VARIATIONAL ANALYSIS OF ARBITRARILY ORIENTED THICK IRIS COUPLING A RECTANGULAR AND AN ELLIPTICAL WAVEGUIDE

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ABSTRACT

Elliptical waveguide is receiving growing interest for likely application to tuningless dual mode filters. Its coupling to a rectangular waveguide takes often place via a thick rectangular iris that can be rotated with respect to the axes of both guides. In this contribution we develop an accurate fullwave multimode variational approach of the coupling iris including the complete Green's functions of both guides and accounting for the 90°-edge condition in the field expansions on the iris apertures.

INTRODUCTION

A critical point in the realization of tuningless dual mode filters in circular cylindrical or elliptic cylindrical waveguides is the proper dimensioning of the coupling elements. Some work to this effect appears to be available in the classical cylindrical waveguide [1], [2], [3], [4]. Elliptical guides, moreover, are finding increasing favour in view of the additional coupling control they afford trhough an appropriate choice of eccentricity . This effect can be used with the pourpose of controlling the coupling between the two orthogonal modes propagating along each cavity forming the filter. In fact, starting from circular cavities, the two orthogonal modes are traditionally coupled by introducing 45° screws or precisely manufactured discontinuities [5]. An alternative solution has been recently proposed by a few authors [6], [7], who suggested to couple the modes by perturbing the original waveguide section, in such a way as to obtain continuous coupling along the guide. In particular, Tascone and his group focused their attention on the square/rectangular waveguides but the principle applies to circular/elliptical waveguides as well. In order to best take advantage of this physical effect, the coupling between the feeds and the elliptical cavities ought to excite both propagating modes of the latter. Therefore, an important design element is the angle of mutual rotation between each guide and the coupling iris (Fig.1 and Fig.2). The iris itself is to be considered of arbitrary thickness. In view of the proposed application the characterization has to be very accurate.

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THEORY

We use a multimode variational approach to the problem [8], e.g. of the type of [9], where the multimode impedance matrix of the thick iris is expressed as:

$$z_{ij} = \mathbf{P}_i^T \cdot \mathbf{Y}^{-1} \cdot \mathbf{P}_j \quad i,j = 1, n_a;\ n_a = n_e + n_r \quad (1)$$

Where $\mathbf{Y}$ stands for the discretized $(n_a \times n_a)$ Green's admittance of the junction including thick iris and localized modes $(n > n_a)$ of both the rectangular and elliptical guides, n_e and n_r being the number of accessible modes taken in the elliptical and in rectangular waveguide respectively.
$\mathbf{P}_i$ is a n_a-dimensional vector expressing the tranverse distribution of the i-th accessible mode in terms of the expansion basis taken on the appropriate aperture of the iris: S_e or S_r according as $1 \leq i \leq n_r$ or $n_r + 1 \leq i \leq n_a$ (Fig.3). The expansion basis is taken in the form of a product of a Gegenbauer polynomial $G_k{}^{\nu}$ in ξ and one in η respectively times a weight function w that takes care of the edge conditions on the iris edges. For istance, with reference to Fig.4, the component E_η

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is expanded as

$$E_\eta(\xi,\eta)=\sum_{k,m}V_{km}\frac{G_k{}^{7/6}(\xi)}{\sqrt{a'}N_{\xi k}}\frac{G_m{}^{1/6}(\eta)}{\sqrt{b'}N_{\eta m}}w(\xi,\eta) \quad (2)$$

Where $w(\xi,\eta)=(1-(\frac{2\xi}{a'})^2)^{2/3}(1-(\frac{2\eta}{b'})^2)^{-1/3}$, $N_{\xi k}$ and $N_{\eta m}$ are normalization constants. In view of the rotation of the axes of the iris with respect to those of both guides, the superposition integrals are carried out numerically. The numerical efficiency increases considerably if integrable singularities are eliminated by means of the following change of variables:

$$\frac{2\xi}{a'} = \sin u \quad (3)$$

$$\frac{2\eta}{b'} = \sin v \quad (4)$$

In fact the above transformation regularizes the term $w\,d\xi\,d\eta$, namely :

$$w\,d\xi\,d\eta \rightarrow \cos^{7/3}u\,\cos^{1/3}v\,dudv \quad (5)$$

A similar reasoning applies to the component E_η as well.

It is emphasized that the explicit inclusion of the edge conditions greatly enhances convergence and accuracy with respect to those achieved with the ordinary choice of iris expanding functions.

RESULTS

In order to check the accuracy of the method, we calculated and measured the resonant frequencies of a circular and an elliptical cross-section resonator, coupled to rectangular waveguides via some irises having different sizes and thicknesses. It is emphasized that for the purpose of checking the accuracy of the method, the circular geometry is more critical than the elliptical one, since we are actually using the eigenmodes of the latter (Mathieu functions [14]) in order to describe the field of the former. Fig. 5 shows the comparison between theory and experiment for the circular resonator while Fig. 6 refers to the elliptical case. In both cases the agreement between theory and experiment is quite satisfactory. With regard to numerical efficiency, it has to be noted that this is a difficult problem involving the calculation of thousands of overlapping integrals between the modes of the elliptical waveguide (Mathieu functions) [10], [11], [12], [13], the modes of the rectangular feeds and the basis functions employed for discretizing the unknown interface fields. Moreover, a further change of variables is necessary in order to take into account the rotation of the iris with respect to the feed. Therefore, the time required for a complete analysis of the junction over a full waveguide band (401 frequency points) is about 1 hour on a Digital α 300X series, considering as accessible the TE_{10} for the rectangular waveguide, the TE_{c11} and TE_{s11} for the elliptical one and considering 9 basis functions for each interface (the dimension of the discretized admittance $\mathbf{Y}$ is 36×36). That time does not include the calculation of the modes of the elliptical waveguide, that results from a different code. We took also 100 modes of each guide for representing the reactive field. The efficiency of the code can be improved by following the procedure of frequency extraction indicated in [9].

