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NUMERICALLY EFFICIENT TAPER ANALYSIS WITH CONTROLLED RESOLUTION

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ABSTRACT

Circular waveguide tapers which are frequently used in gyrotrons are analyzed based on subdividing the taper into waveguide steps and uniform waveguide sections. Using a special subdivision and controlling the field resolution leads to a high speed-up factor compared to conventional approaches.

STATEMENT OF THE PROBLEM

Fig. 1 shows the contour function of a circular waveguide taper. Tapers like this are often used in the output circuit of gyrotrons. The two ports of such a taper are connected to the output waveguide and to the interaction cavity. Since the operation of a gyrotron strongly depends on any kind of load reflections it is desirable to know exactly the properties of the output taper with respect to return loss and to spurious mode suppression.

In [1], two methods have been described which are suitable for the analysis of such tapers. The first method integrates the coupled wave equations, whereas the second method makes use of a subdivision of the taper into waveguide steps and uniform waveguide sections. The scattering matrix of a single step has been calculated by a mode-matching method, and the scattering matrices of the individual waveguide junctions are cascaded to obtain the resulting scattering matrix. Both methods are extremely cpu time consuming if long tapers are considered and if high accuracy is required.

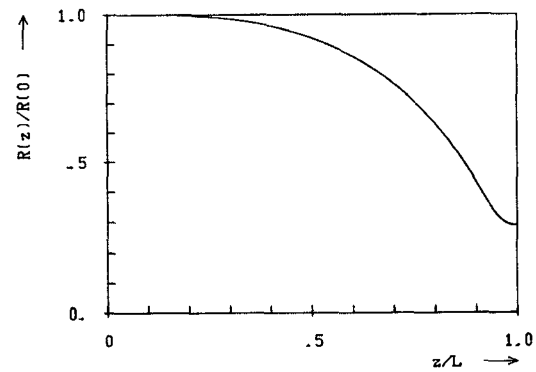

Figure 1: Contour function of a circular waveguide taper.

BASIC FORMULATION

In this contribution, an analysis is proposed which is similiar to the second method presented in [1]. Both methods are based on the generalized scattering matrix technique [2], but they differ, however, in the following:

The method presented in [1] takes a constant number of evanescent modes into account throughout the taper, which leads to a nonuniform resolution. To understand this one has to keep in mind that the resolution is related to the number of modes and to the local radius [3]. In our contribution, the number of evanescent modes is properly adjusted so that a uniform resolution is guaranteed along the taper.

Furthermore, we have introduced a quantity η ($\eta \geq 1$) which is defined as the ratio of two mode numbers. The first is the number of the modes which are considered for the analysis of one waveguide step discontinuity. The second mode number corresponds to the propagating and evanescent modes which are taken into account for the interaction of these discontinuities. The quantity η allows distinguishing between modes which are only responsible for local energy storage in the immediate vicinity of a step (due to their large damping coefficient, these modes cannot interact with the adjacent steps), and those for which the interaction with other steps cannot be neglected. Consequently, the number of the modes which are considered for the interaction of the steps can be chosen much smaller than that in the method presented in [1] if η is appropriately adjusted. Hence the introduction of the mode ratio η leads to a considerable improvement with regards to both accuracy and efficiency.

The speed-up of the analysis results from a new way in which the taper is subdivided. Usually tapers are subdivided into waveguide sections of equal length, see Fig. 2. The matrix corresponding to the mode coupling by a waveguide step depends only on the ratio of the radii at both sides of the step. Hence if the waveguide sections are chosen so that

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this ratio is kept constant, see Fig. 3, the same coupling matrix can be used throughout the taper.

NUMERICAL RESULTS

The use of only one coupling matrix in the analysis leads to a high speed-up factor which is defined as the ratio of the cpu time corresponding to a taper subdivision into sections of equal length and to that corresponding to the new subdivision. Table 1 gives some numerical results for a linear taper. These results show that the speed-up factor gets larger if the number of steps is increased.

CONCLUSIONS

The analysis of circular waveguide tapers based on a new subdivision of the structure and controlling the field resolution has been suggested. The results underline the high numerical efficiency of the method.

ACKNOWLEDGEMENT

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Number of steps	cpu time in s: Conventional subdivision	cpu time in s: New subdivision	Speed-up factor
16	13.3	4.4	3.0
32	25.3	6.6	3.8
64	50.9	11.4	4.5
128	104.9	20.8	5.0

Table 1: Speed-up factors for the analysis of a linear taper as a function of the number of steps.

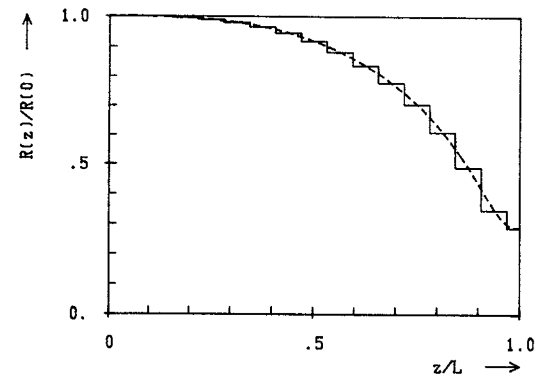

Figure 2: Subdivision of a taper into sections of equal length.

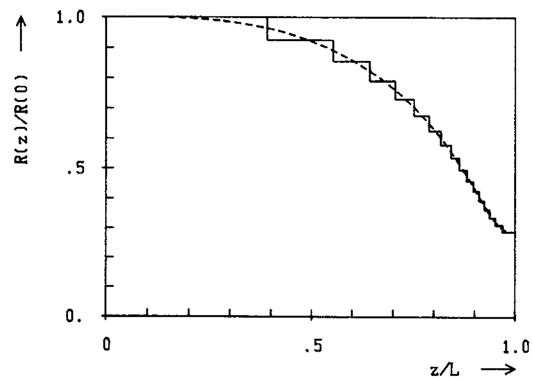

Figure 3: Subdivision of a taper into steps with an equal ratio of the corresponding radii.