MODELING OF COUPLING SCREW IN CYLINDRICAL MULTIMODAL CAVITY FILTERS

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ABSTRACT

In this letter we present the modelling of screws in cylindrical multimodal cavity filters. The mode spectrum of each ridge circular waveguide is obtained using the Boundary Element Method (BEM) and the Contour Integration Technique (CIT). Afterwards, the complete structure composed of uniform waveguides is cascaded by a Multimodal Variational Method (MVM). This method is used with a new process to find out the number of modes. The computing time can be significantly reduced, by a factor of 3, applying this procedure.

INRODUCTION

Ultra high frequency filters, which are currently used in electronic equipments for radiocommunication satellites, are mostly composed of passive components. Optimal filtering performances can be achieved with high power transmission, but their main drawback in the satellite equipment is their dimensions and their mass. For several years, engineering projects have developed ultra high frequency filters, with metallic cavities dual modes resonators, to respect the electrical and mechanical constraints on power. The classical structure of bimodal cavity's filters is a filter with six poles and three bimodal cavities. Cylindrical and rectangular cavities operate with TE_{11N} polarized resonant modes. Consequently, two orthogonal modes for each cavity can be used independently and it is therefore called bimodal. A screw placed in 45° couples the two modes of the cavity by destroying the field symmetry. The coupling is guaranteed by placing small irises between cavities. The irises width and thickness are imposed by technology. The advantages of the bimodal cavities can be extended to three-mode and in general to multimodal cavities.

As it has been seen before, screws achieve interpolarisation couplings. As a consequence, they have to be precisely considered. The purpose of this study is a rigorous modeling of the screws and the coupling irises by using equivalent circuits. Discontinuities have been taken into account to avoid long and fastidious adjustments necessary in the past for achieving the required specifications. As a rule, achievement of more complex filters such as filters with trimodal cavities can be considered. Appropriate modeling tools are used to carry out this study. The multimodal variational method well established and already applied to several cases is used. The present study concerns to the screw modeling in the bimodal cylindrical structure, which constitute the elementary cell of complex ultra high frequency filters. In order to improve computation time and characterize ridged circular waveguides, many researchers [1],[2] have developed methods based on the modal matching principle and the integral formulation of the fields [3]. The drawback of these methods is the restriction to ridged circular waveguide study. Another method using dyadic Green's functions has been developed by G. Conciauro [4] to characterize ridged circular waveguides, and improved by Arcioni [5].

This paper deals with the boundary elements method that, without restriction to the ridge shape, presents examples for ridged rectangular and circular waveguides. This method is based on the same principles as Montgomery's method: integral formulation of the fields solved thanks to Galerkin's method. The cutoff wavenumbers in arbitrary ridged waveguides can be readily determined by this method. All modes determination at the discontinuity planes is guaranteed by specific conditions applied to the numerical solutions.

DESCRIPTION OF THE METHOD

The studied structure is shown in fig.1a. In practice, the screws used to tune filters are cylindrical posts. The method proposed in this paper is a combination of the BEM-CIT methods and MVM method. The screw is assimilated by a notch of rectangular cross section, with an equivalent circular surface (fig.1b).

a) b)

Fig.1 : a) The studied structure ; b) The equivalent surface of the screw.

CUTOFF CONSTANTS DETERMINATION FOR CIRCULAR WAVEGUIDE RIGDED

The modeling method is divided in several successive steps. Its begin with the resolution of Helmholtz's equation, through a Green's function satisfying the boundary conditions, and finish in a matrix form by projection of the operators deduced from the segmentation method with Galerkin's procedure [6].

- In this waveguide, the electric and magnetic fields satisfy Helmholtz's equation (1).

$$\left(\nabla_t^2 + k_c^2\right)\begin{pmatrix} E_z \\ H_z \end{pmatrix} = 0 \tag{1}$$

where

$\nabla_t^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$: is the Laplace's operator at the discontinuity plane.

k_c is the cutoff wavenumber of the mode considered.

