IRIS HOLE ROUNDING INFLUENCE ON THE DISK LOADED WAVEGUIUDE PARAMETERS

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Abstract

This report illustrates the method of determing parameters of disc loaded waveguide (DLWG) with rounded iris hole edge using the same parameters of DLWG without rounding. The special coefficient is proposed and calculated.

1. Introduction

Sometimes it is desireable to round iris hole sharp edge in DLWG or other superhigh frequency structure to increase the breakdown field limit value. On the other hand, someone can find it much easier to calculate rectangular shape geometry or to use widely published reference data on the DLWG without rounding [1,2].

The problem to account for iris hole rounding can be solved by the use of Slater's perturbation theorem [3].

During design and experimental research of X-band accelerating structures we have got quite satisfactory and practicable data [4].

2. Fundamental relations

2.1. General remarks

Iris hole rounding provides some frequency shift that can be considered as some new equivalent hole radius a' instead of a as shown in Fig.1.

Dividing by the wavelenght λ one can obtain

$$\frac{a'}{\lambda} = \frac{a}{\lambda} + \Delta\left(\frac{a}{\lambda}\right) \qquad (1)$$

The problem is to determine parameter $\Delta(\frac{a}{\lambda})$. For example, if rounding radius R is equal to iris halfthickness $\frac{t}{2}$, considering $\Delta(\frac{a}{\lambda})$ as a result of dark

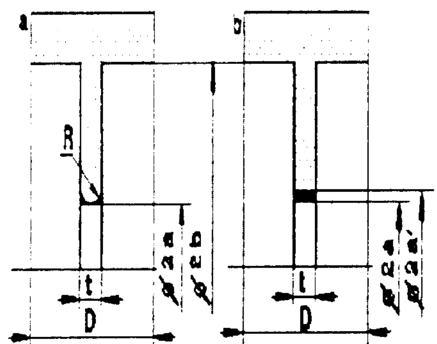

Fig.1 DLWG cell with rounded iris hole edge (a) and without rounding (b).

dashed crosses' toroidal-shaped volumes V_1 and V_2 equivalence in Fig.1 a) and b) positions gives

$$\frac{a'}{\lambda} = \frac{a}{\lambda} + \frac{(1 - \pi/4)}{2} \cdot \frac{t}{\lambda}. \qquad (2)$$

But results we obtain using this equation are false due to field value difference on the rounded surface and at the sharp edge.

2.2. Field relationship influence

Using the Slater's equation we express the situation reflected in Fig.1a) as

$$f_1^2 = f_0^2(1 - \frac{1}{4W_1}\int\varepsilon_0 E_1^2 dV_1) \qquad (3)$$

and for Fig.1b)

$$f_2^2 = f_0^2(1 - \frac{1}{4W_2}\int\varepsilon_0 E_2^2 dV_2),$$

where

f_0 is mode frequency for unperturbed radius a without rounding;

f_1 and f_2 are the same mode frequencies due to rounded hole edge and for equivalent radius a';
E_1 and E_2 are the field strentghs in dark dashed areas;
W_1 and W_2 are stored energies.
As $W_1 \simeq W_2$ frequency equivalence $f_1 = f_2$ would hold under the condition

$$\int_{V_1} E_1^2 dV = \int_{V_2} E_2^2 dV, \qquad (4)$$

Let us rewrite equation (4) supposing that volumes V_1 and V_2 are negligibly small compared to cavity volume. Using the average over the dark dashed areas field strentgh values we get

$$\overline{E}_1^2 \cdot V_1 = \overline{E}_2^2 \cdot V_2 . \qquad (5)$$

The normalized field value at the iris surface for the fixed mode depends on the border shape, i.e. we can suppose

$$\overline{E}^2 = K_E \overline{E}_1^2 , \qquad (6)$$

where K_E is proportional coefficient.

2.3. Final expressions

Solving the last two equations together one obtains

$$K_E V_1 = V_2 . \qquad (7)$$

Hence the second equation is transformed as

$$\frac{a'}{\lambda} = \frac{a}{\lambda} + K_E \frac{(1 - \pi/4)}{2} \cdot \frac{t}{\lambda} . \qquad (8)$$

The cavity radius b comes out as

$$\frac{a}{b} = \left(\frac{a}{b}\right)' \cdot \left[1 - \frac{K_E \cdot (1 - \pi/4)}{2} \cdot \frac{t/\lambda}{(a/\lambda)}\right] . \qquad (9)$$

The last two equations express the method proposed. The essence is that if one has $\frac{a'}{\lambda}\left(\left(\frac{a}{b}\right)'\right)$ dependence for DLWG without rounding the corresponding dependence $\frac{a}{\lambda}\left(\frac{a}{b}\right)$ for DLWG with rounded iris hole edge one can obtain using (8) and (9). The later equations are valid for $R = \frac{t}{2}$, but in other cases the way is similar.

