Design and Simulation of Cavity and RF Section for High Power (CW) Klystron

Payal Dewan Thakur, Deepender Kant, Neeta Khulbe, Rakesh Meena, A.K. Bandyopadhyay, L.M. Joshi*
Central Electronics Engineering Research Institute (under CSIR), Pilani, India
*Lovely Professional University, Jalandhar, India

E-mail: Payalt84@gmail.com, joslm@rediffmail.com

ABSTRACT

The re-entrant cavity for 350MHz, 100kW (CW) power klystron has been designed. Analytical methods and different CAD tools such as CST Microwave Studio & SUPERFISH have been used for designing the cavity. Then AJDISK code has been used for the design of RF section. In this paper the authors will be presenting the optimized design parameters and simulation results.

INTRODUCTION TO HIGH POWER (CW) KLYSTRON

A klystron is a device used for amplifying microwave signals, based on the principle of velocity modulation. The high power klystrons are used in high energy accelerators, experimental nuclear fusion research, radars, and microwave heating equipments. The major components of the device are the electron gun, RF section and the collector. The RF section consists of a series of re-entrant cavities connected together with hollow metallic pipe called drift tube. In this region electron beam interacts with the input RF signal to be amplified. Thus RF section design plays a vital role in deciding the tube performance parameters like gain, bandwidth and the overall efficiency [1][2]. In the RF section for the present klystron, there are five cavities, which consist of one input cavity, one output cavity and three intermediate cavities.

CAVITY DESIGN

The cavities used in the klystron are of cylindrical re-entrant type such as shown in figure 1. The main design parameters of the cavity are; cavity height 'h', drift tube radius 'b', gap 'g' between two drift tubes inside the cavity and cavity radius ‘a’.

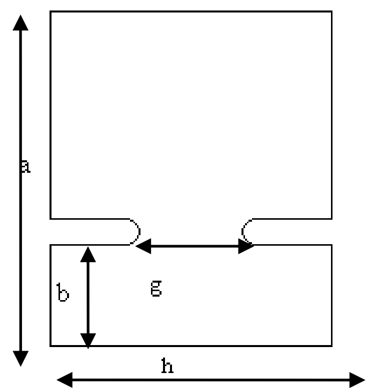

Fig.1: Schematic of a klystron cavity

The klystron specifications under design are given in Table1 as follows.

Table1

PARAMETERS	VALUE
Operating Frequency	350 MHz
Output RF power	100 kW(CW)
Beam Voltage	30 kV
Beam Current	7 A
Efficiency	≈50 %
Power Gain	≈45 db

Initial design of the cavity has been done by analytical formula for 350MHz frequency then simulation has been carried out using SUPERFISH, for design optimization and later the simulation has been done by CST Microwave Studio (MWS), both the results are compared.

Analytical prediction

The theoretical resonant frequency f_0 for a simple cylindrical cavity [2]

$$f = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{X_{mn}}{a}\right)^2 + \left(\frac{p\pi}{d}\right)^2};p_{nm}=2.405$$

For TM_{010} mode the frequency is given by;

f = (c x 2.405)/ 2*π*a

We have calculated cavity radius 'a' for 350 MHz frequency, and it has been taken as an input for the cavity design in SUPERFISH. The simulated result is shown in fig.2, the simulated frequency for a=32.78cm is 350.03 MHz

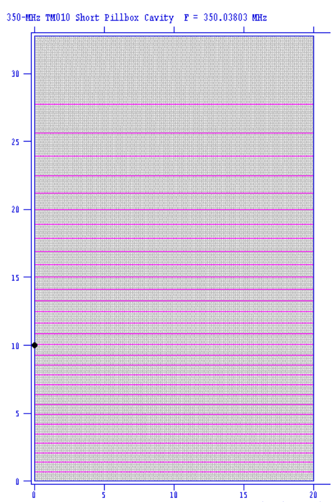

Fig. 2: Simulation for simple pill-box cavity

Now the cavity is made re-entrant and the design optimization is done in SUPERFISH to attain the desired resonant frequency. The result is shown in fig. 3 as follows. The optimized design parameters for 350 MHz frequency are as follows.

