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DISC-TYPE RESONATOR MOUNT IN RECTANGULAR WAVEGUIDE

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ABSTRACT

The field matching technique is applied to analyse a disc-type resonator mount in a rectangular waveguide. Two cases are considered : (i) of a single and (ii) of a double coaxial entry mount. Using the developed theory input impedance of the mount is determined. A comparison between numerical and experimental data for the input impedance is made and shows good agreement.

Introduction

This paper sets out a technique for the analysis of a disc-type resonator diode mount located in a rectangular waveguide. The structure is alternative to the post mount and is used in millimeter-wave and microwave oscillators and amplifiers {1}, {2}, {3}.

Until now, there has not been adequate theoretical analysis of the disc resonator mount and its design rests on experiment.

The mount has been analysed in {1}, {4}. However, the theory proposed in {1} neglects radiation of the resonator and results in a discrepancy with experiment.

In {4} the structure is considered as a scatterer for a dominant waveguide mode and results are not readily applicable for design purposes.

In the analysis presented here the disc resonator is considered as a structure seen from the diode terminals. In contrast to {1} present theory takes a radiation factor into account.

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The method of solving the problem is based on the approximation of the actual field in the cylindrical volume containing the disc by an axisymmetrical radial field. This approximation greatly simplifies the analysis and produces results in a good agreement with experiment.

Method of analysis

Single coaxial entry mount. The analysed mount is shown in Fig. 1. It is similar to a coaxial-waveguide junction but with a new element in the form of a disc attached to the inner coaxial conductor.

The structure can be divided into three cylindrical sub-regions: 1st under the disc, 2nd above the disc and 3rd outside the disc. For a generality the three subregions can be filled with different dielectrics with constant permittivities ε_1, ε_2, ε_3 respectively.

Solid-state circuit design requires determination of the input impedance seen by the TEM coaxial mode at the aperture surface S_a, while looking into the guide. This input impedance is defined as a voltage-current ratio (1):

$$Z_{IN} = \frac{V}{I} \qquad (1)$$

where: $V = -\int_a^b \bar{E}a(r,y=0)\bar{a}_r \, dr$,

$$I = \frac{1}{\ln\frac{b}{a}} \int_o^{2\pi}\int_a^b \bar{H}a\,(r,\phi,y=0)\bar{i}_\phi \, dr\, d\phi;$$

$\bar{E}a$, $\bar{H}a$ - electric and magnetic fields in the aperture S_a; r,ϕ,y - cylindrical coordinates. The definition (1) uses orthogonality properties which hold between coaxial modes. In order to find the input impedance of the mount the radial component of $\bar{E}a$ is approximated by TEM coaxial mode $\bar{E}_a.\bar{a}_r = -\frac{V}{\ln\frac{b}{a}}\frac{1}{r}$ and the $\bar{H}_a.\bar{i}_\phi$ component is to be determined.

Determination of $\bar{H}_a$ can be simplified if the actual field in the cylindrical volume containing the disc is approximated by axially symmetric field. This approximation is used here.

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Under this assumption, the field in the 2nd subregion and at the boundary r=R of the 3rd subregion can be expressed as a linear combination of TM to y direction radial modes.

The field in the 1st subregion contains TEM and TM to y radial components. The TEM component can be easily extracted by substituting the aperture by a magnetic current $\bar{M}_a = \bar{a}_y \times \bar{E}_a$ and creating a coaxial resonator, (through extending the outer coaxial conductor into the guide). Such a procedure, which employs the Schelkunoff field equivalence principle has been used before in {5}.

The remaining TM radial field components can be found after imposing conditions for y-electric and ϕ-magnetic components at the common boundary surface r=R for the 3 subregions. While the subregions 1 and 2 represent simple parallel plate radial guides, the 3rd subregion represents the rectangular waveguide. However, the rectangular guide with arbitrary terminations can also be considered as a radial guide and it is possible to extract TM axially symmetric components of the field at r=R surface {6}.

As a consequence the continuity conditions for the field at r=R lead to the infinite set of algebraic equations, which after truncating are solved by using standard algebraic methods.

$\bar{H}_a$ is obtained as a linear combination of TEM and TM components represented by cylindrical functions. After inserting $\bar{H}_a$ into (1) the required input impedance of the disc resonator mount is found.

Double coaxial entry mount. Having developed a theory for a single coaxial entry mount it is not so difficult to extend it for a double coaxial entry mount.

That can be obtained through circuit theory for a two-port network. After assuming that the second coaxial aperture with dimensions c,d is created in a top wall y=B of the guide, coaxially located with the first aperture, the analysis proceeds as follows.