CONCLUSIONS

We have developed a variational approach for modelling the coupling between a rectangular and an elliptical waveguide via an arbitrary oriented thick iris. A comparison between theoretical and experimental results for the circular guide case shows the accuracy of the method.

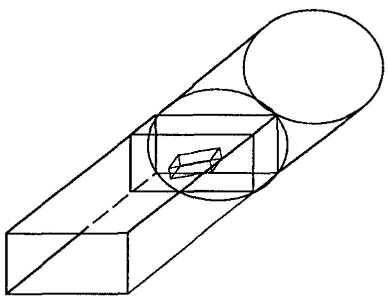

Fig. 1. Transition between a rectangular and an elliptical waveguide via a thick iris

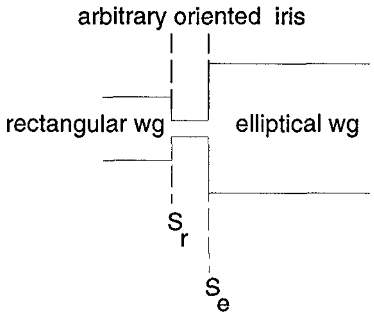

Fig. 2. longitudinal section of the structure examined

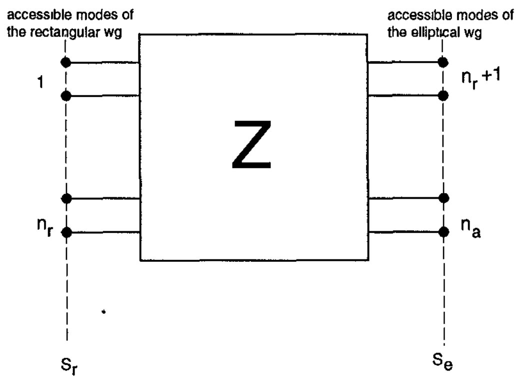

Fig. 3. Black-box equivalent circuit of the iris

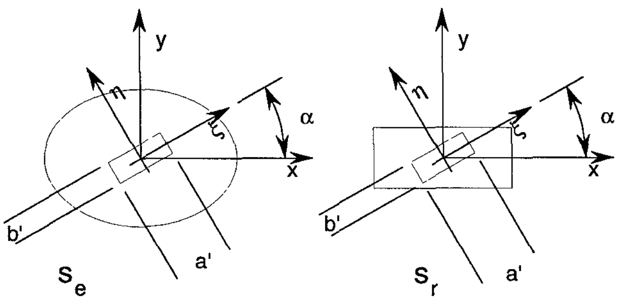

Fig. 4. Geometries at the two interfaces S_r (rectangular wg-iris) and S_e (iris-elliptical wg)

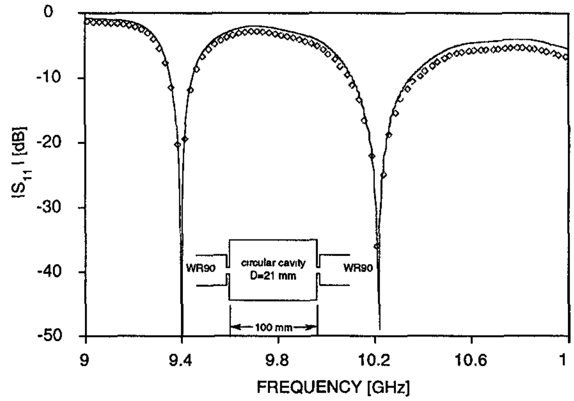

Fig. 5. Comparison between theoretical (continuous line) and experimental points (dots) of a circular resonator coupled to rectangular feeds (WR90) through two identical irises. The resonator diameter is 21 mm, its length 100 mm, while the size of the rectangular irises is 14mm $\times 4$ mm, their thickness 0.150 mm, $\alpha = 0°$

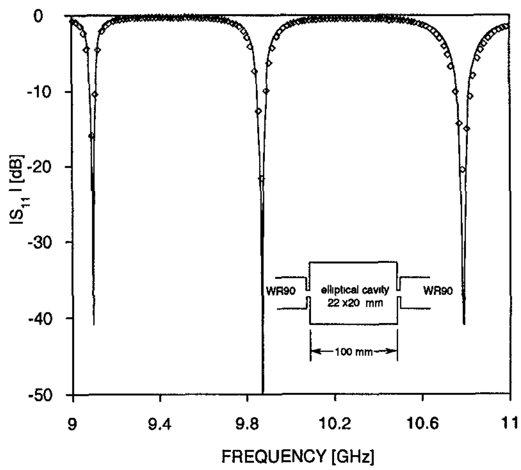

Fig. 6. Comparison between theoretical (continuous line) and experimental points (dots) of an elliptical resonator coupled to rectangular feeds (WR90) through two identical irises. The axes of the elliptical section are 22 and 20 mm, its length 100 mm, while the size of the rectangular irises is 10.16mm $\times 10.16$ mm, their thickness 0.150 mm, $\alpha = 0°$

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