Electromagnetic Design and Analysis of a High Power Tunable Pulsed Magnetron using MAGIC-3D

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Abstract: *This paper presents 3-D electromagnetic simulation of resonant system of a 2.6 MW, 2.998 GHz tunable pulse magnetron using MAGIC3-D Code. This resonant system is a twelve resonator hole and slot type structure with echelon type strapping. Other parts include coupling loops, output seal and tuning mechanism. Coupling is through radial mounted double loop with a dome type glass window. The capacitive tuner, connected to one of the side resonator, consists of metal bellow and a metal piston that can be moved in radial direction. π-mode frequency has been computed simulating position of the tuner to give minimum and maximum frequency values. Corresponding π-mode frequencies found are 2.953GHz and 2.970 GHz giving predicted tuning range of 17MHz. The dispersion characteristic has also been obtained. The cold test model of the magnetron has been fabricated and experimentally characterized. Performance chart has been plotted using in-house computer program. Simulation results have been compared with experimental values and have been found in good agreement except 'Q' values.*

Key words: Electromagnetic simulation, Pulsed Magnetron, MAGIC-3D, Dispersion relation.

I. INTRODUCTION

Although magnetrons are widely used as microwave source of high power microwave radiation, a fundamental understanding of the nonlinear interaction mechanism was little known until powerful Particle-in-Cell simulation tools became available recently [1]. Earlier designers relied on analytical field theory and scaling laws for determining the operating as well as dimensional parameters [2, 3]. Many attempts have been made to simulate the magnetron performance electromagnetically and using 3D PIC simulators [1, 3]. In 2D simulation it was not possible to completely simulate the behavior of the magnetron performance. The 3-D simulation results are found to be in good agreement with experimental results.

In this paper, we present the electromagnetic simulation and design of a tunable pulse magnetron at 2.998GHz with a pulse power at least 2.6MW using MAGIC-3D. The analysis has been carried out to optimize the resonant dimensions of the magnetron for desired performance parameters which are pi-mode frequency and 'Q' values. Computed values have been compared with the experimental results. Dispersion curve have also been obtained for strapped and un-strapped cases. In section II of the paper electromagnetic simulation model is discussed in detail. Section III presents the results from simulation and experiment and also the discussions.

II. SIMULATION MODEL

MAGIC-3D is a user-configurable code that self-consistently solves the full set of time dependent Maxwell's equation and the complete Lorentz force equation to provide the interaction between space charges and electromagnetic fields [2]. A variety of 3D algorithms are available for problem-specific solution. For the better accuracy and reduced simulation time we use the localized meshing technique. The resonant system of the simulation model consists of twelve numbers of hole and slot type resonators. Other parts included in the simulation model are tuner assembly and output loop. The output loops are terminated with matched ports at the outermost shell of the block. The coordinate system used in the simulation is polar coordinate system (r, θ, z). The simulation model has total 47, 67,152 numbers of cells, and almost 52 percents cell are active. The three dimensional view of the simulation model used for cold characterization is shown in Fig.1. To find the approximate resonant frequency of the structure we have first excited the resonant structure by a driver with an impulse signal. The magnitude of FFT of the response signal at slot gaps gives the possible resonant frequency of the structure. The simulated oscillation spectrum of 2.6 MW pulse tunable magnetron is shown in Figure 2.

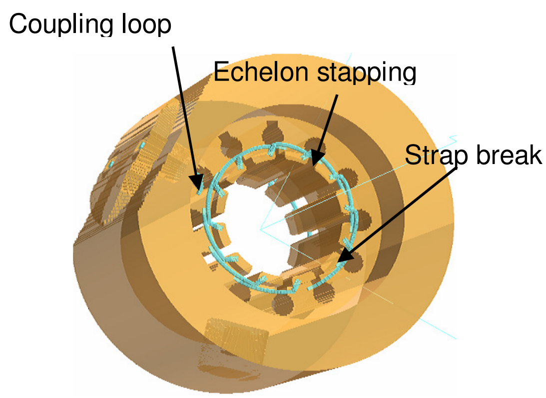


FIG.1. Three dimensional view of simulation model

III. RESULTS AND DISCUSSION

The initial dimensions of this resonant system were obtained using analytical expressions [2] and from a practical 2.0 MW Magnetron developed earlier at CEERI, Pilani [4]. Performance chart has also been computed using a computer program developed at CEERI [5].

