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RF Oscillator: Design Aspects

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Abstract -- High power RF is an essential part of the future fusion reactors and the high power RF technology is still under development. This paper consist of designing the RF oscillator for low power application and high power application which can be done in the steps of understanding of HF amplifiers/oscillators, understanding distributed design aspects of RF oscillator and also in the form of output cavity towards coupling to make a complete system using suitable software among the HFSS, CST and ADS which gives the better utilization/ optimization of develop circuit as well as analytical formulae.
Index Terms—*Tube, RF oscillator, RF power, Tetrode,*

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I. INTRODUCTION

The Radio Frequency, RF application is increasing with the ongoing developments in the areas of broadcasting, defence, and industrial. Radio frequency (RF) is an electromagnetic wave in the range of around 3 KHz to 300 MHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals. High power RF is an essential part of the future fusion reactors and the high power RF technology is still under development. RF power is required to heat plasma to ignition temperature of fusion reaction which is around 4Kev and RF power required is 30MW in the frequency range of 10-100MHz. For heating application we are going to design of RF oscillator. From literature survey we understood the application of heating for high power. It is necessary to understand how RF oscillator is work in RF frequency. That's why first we learn the low power about 7W to 10W.

Well for understanding of RF concept, firstly we consider RF oscillator circuit by using of tube for low power application. That is design in TINA software and simulates it in TINA software. And also calculate its parameter. Secondly we will design 200W RF oscillator and also implement it by using BEL 300 Triode tube. This implementation is done through mechanical work and electrical work. And calculate power supply's parameter like decide the value of power supplies Components. Then go to the testing of the power supply and last testing of whole system.

Then go to the simulation of high power application in CST which can be used in heating application. This paper provide basic conceptual block diagram of RF oscillator. And system can develop by using of tube. Because of transistor device cannot tolerate high power and temperature.

II. BLOCK DIAGRAM OF RF OSCILLATOR

The basic block diagram of this RF system is shown in figure 1. This system's design is developed for high power application which is required at plasma whose main aim that is to develop electricity for commercial area. Here we select Tetrode tube because it is tolerate high power and solve the problem of parasitic oscillation which is generate in triode tube. Tetrode tube has four electrodes. There are plate, screen grid, control grid, cathode, and filament. This block diagram is describing whole system required four power supply. There are plate power supply, screen greed power supply, control greed power supply and filament power supply. Filament power supply is continuously applied to filament of tube. Output of the system is transmitted to the dummy load through transmission line. The compact cwrf free running oscillator will be integrated with DC power supplies, control systems, user friendly control panel etc. this conceptual block diagram of RF oscillator is for high power application where cooling system, controlling and monitoring required.

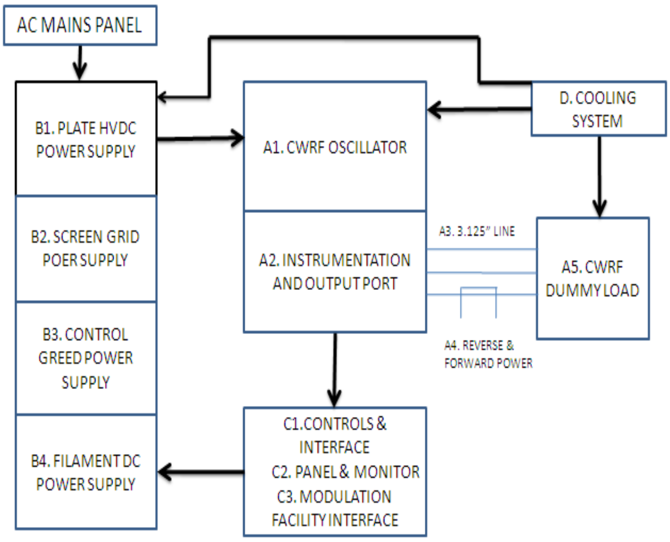

Figure 1 Conceptual block diagram of RF oscillator

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III. WHY TUBE IS STILL USED?

Normally working of oscillators is using solid state devices. But this paper introduced oscillator circuit is operated using vacuum tube. Here tube is introduced because of solid state devices not tolerate high voltage. at high power radio station still use the tubes, especially for power levels above 10,000 watt and frequency above 50MHz. sometimes it is possible to design the oscillator using solid state devices, in which transistors are connected in parallel by wiring and then mixing their output power together in a cascading form. But this whole system requires large heat sink to keep cool. So system is so difficult and also connections of wires are bulky. So in place of transistor, tube can be use and it can be cooled with forced air and water. Therefore it is proposed to design of RF oscillator using Tetrode tube for heating application.

Simplest form of the tube is diode which is consist cathode and plate electrode. Electron emitted by cathode and filament travel through vacuum in tube and collected by the plate. To improve the performance of tube and controlling the flow of current is by addition of grid between cathode and plate. Types of tube are diode, triode, Tetrode, pentode etc. Here symbol of triode and Tetrode shown in figure 2.

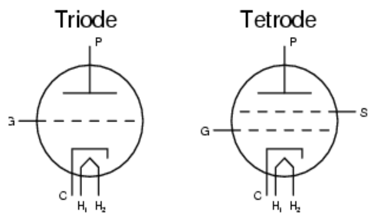

Figure 2 symbol of triode and Tetrode tube

The big disadvantage of triode is the large capacitance between grid and plate. This effect is known as miller effect. That is solved by adding other grid between control grid and plate, known as screen grid. That's way we can select Tetrode tube for high power application and triode for low power application.

IV. RF OSCILLATOR

Oscillation occurs when an amplifier is furnished with a feedback path that satisfies two conditions:

- Amplitude Condition -- The cascaded gain and loss through the amplifier / feedback network must be greater than unity.
- Phase Condition -- The frequency of oscillation will be at the point where loop phase shift totals 360 (or zero) degrees.

