IMPROVEMENT IN CALCULATION OF SOME SURFACE INTEGRALS. APPLICATION TO JUNCTION CHARACTERIZATION IN CAVITY FILTER DESIGN.

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ABSTRACT

This rigorous method allows to reduce a surface integral to a contour integral. The application of this formulation to the study of a circular - to - rectangular waveguide junction reduces more than 50 % computation time of the scattering parameters. The method is applied to calculate the electromagnetic coupling of circular cavities by a rectangular iris. This approach, together with an optimization procedure has allowed the direct design of a filter without any further mechanical adjustments. The obtained results are in good agreement with experimental data.

INTRODUCTION

The electromagnetic coupling of circular cavities by rectangular irises is an important element in the design of microwave filters [1] - [3]. To characterize this coupling, we must determine accurately and rapidly the S matrix of each discontinuity. Then they are cascaded to study the transmission of the total structure. Several formulations have been used to study discontinuities. Finite - differences, finite - elements and TLM are general methods which require important computation facilities. The generalized S - matrix method based on the development of electromagnetic fields at the junction is often used [4]. Recently, a moment method formulation with entire basis and testing functions was used to analyse the transition between rectangular and circular waveguides coupled by a rectangular slot [7]. In the present work, the modelling of different discontinuities is based on a variational integral multimodal method. The junctions are then cascaded by taking into account the number of coupled modes [5] - [6]. This approach provides accuracy, small size matrices, thus rapidity. However, the fields continuity condition at the junction involves scalar products calculation over the surface of the aperture. Then a surface integral must be calculated. In the case of a circular to rectangular transition [8], this integral is carried out numerically. Indeed, the electomagnetic fields expressions of the circular waveguide involve Bessel functions.

In this paper, a rigorous method is developed, allowing the reduction of a surface integral to a contour integral. This method will be applied to the study of the circular to rectangular discontinuity. The time saving is significant. The variation of the coupling between two circular cavities by a rectangular iris is proposed for several iris lengths (fig.1).Our results are compared with experimental data. According to this design approach, a six - pole elliptic filter has been realized and the filter response has been found to be in good agreement with the initial requirements.

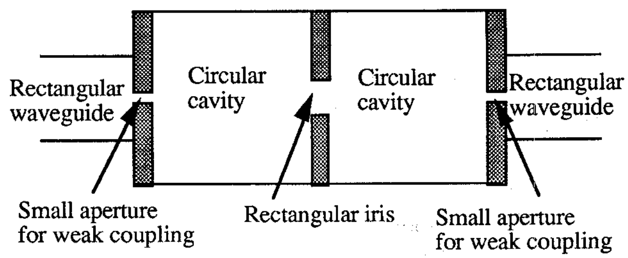
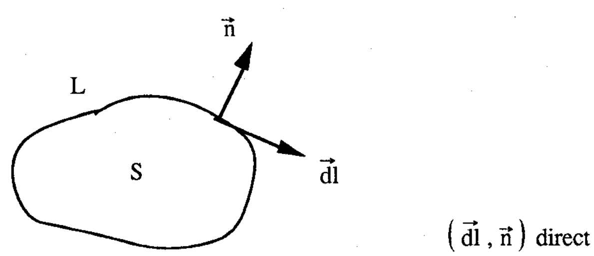


Fig. 1 Coupling between two circular cavities by rectangular iris. Measurement structure.

THEORY

Suppose a surface S limited by a contour L, where the quantity I is calculated by the following integral :



$$I = \int_S (f_x g_x + f_y g_y) \, dS$$

here f and g are two functions of two variables with two components, deriving from functions e, h, E and H (scalar functions of two variables).

$$f_x = \partial_x E - \partial_y H \qquad g_x = \partial_x e - \partial_y h$$

$$f_y = \partial_y E + \partial_x H \qquad g_y = \partial_y e + \partial_x h$$

Moreover, we assume that the following relationships hold :

$$\nabla^2_t \begin{pmatrix} E \\ H \end{pmatrix} = \lambda \begin{pmatrix} E \\ H \end{pmatrix} \qquad \nabla^2_t \begin{pmatrix} e \\ h \end{pmatrix} = \mu \begin{pmatrix} e \\ h \end{pmatrix} \qquad \lambda \neq \mu$$

Then the integral becomes :

$$I = \int_L \left\{ \frac{\lambda}{\lambda - \mu} \left(E \, \nabla e + H \, \nabla h \right) + \frac{\mu}{\mu - \lambda} \left(e \, \nabla E + h \, \nabla H \right) \right\} . \vec{n} \, dl$$

$$+ \int_L \left(e \, \nabla H + E \, \nabla h \right) \times \vec{n} \, . \, \vec{dl}$$

with $\nabla h \, . \, \vec{n} \, dl = \frac{\partial h}{\partial n} dl$

$$\nabla h \times \vec{n} \, . \, \vec{dl} = \frac{\partial h}{\partial l} dl$$

Now, the above relation can be applied to the study of the a circular to rectangular waveguide discontinuity (fig. 2).

