DEVELOPMENT OF OVERMODE RF WINDOW USING MULTIMODE MATRIX FORMALISM

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INTRODUCTION

When developing RF generators with power about 100 MW, the problem of electric strength of output windows arises. With the aim to decrease fields in the region of ceramics, the traditional pill-box window was re-designed: the diameter of the "pill" was extended, which meant the transition to an overmoded, or oversized window (the diameter is much larger than the wavelength). The walls of the "pill" normal to the waveguide axis were transformed into cone tapers [1, 2]. A significant decrease of the field on ceramics can be achieved in the traveling wave window [3]. A decrease of the field near the ceramics-metal contact can be achieved using guarding rings [4], or transforming the operational wave into the H_{01}-wave [5]. In spite of the evident success in the field of RF windows design, there has been no possibility up to now to guide? all the power needed. Taking into account that experiments in this field are too expensive and time-consuming, it would be convenient to have an effective method of calculating fields inside the window. Such a calculation can be performed using the formalism of multimode scattering matrices [6]. Here we present some results of applying this method to calculation of fields in two versions of overmoded RF windows and compare the calculation with experiment.

GEOMETRY OF WINDOWS

Several designs of windows have been elaborated for energy output of the VLEPP klystron. One of these is schematically shown in Fig. 1.

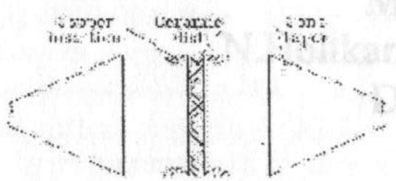

Fig. 1

The window consists of a cylinder part, into which a ceramic disk is brazed, and two cone tapers between the round and rectangular waveguides. In the first version of this design, the copper insertions (guarding rings) were absent. Insertion of the rings gave possibility to increase the canalized power from 10 to 40 MW [4]. The characteristic sizes of the design are: rectangular waveguide 17×8 mm, cylinder diameter 66 mm, cylinder length 40 mm, cone angle $2\alpha = 20°$. The ceramic disk was made of ceramics BK-94-1 and had the thickness about $\lambda_g/2$ for the operation mode H_{11}.

FIELD CALCULATIONS

Amplitudes of the fields in the window and reflection coefficient were calculated with the program COAX, kindly presented by Peter Latham [7] and upgraded by the authors. The added features are: the possibility of calculations in the presence of dielectrics, the value of ε can be introduced in the complex form, so losses in ceramics were taken into account; besides, the imaginary part of frequency was incorporated to account for the losses in the metal walls. Without the correction for losses, the calculated and measured reflection coefficients differed substantially. The horn window was presented as a series of coaxial cylinders; the number of the cylinders and of the modes considered was chosen according to convergence of the result.

FIELDS ON THE WINDOW AXIS

In Fig. 2, the graph of the E_r field on the window axis with the guarding ring for the frequency of 14 GHz, and the calculation geometry are presented. 28 modes in ceramics and from 10 to 4 modes in the other parts of the window were taken into account

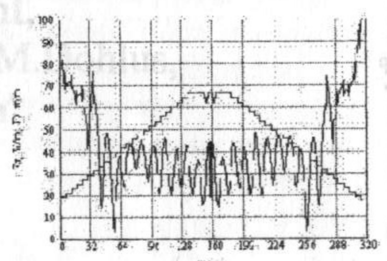

Fig. 2

REFLECTION COEFFICIENT IN A BROAD FREQUENCY RANGE

Measurements and calculations were done in the frequency band from 13 up to 15 GHz. Dependence of Γ^2 on the frequency for the window with the guarding rings is shown in Fig. 3. The dots correspond to the measured data. The picture shows that the results are close enough in the range much broader than the operational frequency bandwidth. The calculated data are sensitive to changes of ε and geometrical sizes. Transitions from the rectangular waveguide to the cone are not taken into consideration but this does not make any appreciable difference with the measured data.

