

Design and Development of Electromagnet for 3 MW S-Band Tunable Pulse Magnetron

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Abstract- This paper presents design and development studies of an electromagnet for testing of a high-power 3.0MW S-Band 2.856 GHz tunable pulsed magnetron using CST microwave studio. Based on the design and optimized parameters a prototype of electromagnet with hinge type plates have been developed and tested. The electromagnet has been tested with constant current source up to 28 A of current and the required magnetic field of 1600 Gauss with the required field profile between the pole pieces has been achieved at the operating current of 25-26 A. For cooling of the electromagnet external water cooling arrangement has been made and the water flow rates has been kept at 5L/m. The in-house developed 3 MW magnetron has been tested with the developed electromagnet and the results are acceptable.

I. INTRODUCTION

LINAC based X-Ray machines are extensively used for industrial, medical and Security applications. These LINAC based X-ray machines use high power microwave sources such as Klystrons and Magnetrons. Magnetrons being inherently efficient, compact and small size provides economical solution. Magnetron is a cross field device basically a diode, with a magnetic field parallel to its axis. It provided the impetus for the development of microwave radar during World War II [1]. The first, two-pole magnetron was developed in 1921 by Albert Hull at General Electric's Research Laboratories, New York, as an outgrowth of his work on the magnetic control of vacuum tubes, but it was only an interesting device until 1940. In 1929, K. Okabe working with H. Yagi at the Tohoku College of engineering also used a magnetron in which the anode was divided in two segments and its lowest operating wavelength was 12 cm. [2-3]. Prior to World War II, frequencies up to several hundred MHz could be generated by conventional triode, tetrodes etc, but significant amount of power was not possible above few hundred MHz [4]. During World War II, there was an urgent need for generation of high power microwave for radar transmitters which geared up the development of magnetron to its present status [5].

CSIR-CEERI has successfully developed and delivered a series of high power pulse magnetrons in S-band with a pulse output power from 500 kW to 3 MW. The magnetic focusing system is one of the main component of these magnetrons. The function of the DC magnetic system is to provide magnetic field parallel to the axis of cathode. The magnetic field causes electrons attracted to the positive outer part of the resonant structure, to spiral outward in circular path rather

than moving directly to the anode. Like cathode, the magnetic field in magnetron also plays a different role as compared to the linear beam tubes. It plays a direct role in beam-wave interaction process unlike linear beam devices where DC magnetic field is used only to focus the electrons. All these magnetrons uses either a permanent magnet or a solenoid type electromagnet. By using a electromagnet user has a better control over the operating region as the user can operate in a broad operating region of operation by changing the magnetic field. This paper describes the method to design and development of an electromagnet for the testing of a high power S-band pulse magnetron. The required magnetic field for this magnetron is about 1600±50 Gauss and it has a axial mounted cathode support. The paper has been divided into four sections including the introduction in section I. Section II describes the electromagnet design and modeling parameters using CST Microwave studio. The simulation and experimental results have been discussed in section III followed by the conclusion in section IV.

II. DESIGN AND MODELING

A solenoid is a coil of wire designed to create a strong magnetic field inside the coil. By wrapping the same wire many times around a cylinder, the magnetic field due to the wires can become quite strong. The number of turns N refers to the number of loops the solenoid has. More loops will bring about a stronger magnetic field. Ampere's law can be applied to find the magnetic field inside of a long solenoid as a function of the number of turns per length N/L and the current I . According to amperes law for solenoid coil the maximum magnetic field of single coil at the centre of the coil is given by the equation (1).

$$B = \frac{\mu_0 NI}{L} \quad (1)$$

and the current density for N turns

$$J = \frac{NI}{A} \quad (2)$$

where B is magnetic field (in gauss), N is number of turns in coil (in integer), I is current flowing in the coil (in Amperes), L is length of the coil wire (in mm) and μ is permeability of vacuum (amperes per meter) respectively.

Depending on the requirement of the magnetic field (~1600 Gauss), the cross section of the rectangular wire has been

