DETERMINATION OF THE GEOMETRIC SIZE OF THE COMMUNICATION HOLE OF TWO CYLINDRICAL WAVEGUIDES

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Abstract: It is always relevant to improve performance in electrodynamic systems. When solving problems on the electrodynamic characteristics of hollow coupled systems, the question is often asked about the relationship between them, about the form of the communication hole with a certain orientation of the guide axes in the system elements and its geometric dimensions. Such a system is a generator (small-sized local oscillator 8 mm range). The inclusion of a high-Q stabilizing resonator in the Gunn diode generator significantly improves its characteristics.
The use of a low-quality coaxial chamber as a diode section increases the generation stability. However, this complicates the numerical calculations of the electrodynamic system of the generator due to the uncertain configuration of the communication hole, since it arises as a result of the intersection of two cylindrical volumes of a coaxial waveguide and a high-quality cylindrical resonator.
In the present work, the task is determination of the shape and size of the intersection figure of two unequal radii of cylindrical volumes with axes orthogonally located in relation to each other at a distance.
The resulting shape of the intersection figure in a planar approximation forms a flat ellipse. The larger diameter of the coupling ellipse depends on the diameter of the resonator, the smaller on the inner diameter of the coaxial chamber, depending on the distance between their axes.
It is necessary to determine the equivalent rectangular hole of the connection. Its presence simplifies the construction of a tangent electric field at the communication hole, which is necessary for numerical calculations of the electrodynamic characteristics of the system.
In this case, with constant diameters of the cylindrical resonators, the geometrical dimensions of the hole depend only on the distance between the axes.
It is with this circumstance that they are dealing with the study of the connection between a cylindrical coaxial diode section and a high-Q stabilizing resonator. Unlike other circuits, where the diode is included in the waveguide section, in this case, its inclusion is made in a coaxial line.
Keywords: generator, cylindrical waveguide, small-sized local oscillator, coaxial camera, Gunn diode, resonator.

1. Introduction

It is important to calculate the relationship of the elements of a cylindrical generator to determine the electrodynamic characteristics. In particular, the issue of determining the geometric dimensions of the coupling hole in the local oscillator for a cylindrical resonator with a coaxial waveguide chamber orthogonally placed on their axes is important.

Calculation of the loaded Q factor can't be performed without determining the shape and size of the communication hole between the resonator and the coaxial diode chamber of the generator.

2. Methods

The projection method is used for two connected hollow cylindrical structures – a coaxial waveguide and a cylindrical resonator (**Fig. 1**).

Their radii are respectively equal to r and R, t is the distance between the axes. The shape of the intersection shape in most cases is determined when constructing the studied intersection of the shapes according to the rules of descriptive geometry.

When considering projections of the system on planes that are parallel to the axes, it can be assumed that the curved figure defining the communication hole is an ellipse. It is also possible to assume that it is approaching a flat ellipse with diameters: a – larger, smaller. In **Fig. 1**, this figure has projections on planes in a rectangular coordinate system in the form of segments with chords a and b and with heights h and k.

Let's accept the condition that the radii of the waveguides R and r in the region of the communication hole do not differ from the values in the regular part of the waveguides and $(R+r)<t$.

According to **Fig. 1** the magnitude of the larger diameter of the ellipse a is determined from the expression:

$$a=2\sqrt{2hr-h^2}, \qquad (1)$$

where h is the height of the segment. Since the distance between the axes is $t=(R+r)-h$, let's obtain:

$$a=2\sqrt{2\left[(R+r)-t\right]R-(R+r)-t}=$$

$$=2\sqrt{R^2-(t-r)^2}, \qquad (2)$$

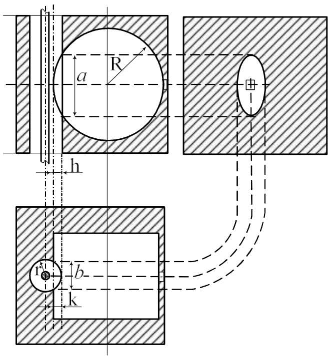

Fig. 1. Projections of two connected hollow cylindrical structures

The value of the small diameter of the ellipse b is determined from the expression:

$$b=2\sqrt{2kr-k^2}, \qquad (3)$$

where

$$k=r-(t-R),$$

so

$$b=2\sqrt{r^2-(t-R)^2}.$$

The area of the communication hole, subject to the planarity of the ellipse, is:

$$S=\pi\sqrt{a\times b}=$$

$$=4\pi\sqrt{\left[r^2-(t-R)^2\right]\times\left[R^2-(t-r)^2\right]}. \qquad (4)$$

Provided that

$$t=R+r,\ S=0.$$

3. Results

In a real circuit for a generator: R=6.4 mm and r=2.0 mm. **Table 1** shows the dependence of the radii b and a on the distance between the axes t.

In accordance with the **Table 1**, the dependences of the ellipse radii a and b on the distance between the axes t are shown in **Fig. 2, 3.**

As can be seen from the **Table 1**, the diameters a and b behave similarly when t changes. The larger the ellipse radii, the smaller the distance between the axes of the cylindrical elements. When conducting a numerical analysis, when the coordinate function system characterizing the field distribution at the hole is constructed based on the solution of the membrane equation (under the boundary conditions of equality of the electric field along the hole contour), difficulties arise. Therefore, given the complexity of the hole contour, with some approximation, it is possible to replace the elliptical contour with an equivalent rectangular one.