In a manner similar to (1) we define voltages and currents V_2, I_2 for S_{a2}. V_1, I_1 and V_2, I_2 are coupled through the admittance matrix $\{Y_{ik}\}$:

$$I_1 = Y_{11} V_1 + Y_{12} V_2 \;,\; I_2 = Y_{21} V_1 + Y_{22} V_2 \qquad (2)$$

$Y_{11} = 1/Z_{IN}$, where Z_{IN} is given by (1). Y_{21} can be found as a result of the analysis for a single entry mount by using I_2 as expressed by $H_\phi(r,y=B)$. To find Y_{12}, Y_{22} the ports should be reversed and the above procedure repeated.

Input admittance is then given by (3)

$$Y_{IN} = Y_{11} - Y_{12} Y_{21}/(Y_{22} + Y_L) \qquad (3)$$

where Y_L is a load admittance at the coaxial aperture Sa_2.

Results

To check the theory a special waveguide-coaxial line junction was designed. The mount consisted of a standard X-band rectangular waveguide matched at both ends and 7mm 50Ω coaxial lines. The mount allowed substitution of discs, which could be moved smoothly along the inner conductor of the coaxial line. The input impedance Z_{IN} was measured in a frequency band 6.5 - 12.5GHz with an 8109B Hewlett-Packard network analyser.

A comparison of numerical and experimental results is shown in Fig. 2.3. Numerical results were obtained with few radial modes in the 1st and the 2nd subregions and 10 modes in the 3rd subregion. A comparison between theory and experiment shows good agreement.

Conclusions

An analytical approximate method has been found to determine the input impedance of a disc resonator mount, located in a rectangular waveguide. The method produces results in good agreement with experiment and it can find useful application in design of solid state devices employing this type of mounting structure.

Acknowledgements

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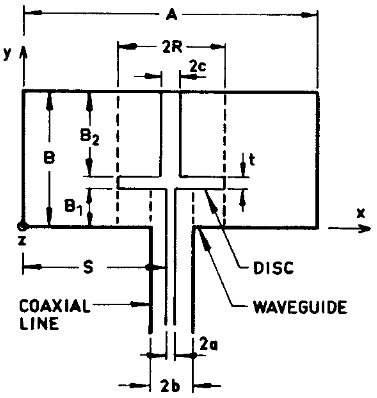

Fig. 1. Disc-type resonator mount with gap created by coaxial-waveguide entry.

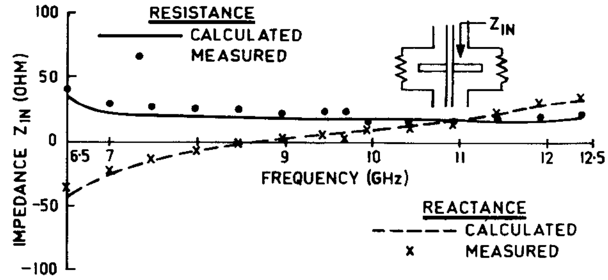

Fig. 3. Comparison between theoretical and experimental values of input impedance Z_{IN} for double coaxial entry mount with dimensions as in Fig. 2 but with $B_1 = B_2 = 3.08$mm and with the second coaxial line with dimensions $c = a$, $d = b$, $Z_c = 50\Omega$ terminated with matched load.

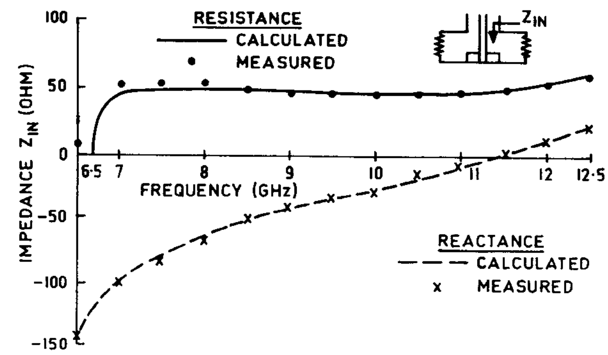

Fig. 2. Comparison between theoretical and experimental values of input impedance Z_{IN} at the coaxial aperture plane for single coaxial entry disc mount with: $A = 22.86$mm, $B = 10.16$mm matched guide, $S = A/2$; $2R = 10$mm, $t = 4$mm disc, $B_1 = 6.16$mm and with $a = 1.52$mm, $b = 3.5$mm, $Z_c = 50\Omega$ coaxial line.