Cavity height 'h' = 20cm
Drift tube radius 'b' = 3.2cm
Gap 'g' = 3.0cm
Cavity radius 'a' =19.67cm

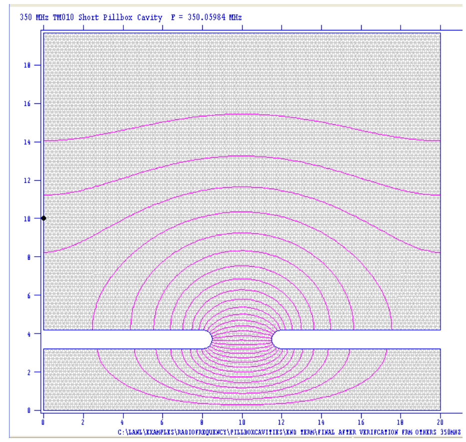

Fig.3: Simulation for Re-entrant cavity

Then we have calculated the R/Q for the cavity using the expression

$$\frac{R}{Q} = \frac{V^2}{2\omega U}$$

Where U is the electrical energy stored in the gap, V is the RF voltage across the gap. The value for U can be taken from the (.SFO) file and V from the (.TBL) file generated by SUPERFISH simulation. The later file gives the electric field distribution in the cavity as shown in fig.4

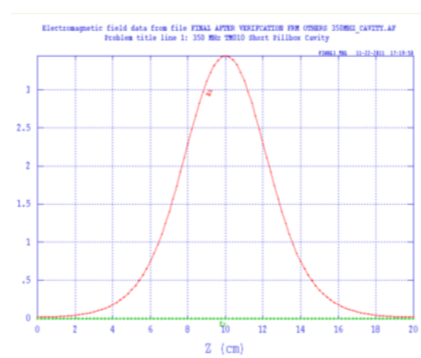

Fig. 4: Electric field distribution in the cavity

The R/Q for the cavity has been obtained as 136.7Ω. The optimized dimensions from

SUPERFISH are taken as input for CST MWS to verify the frequency and R/Q. The cavity has been re-simulated in 3D using CST-MWS as shown in fig 5.

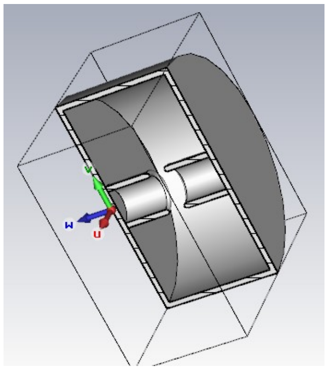

Fig.5: Simulation of cavity in CST-MWS

The corresponding frequency is found to be 348.98 MHz which is close to the SUPERFISH results. The magnetic field pattern in the cavity is shown in fig 6. The R/Q value has also been calculated using CST-MWS. The comparison of the results from CST MWS and SUPERFISH are given in table 2.

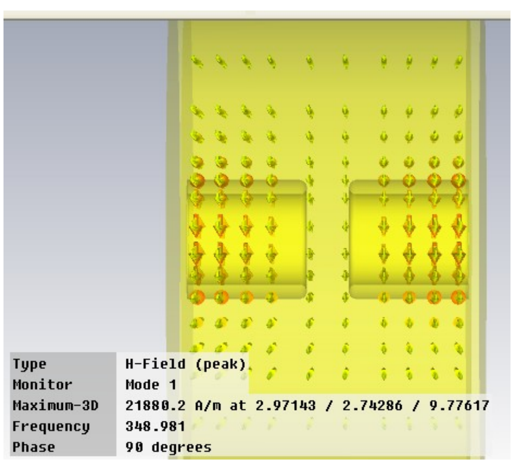

Fig.6: H-field lines along the cross section

Table 2

Parameters	SUPERFISH	CST
Frequency(MHz)	350.05	348.9
R/Q (Ω)	136.7	136.2

DESIGN OF RF SECTION

The initial design of RF section has been done using AJDISK code[4]. The optimal spacing between the cavities for the maximum output power has been determined using this code. The result of AJDISK confirms that efficiency of more than 50% and gain 45db can be achieved. The AJDISK output plots are given in fig 7.

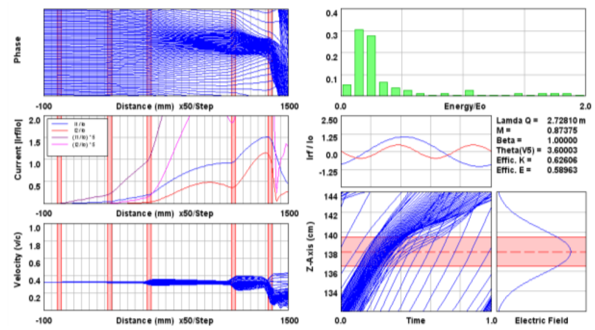

Fig.7: Simulation through AJDISK

CONCLUSION

The design of cavity for a 350MHz, 100 kW CW klystron has been done using different CAD tools and the results are in mutual agreement. The initial design of RF section has been also completed using AJDISK code.

REFERENCES

[1] M.J.Smith, and G. Phillips, *POWER KLYSTRON TODAY*, Research Studies Press (1995)

[2] A.S.Gilmour, Jr. "*MICROWAVE TUBES*", Artech House, 1986.

[3] "The Effect of Space Charge on Bunching in a Two-Cavity Klystron", G. MIHRAN

[4] SLAC klystron lectures series

www.slac.stanford.edu