Table 1
Dependence of the ellipse radii *a* and *b* on the distance between the axes t

t, mm	a, mm	b, mm
8,3	2,24	1,25
8,0	4,44	2,40
7,0	7,98	3,80
6,8	8,46	3,98
6,4	9,29	4,07

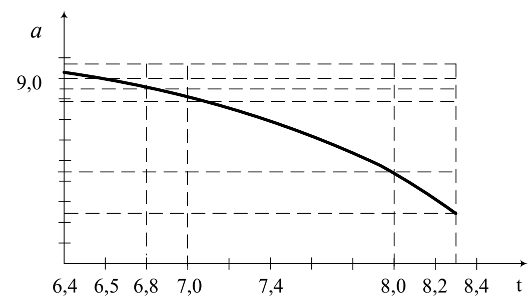

Fig. 2. The dependence of radius *a* on the distance between the axes *t*

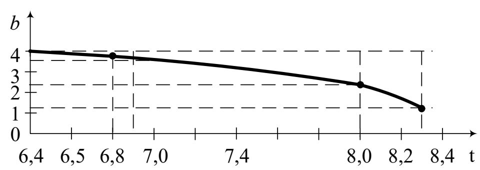

Fig. 3. The dependence of radius *b* on the distance between the axes *t*

With this change (as *t* changes), it is convenient to consider the gap width to be variable. The area of the ellipse is equal $S = \pi\sqrt{a \times b}$, and the area of the rectangular slit is $S = m \times n$. If choose a slit width equal to the small diameter of the ellipse ($a=n$), then the length of the slit ($b=m$) changes insignificantly when t changes. This is convenient when choosing a system of coordinate functions characterizing the distribution of the field at the communication hole.

The results of these calculations in the form of the dependences of the dimensions of the rectangular slit on the distance between the resonator axes and the coaxial camera for this generator are given in **Table 2** and in **Fig. 4**.

Table 2
The dependence of the dimensions of the rectangular gap on the distance between the axes of the resonator and the coaxial camera

t, mm	n, mm	m, mm
8,3	1,25	4,2
8	2,4	4,27
7	3,8	4,53
6,8	3,9	4,57
6,4	4	4,48

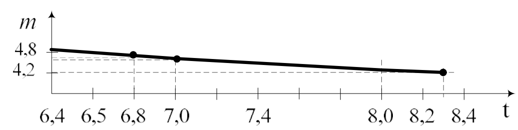

Fig. 4. Dependence of the height of the equivalent rectangular gap on the distance between the axes of the ellipse

The shape and magnitude of the bond in a small-sized local oscillator are determined for the intersection of two unequal radii of cylindrical volumes with axes orthogonally located relative to each other at a distance.

4. Discussion and conclusions

The results can be applied in calculating the coupling between the coaxial diode section and the cylindrical resonator to determine the stability of the generation. Results are only for given values of R=6.4 mm and r=2.0 mm. They are also important for determining the loaded Q-factor of a stabilizing cavity resonator in a generator. In the future, it is possible to verify the results experimentally for a small local oscillator.

References

1. Bronshteyn, I. N., Semendyaev, K. F. (1984). Spravochnik po matematike dlya inzhenerov i uchashchihsya vtuzov. Moscow: Nauka, 720.
2. Prigent, M., Camiade, M., Nallatamby, J. C., Guittard, J., Obregon, J. (1999). An efficient design method of microwave oscillator circuits for minimum phase noise. IEEE Transactions on Microwave Theory and Techniques, 47 (7), 1122–1125. doi: https://doi.org/10.1109/22.775446
3. Zeniv, I. O. Krylov, V. M., Monoilyk, V. A. (2013). Dvuhdiodnyy impul'sniy generator 8 mm diapazona. Zviazok, 6.
4. Zeniv, I. O. (2014). Stabilized millimetric band oscillator with a doubling of output power. Telekomunikatsiyni ta informatsiini tekhnolohiyi, 3, 106–110.
5. Zheng, B., Zhao, Z., Lv, Y. (2010). A K-band SIW filter with bypass coupling substrate integrated circular cavity (SICC) to improved stopband performance for satellite communication. Progress In Electromagnetics Research C, 17, 95–104. doi: https://doi.org/10.2528/pierc10092403

6. Kolondzovski, Z., Petkovska, L. (2005). Determination of a synchronous generator characteristics via Finite Element Analysis. Serbian Journal of Electrical Engineering, 2 (2), 157–162. doi: https://doi.org/10.2298/sjee0502157k
7. Zeniv, I. O., Krylov, V. M. (2016). Small heterodyne of 8-millimetr range using the Gunn diode stabilized by high-Q resonator. Naukovi zapysky Ukrainskoho naukovo-doslidnoho instytutu zviazku, 1, 97–104.
8. Berhausen, S., Paszek, S. (2015). Use of the finite element method for parameter estimation of the circuit model of a high power synchronous generator. Bulletin of the Polish Academy of Sciences Technical Sciences, 63 (3), 575–582. doi: https://doi.org/10.1515/bpasts-2015-0067
9. Angiulli, G., Arnieri, E., De Carlo, D., Amendola, G. (2009). Fast Nonlinear Eigenvalues Analysis of Arbitrarily Shaped Substrate Integrated Waveguide (SIW) Resonators. IEEE Transactions on Magnetics, 45 (3), 1412–1415. doi: https://doi.org/10.1109/tmag.2009.2012650
10. Bondarenko, T. G., Zeniv, I. O., Nizhnyk, R. S. (2017). Research results of solid-state wave gyroscope with metallic resonator. Naukovi zapysky Ukrainskoho naukovo-doslidnoho instytutu zviazku, 1 (45), 49–58.

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