pins has been done in [5], will be investigated carefully and also compared with full height pins.

## 2 RGW RESONATOR

This section will give the results of the Q value and insertion loss of the short-circuit resonator made by RGW with half-height pins, and also will be compared with the full height pins case.

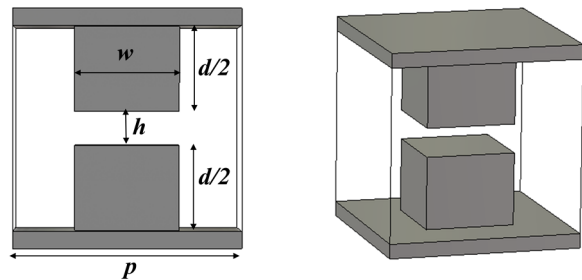


Figure 1: Geometry of the unit cell of half-height pin.

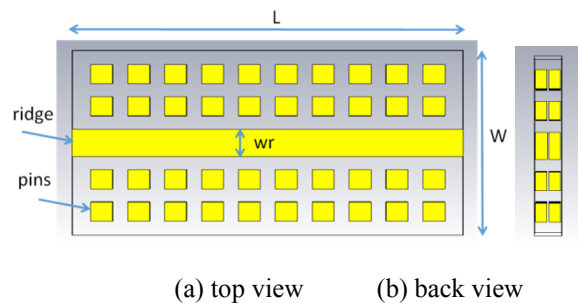


Figure 2: Geometry of the short-circuit ridge gap waveguide resonator

As shown in Fig.1, the half-height pin has the width of  $w$ , the air gap  $h$  is located in the middle of the two half-height pins, and the height obviously is the half of the conventional one, full height pin, denoted as  $d/2$ , and  $p$  is the period of the pins. Based on the half-height pin form, a short-circuit RGW resonator is given in Fig.2. The width of the ridge is denoted as  $w_r$ , and the size of whole short circuit resonator is  $W \times L$ . Note that the ridge here also has been cut into two same parts as the pins. There are two column of the pins at the both sides of the ridge, which can effectively attenuate the field quickly to guarantee the wave propagation along the ridge by the result of the stop band characteristic of the half-height pins, here for the values in Table.1, the stop band of the unit ridge and pin is 32GHz-73GHz. And the ridge is connected to the metal walls to get the short circuit characteristic. The Q value calculation is done with the help of the Ansys HFSS Eigenmode solver, while the insertion loss is simulated in CST software.

In Fig.3, we can see the 8-order resonance field distribution at about 53.3GHz with the resonator length  $L=22.25$  (about 4 wavelengths).

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## 2.1 Q value and insertion loss analysis with different air gap $h$

We know that for the RGW, the field intensively distributed in the air gap which can be seen in Fig.3. If the air gap  $h$  increases, the current density will be less concentrated in the air gap. Of course the Q value will be larger, and the insertion loss would be lower.

Parameter	Value (mm)
$p$	2.1
$d$	1.4
$h$	0.1
$w$	1.25
$w_r$	1.8
$L$	22.25
$W$	11.9

Table 1: Parameters and their values.

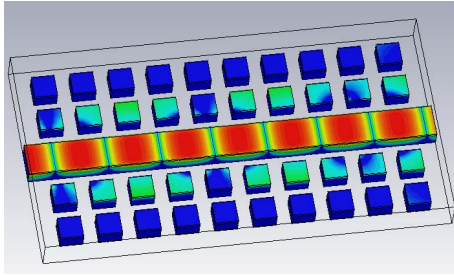


Figure 3: 2D color plot of E-field in the air gap between the half-height pins and ridges

The following is the simulated results to further verify our above discussion. The resonator in Fig.2 is made of copper with conductivity of  $\sigma = 5.8 \times 10^7$  S/m. The air gap  $h$  is set to vary from 0.1mm to 0.4mm, from Fig.4, the unloaded Q value is from 400 to 1600, and the insertion loss has its highest value with  $h=0.1$ mm in Fig.5, it is about 0.17dB/10mm at 55GHz, with the higher air gap  $h$ , the insertion loss keeps around 0.1dB/10mm. So the insertion loss does not change as rapidly as the unloaded Q value when air gap  $h$  varies from 0.2mm to 0.4mm.