E_z is the generic function of TM modes.

H_z is the generic function of TE modes.

The z dependency is assumed to be in $e^{-\gamma z}$, where the propagation constant γ is calculated from the dispersion relation : $\gamma^2 = k_c^2 - k_0^2$

where k_0 is the propagation constant in free space : $k_0^2 = \omega^2 \mu_0 \varepsilon_0$.

The boundary conditions that must be satisfied on perfectly conducting surfaces are :

$$E_z = 0 \text{ (TE modes) and } \frac{\partial H_z}{\partial n} = 0 \text{ (TM modes)} \tag{2}$$

- The method consists in choosing a Green's function that satisfies the boundary conditions on the external rectangular/circular contour. So the equation (1) becomes:

$$\left(\nabla_t^2 + k_c^2\right) G(r, r') = -\delta(r, r') \tag{3}$$

From the equation (3) and the boundary conditions (2), Green's second identity is deduced, which can be expressed with contour integral formulation as shown in equations (4) and (5).

$$\text{TE case : } H_z(r) = -\int_{Ridge\ Contour} H_z(r') \frac{\partial G(r, r')}{\partial n'} dr' = 0 \tag{4}$$

$$\text{TM case : } \int_{Ridge\ Contour} \frac{\partial E_z(r')}{\partial n'} G(r, r') dr' = 0 \tag{5}$$

Those equations correspond to Neumann's and Dirichlet's problem, respectively. The boundary conditions specific to TE and TM modes allow a restriction of the integration domain to the ridge contour.

- To solve these integral equations, the ridge contour is divided in several segments d_i (i.e. the boundary elements method is applied to the ridge contour), where basis step functions are defined as follow:

$$h_i(r) = \begin{cases} \frac{1}{\sqrt{d_i}} & \text{if } r \text{ is on the ridge} \\ 0 & \text{anywhere else} \end{cases} \tag{6}$$

Then H_z and $\frac{\partial E_z}{\partial n}$ are developed in a series of normalized constants functions (6), and substituting in equations (4) and (5), leads to the integral operators (7) and (8).

$$\hat{G}_z^{TM}(h_i) = \int_{d_i} G_z(r,r') \cdot h_i(r')dr' \tag{7}$$

$$\hat{G}_z^{TE}(h_i) = \int_{d_i} \frac{\partial G_z(r,r')}{\partial n} \cdot h_i(r')dr' \tag{8}$$

The TM operator defined in equation (7) is symmetrical, whereas the TE operator, defined in (8), is not one. The symmetry is a necessary condition to the definition of a dispersion function monotonous for the k_c parameter: this is the main point of the recursive method. For the case of the TE modes, it is already possible to build a monotonous function from a vector formulation instead of use a scalar one, and then apply the recursive method [6]. The results presented here are obtained by applying the recursive method in both cases (TE and TM modes).

- Finally, the Galerkin's method is applied to the equations (7) and (8), which leads to the resolution of a system of equations in a homogeneous matrix form $[A][X]=[0]$ (where [A] is a square matrix, whose dimensions depend only on the number of the segments chosen to discretize the ridge contour and [X] is the column vector of unknowns variables, which are the generic functions values H_z or $\frac{\partial E_z}{\partial n}$ on the contour, depending on the case).

The cutoff wavenumbers are the nontrivial solutions of $[A][X]=[0]$, i.e., the zeros of the *det*([A]).

MULTIMODAL VARIATIONAL METHOD

The developed method is based on the transcription of the boundary conditions at the interface between two waveguides by an electric equivalent circuit [7], [8], as shown in fig. 2. Electromagnetic fields between the two waveguides are written in the discontinuity plane (P).