The physical interpretation of K_E is coefficient that shows the difference between the sharp border field compared to a rounded surface field.

3. Experimental verification

Due to experimental results on the $\frac{a'}{\lambda}\left(\left(\frac{a}{b}\right)'\right)$ and $\frac{a}{\lambda}\left(\frac{a}{b}\right)$ dependences we obtained K_E values for different iris thicknesses and modes, shown accordingly in Fig.2 and Fig.3.

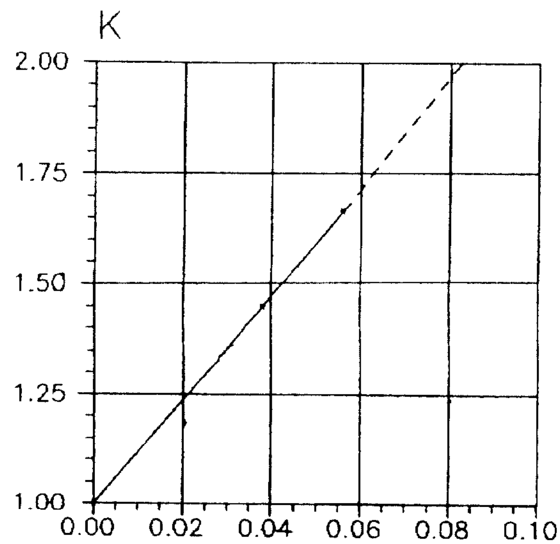

Fig.2 Coefficient dependence on iris thickness.

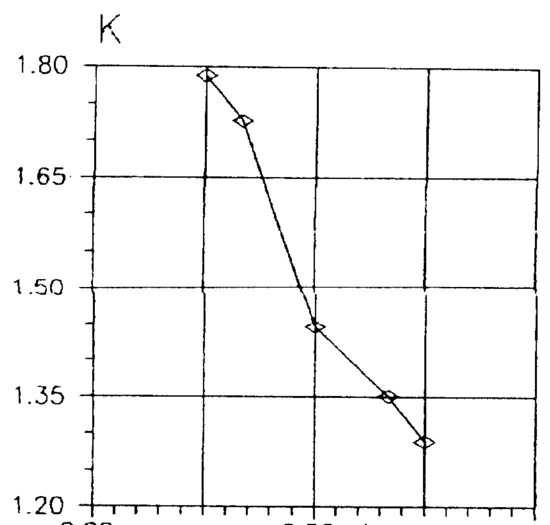

Fig.3 Coefficient dependence on phase shift per cell.

The first values obtained were K_E=1,6667 for t/λ = 0,056 and K_E= 1,4463 for t/λ = 0,038. Dependence K (t/λ) is close to a nearly straight line. Coefficient K does not alter with respect to period of structure and true for any phase velocity β_p as well as for hole radius a at any fixed oscillation mode θ. Those results for t/λ = 0,038 are enclosed into Table 1 below. The related radius $\frac{a}{\lambda}$ interval extends from about 0,08 up to 0,21 and phase shift per cell θ from $\frac{\pi}{4}$ to $\frac{3\pi}{4}$; $\frac{a}{b}_{calc}$ are values obtained using the method described and $\frac{a}{b}_{exp}$ are the experimental results referred to in [3].

Table 1
Comparison of the calculated and experimental results

θ	$\frac{a}{\lambda}$	$\frac{a}{b}$ calc	$\frac{a}{b}$ exp	$\Delta\frac{a}{b}\cdot 10^4$	K_E
$\frac{\pi}{4}$	0,07811	0,2002	0,2000	2,0	1,7878
	0,21097	0,4783	0,4800	-1,7	
$\frac{\pi}{3}$	0,07775	0,2008	0,2000	0,8	1,7268
	0,20862	0,4797	0,4800	−3,0	
$\frac{\pi}{2}$	0,07744	0,20016	0,2000	1,6	1,4463
	0,20681	0,47992	0,4800	−0,8	
$\frac{2\pi}{3}$	0,07728	0,20015	0,2000	1,5	1,3512
	0,20605	0,47987	0,4800	−1,3	
$\frac{3\pi}{4}$	0,07720	0,19999	0,2000	−0,1	1,2884
	0,20567	0,47997	0,4800	−0,6	

4. Conclusions

The method to account for iris hole edge rounding has been realized and proved, coefficient K_E values are obtained for a number of DLWG parameters. Average error of calculation is less then 0,1 - 0,2 % .

5. Acknowlegments

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6. References

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