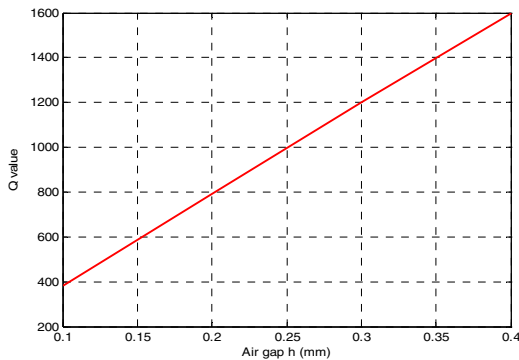


Figure 4: The simulated unloaded Q value under different air gap  $h$

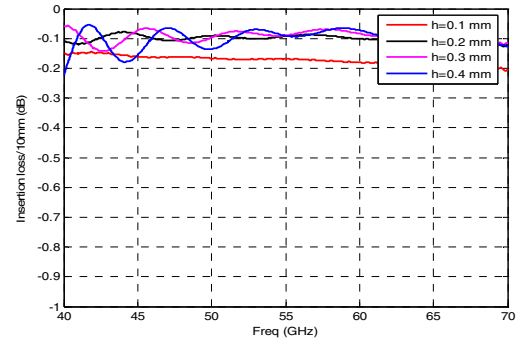


Figure 4: The simulated insertion loss under different air gap  $h$

## 2.2 Q value and insertion loss analysis with different ridge width $w_r$

The theory and simulation analysis in section 2.1 indicated that air gap  $h$  has great influence on the Q value and insertion loss. In this section, we will do the same analysis with different ridge width  $w_r$ . We can obtain that from the Fig.5, the Q value decreases with the increased ridge width  $w_r$ , but it changes slower than the air gap, it is from 640 to 460 with the range of  $w_r$  0.2mm to 1.8mm, obviously, the insertion loss has the lowest value with the biggest  $w_r$ .

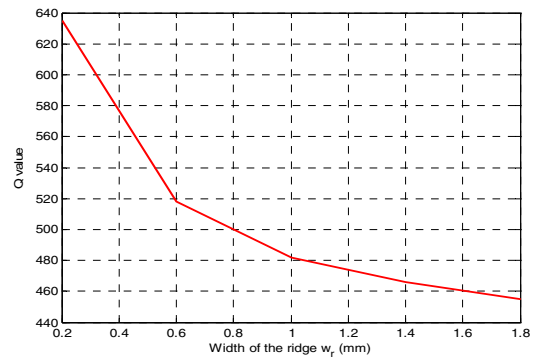


Figure 5: The simulated unloaded Q value under different width of the ridge  $w_r$

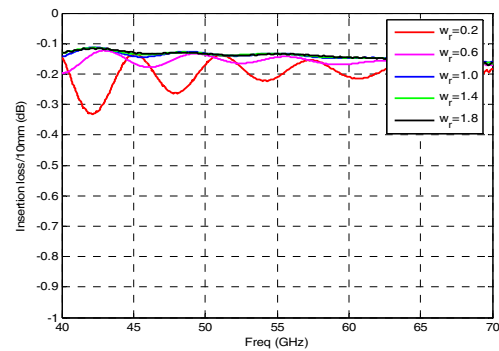


Figure 6: The simulated insertion loss under different width of the ridge  $w_r$

### 2.3 Q value comparison between the half-height pin and full height pin RGW

Since the half-height pin is newly proposed, here we should investigate the difference between the two pin forms with Q value, the following Fig.7 shows the Q value under different air gap  $h$ , it can be seen the Q value is nearly the same under the different pin forms. It means they have almost the same performance which further verifies the results in the former literature [4], but the half-height pin based gap waveguides can be easily manufactured with low cost, especially at the high frequency.

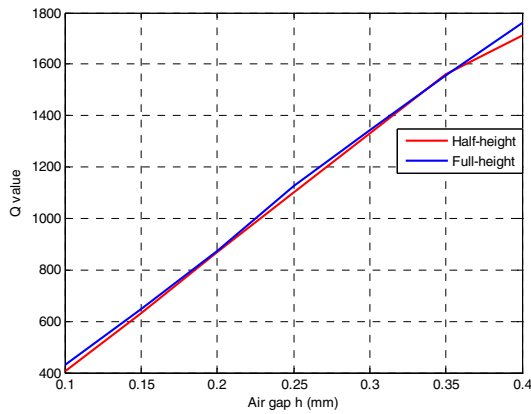


Figure 7: The Q value with different air gap with half-height pin and full height pin cases

### 3 CONCLUSION

The Q value and insertion loss have been analyzed with the half-height pin in RGW in this paper, the two parameters: air gap  $h$  and ridge width  $w_r$  mainly influence the Q value and insertion loss, which can pave the way for designing related components, such as the gap waveguide filters.

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