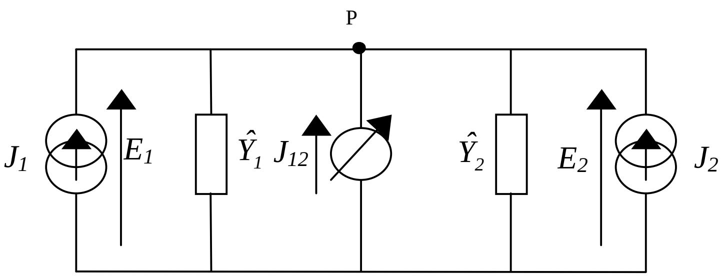


Fig.2 : Electric equivalent circuit for one discontinuity.

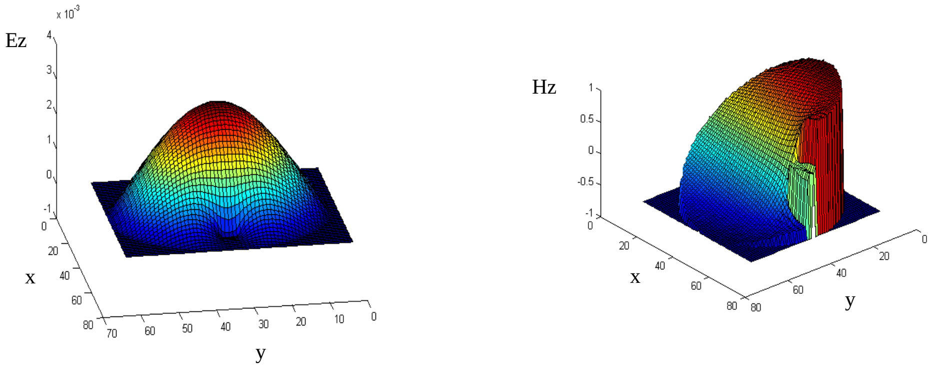
After several mathematics manipulations, the matrix [Z] characterizing the discontinuity appears. The reduced [z] matrix is deduced from chaining two elementary matrixes [Z]. The diffraction matrix [S] is obtained from this normalized matrix [8].

NUMERICAL RESULTS

Electric fields are tested in the case e/2r=0.08, h/2r=0.2, magnetic fields in the case e/2r=0.04, h/2r=0.25. As shown in fig.3, the boundary conditions are satisfied (electric and magnetic fields are null on the metal) for the criteria of convergence used: 11 segments on half of the contour and 4000 modes in the Green's function series.

After having verified the cutoff wavenumber of the ridged circular waveguide, the modeling of the screws is studied by applying the variational multimodal method.

Fig.4 represents the magnitude of the reflection coefficients of a cavity excited by two rectangular waveguides WR 75. This result is shown that the resonant mode is shifted as a function of the depth *h* of metallic notch. The adjustment of the filter central frequency is provided by this means.



a) b)

Fig.3 : a) 3D representation of fields TM_{01} for e/2r=0.08, h/2r=0.2 ; 3D representation of fields TE_{11} for e/2r=0.04, h/2r=0.25.

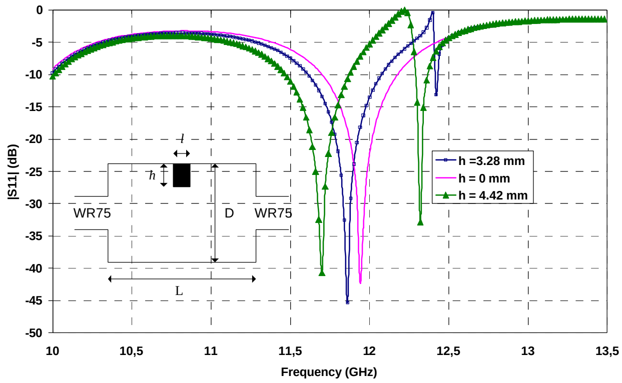


Fig.4: The magnitude of the reflection coefficients of a cavity excited by WR75.

CONCLUSION

In this work, the screws of a filter study has been achieved thanks to a method combining the BEM-CIT and the MVM. More complex structures, like bimodal and trimodal filters including coupling and adjustable screws, will be simulated with this method and comparison with measurements will be achieved.

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