Computed performance chart is shown in Figure 3. The analysis has been carried out to arrive at a design of the rf system of this magnetron for operation at 2.998 GHz with a pulse power of at least 2.6 MW. The performance parameters for this analysis are pi-mode frequency, unloaded & loaded "Q" and separation between pi-mode and adjacent mode frequency.

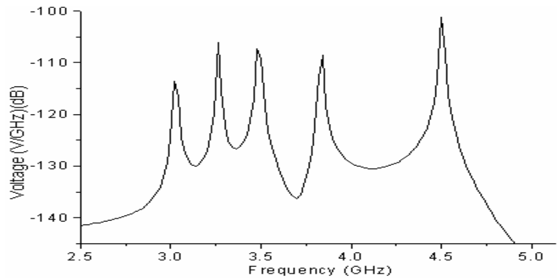


FIG.2. Oscillation spectrum of 2.6 MW Magnetron

3-D tetra-hedran mesh elements have been used. Optimization of the dimensions of the resonator etc. has been achieved by adopting an iterative procedure. Figure 4 (a) shows the photograph of the cold test model of the magnetron developed at CEERI and table.1 compares the simulated and the experimental results.

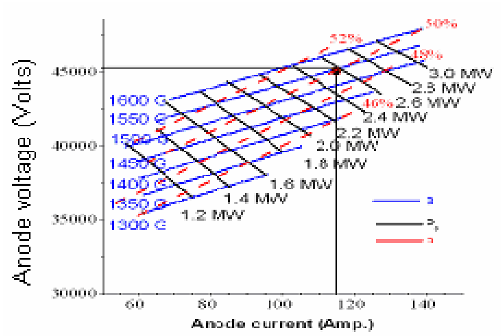
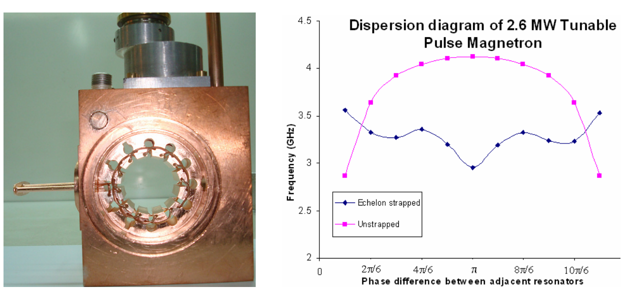


FIG.3. Computed performance chart



(a) (b)

FIG.4. (a) 2.6MW Magnetron cold test model (b) Computed dispersion diagram

It is seen that the simulated results agree reasonably well with the measured valued except for the "Q" values. Reasons for this seem to be poor surface finish of the cavity walls of the practical cold test model. One of the important properties of the reentrant coupled cavity resonant system of the magnetron is its dispersion characteristics.

Table.1: Comparison of simulated results with experimental value

Parameters	Simulated value Tuner settings		Measured value Tuner settings	
	Lowest end	Highest end	Lowest end	Highest end
π-mode frequency (GHz)	2.953	2.970	2998	3019
Loaded "Q"	121	128	111	86
Unloaded "Q"	2800	2791	1203	
Separation of pi-mode with adjacent mode (MHz)		197	105	116

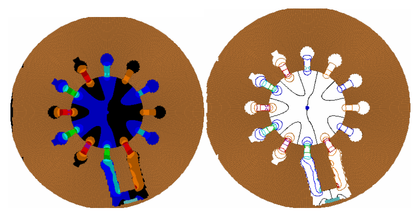


FIG.5. Electric field contour plots for π-mode

It has also been computed in this analysis and shown in figure 4(b). The six main nodes of oscillations of the 12 resonators rf system is clearly seen with pi-mode frequency being the lowest and equal to 2.95032 GHz. A sensitivity analysis is also being carried out using Magic 3-D in order to decide manufacturing tolerances.

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