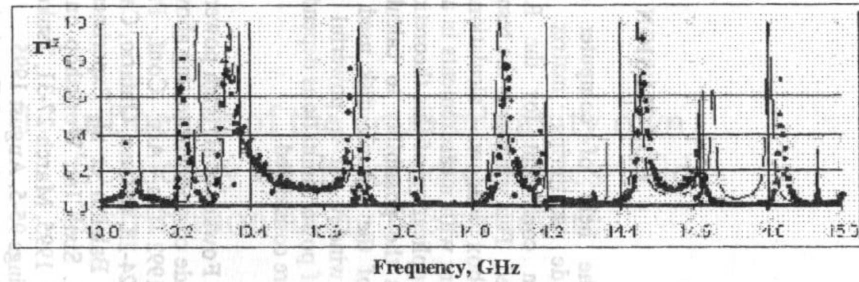

Fig. 3

RESULTS OF CALCULATING FIELDS ON CERAMICS

The calculation was done for two window geometries: with the guarding rings (case a) and without them (case b). The input wave power was equal to 1 mW throughout. 5 TE- and 5 TM-modes were taken into account.

The following graphs are isolines for tangential electric field strength (V/m) on the ceramics surface, Fig 4 (case a) and Fig. 5 (case b).

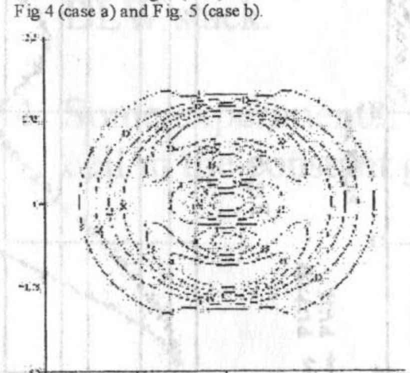

Fig. 4

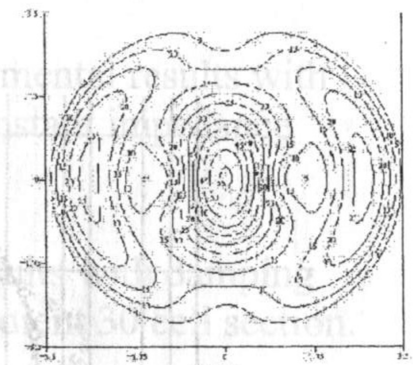

Fig. 5

Because of dipole symmetry of the field, it is reasonable to show dependence of the field (E_t) on radius for angles of 0 and π/2, these dependencies are presented in Fig. 6 (case a) and Fig. 7 (case b).

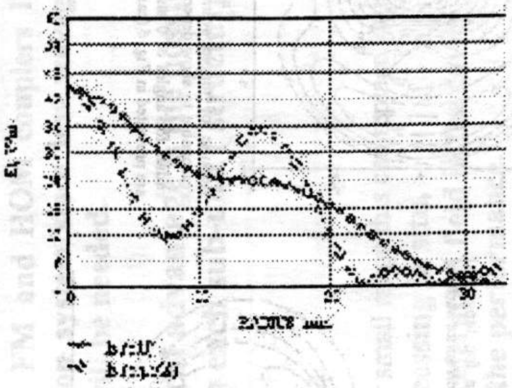

Fig. 6

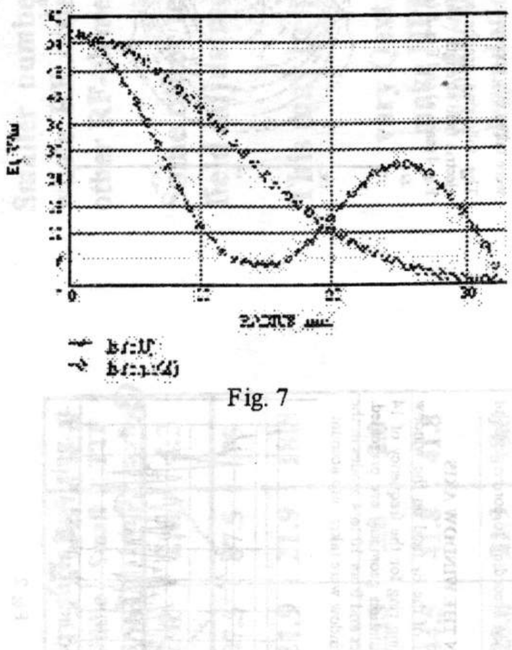

Fig. 7

CONCLUSION

With the help of computer code using the multimode scattering matrix formalism, the reflection coefficient for the RF window was calculated. This window is the result of evolution of the pill-box window. Calculations are in a good agreement with measurements in a broad frequency band. Application of this theoretical approach also provides the possibility to calculate fields in the region of the ceramic disk used in the oversized output window of a powerful generator. Some causes of power limitations depending on a window design are considered.

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