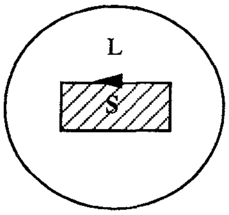


Fig. 2 Circular - to - rectangular waveguide junction.

Then the integral is reduced according to the character of the modes, TE or TM, on each side of the interface.

1 - TE - te modes :

$$I = \int_L \frac{\mu}{\mu - \lambda} \, h \, \frac{\partial H}{\partial n} \, dl$$

2 - TM - tm modes :

$$I = \int_L \frac{\lambda}{\lambda - \mu} \, E \, \frac{\partial e}{\partial n} \, dl$$

3 - TM - te modes :

$$I = \int_L E \, \frac{\partial h}{\partial l} \, dl$$

4 - TE - tm modes :

$$I = 0$$

The E, H, e and h functions are calculated by using Maxwell' s equations.

NUMERICAL AND EXPERIMENTAL RESULTS

The scalar products have been evaluated with the surface integral method as well as with the contour integral method. The error on the scalar products values is less than 10^{-3} % . These results validate our formulation. Fig. 3 shows the comparison between the computation times required to obtain the same results by the two methods (surface integral, contour integral).

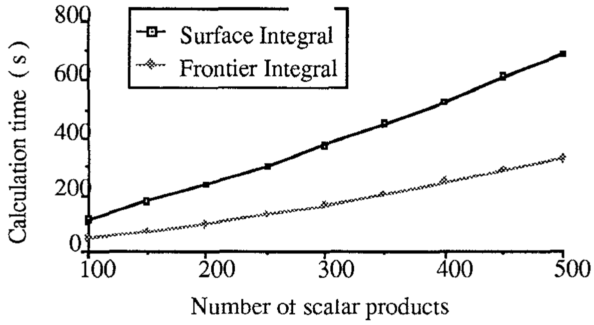


Fig. 3 Comparison of the calculation time according to the integration method for circular - to - rectangular junction.

The contour integral method is seen to be two to three times faster. The application leads to a considerable time saving for the scalar product calculation and consequently for the S - matrix calculation of the circular - to rectangular junction.

The method is used to calculate the coupling between two circular cavities by a rectangular iris. The structure used for measuring the coupling between cavities is shown in fig. 1. The cavities are coupled to the input (or the output) waveguides through small apertures in order to ensure weak couplings. The transmission of the structure is characterized by means of the bandwidth of the frequency response (fig. 4).

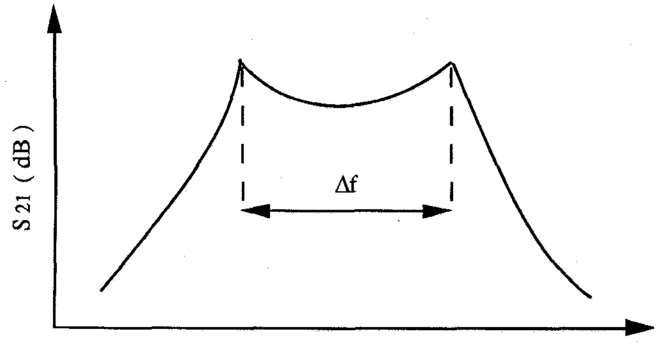


Fig. 4 Transmission response of two coupled cavities Δf : bandwidth.

The bandwidh has been measured for several iris lengths. The diameter and length of the cylindrical cavities are respectively 26,46 mm and 42,4 mm. The iris length is varied as a parameter, while its width and thickness are fixed to 1 mm.

Then the theoretical variation of the bandwidth with the length of the rectangular iris has been calculated and presented in fig. 5.

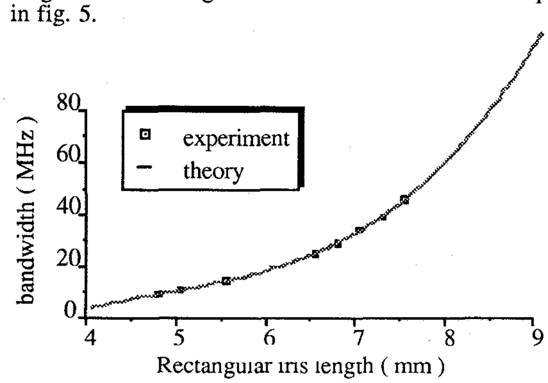


Fig. 5 Comparison between calculated and measured bandwidth obtained by two circular cavities coupled by a rectangular iris.

In practice, thin irises are used where their lengths are determined in function of the desired bandwidth. The input waveguide is excited by the fundamental mode TE $_{10}$, which is the only propagating mode. So only TEmn and TMmn modes, with m odd and n even for rectangular waveguide and m odd for Bessel functions Jm of circular waveguides are considered. 350 circular modes are taken in the cavities, 10 modes in the iris of which 3 are coupled modes [6]. The experimental data are in good agreement with the theoretical results.

According to this design technique, a six - pole elliptic filter has been realized (fig. 6).

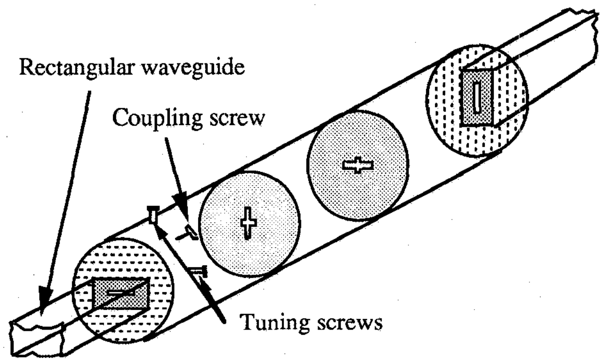


Fig. 6 Dual - mode six - pole filter.

The required specifications are the followings :

- central frequency : 11,85 GHz
- bandwidth : 40 Mhz
- VSWR in the passband : < 1,15

The bandwidth variation with the iris length is represented in fig. 7.

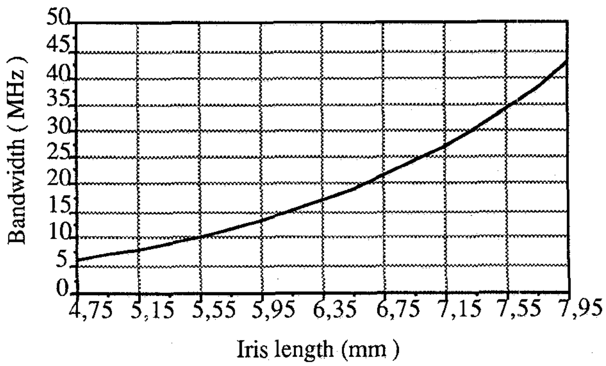


Fig. 7 Bandwidth as a function of the iris length (filter cross iris)

The dual - mode cavity filter has been realized using these values. The filter response has been measured (fig. 8) and a very good agreement is observed with the predicted values. There has been no need for any further mechanical adjustements.

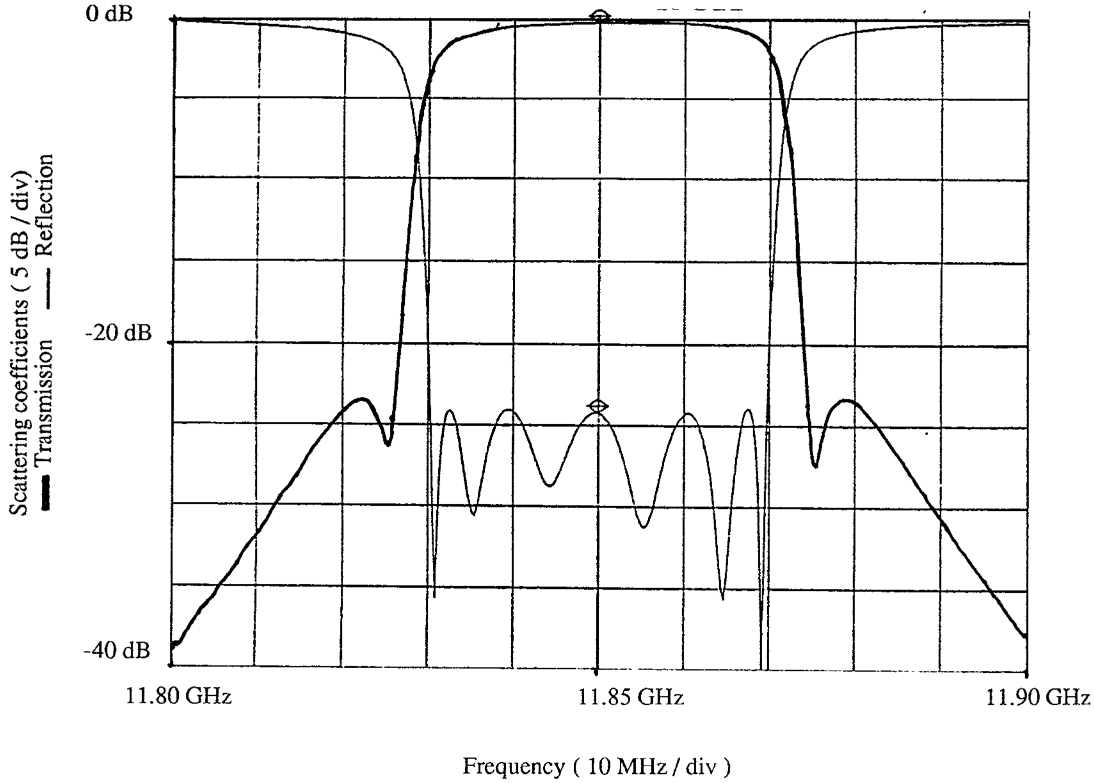


Fig. 8 Measurement response of the six - pole elliptic filter.
Required values : f0 = 11. 85 GHz, bandwidth 40 MHz,
VSWR < 1.15.

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