Oscillators are circuits that generate a continuous voltage output waveform at a required frequency with the values of the inductors, capacitors or resistors forming a frequency selective LC resonant tank circuit and feedback network. The frequency of the oscillatory voltage depends upon the value of the inductance and capacitance in the LC tank Circuit. The frequency at which this will happen is given as:

$$X_L = 2\pi fL \text{ and } X_C = 1/2\pi fC$$

$$\text{At resonance: } X_L = X_C$$

$$\therefore 2\pi fL = 1/2\pi fC$$

Therefore resonance frequency of an LC oscillator is

$$f = 1/2\pi\sqrt{LC}$$

Where:

L is the Inductance in Henries
C is the Capacitance in Farads
f is the Output Frequency in Hertz

This equation shows that if either L or C is decreased, the frequency increases.

Now we considered Colpitts oscillator with the use of triode tube and simulate it in TINA software for understand of the RF oscillator. The circuit diagram of the RF oscillator is shown in figure.

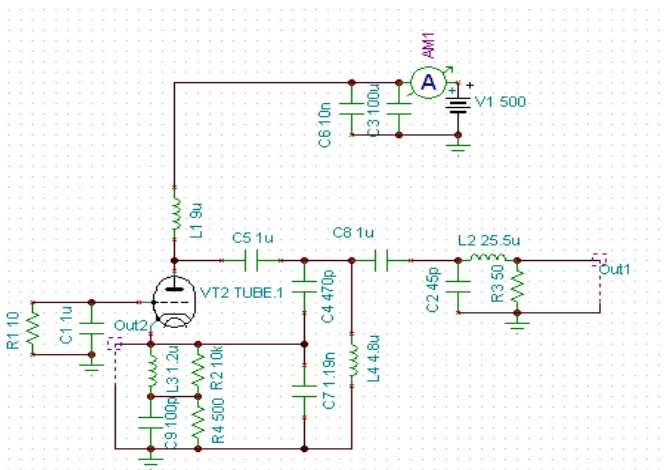

Figure 3 RF oscillator circuit

whole system is operate using triode tube because of output power is upto 10W so there is not required tetrode tube.triode tube has three electrode. there are plate, control grid, cathode and filament. Here we check the LC oscillator because of it is operate at high frequency. In this circuit, DC power supply is applied to plate of the tube. through the inductor which is block the flow of RF from tube to DC supply. At grid side resistor and capacitor act as source. which is positive with respect to the cathode. LC tank circuit is genertae RF frequency like 5MHz. capacitor C5 is DC blocking capacitor and C8 is coupling capacior. When supply is applied then DC is convert into RF at the plate electrode and amplified signal is fed back to device through cathode. And output is genrate that is transmit to dummy load through LC matching network.

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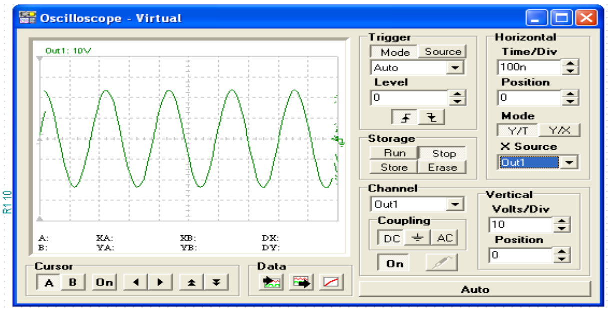

Figure 4 simulate waveform of RF oscillator

The output waveform of this RF oscillator is shown in figure and calculated parameter shown in table. And also provide equation for parameter.

Calculation parameter equation

DC plate power= DC plate voltage* DC plate current

Frequency= $1/2\pi\sqrt{LC_t}$, $C_T= C_1C_2/ C_{1+} C_2$

RF output power= $V^2/8R$

Efficiency= RF output power/ DC input power*100

Calculated parameter

Sr. no.	parameter	value
1	DC plate voltage	500V
2	DC plate current	31mA
3	DC plate power	15.5W
4	Frequency	5MHz
5	RF output power	7.56W
6	efficiency	50.45%

Figure 5 calculated parameter of RF oscillator

V. SELECTION OF TRANSMISSION LINE

For high power application, we introduced transmission line for transmission of power from output to the dummy load that is described in block diagram of RF oscillator. This paper provide selection of transmission line size by the equation,

$$Z_0 = \frac{138}{\sqrt{\varepsilon_r}} \log \frac{b}{a}$$

Where:-
b- Outer diameter
a- inner diameter
ε_r-dielectric material for air = 1

Reflection co-efficient -- The reflection coefficient measures the amplitude of the reflected wave versus the amplitude of the incident wave. The expression for calculating the reflection coefficient is as follows

$$\Gamma=\frac{Z_L-Z_0}{Z^L+Z_0}=\frac{VSWR-1}{VSWR+1}$$

VSWR – VSWR evaluates the ratio of the peak amplitude of the voltage of the wave on the transmission line versus the minimum amplitude of the voltage of the wave. A VSWR of 1 is ideal; this indicates that there is no reflected power at the port. When the transmission line are not perfectly matched, reflections travel back towards the source and cause a standing wave to form.

$$VSWR=\frac{V^{MAX}}{V^{MIN}}$$

Return loss -- This is measure of the power loss due to reflection of the signal due to impedance mismatch of the transmission line, given by

$$RL = -20 \log_{10} |\Gamma|$$

VI. SIMULATION DETAILS

Here low power application is simulate in TINA software for basic understanding. But for high power application is not simulated in TINA software because it is not consists characteristic of tube. Since we can simulate it in CST software. electromagnetic field simulation allowing the engineer to fully characterize and optimize an RF design without changing tools.

VII. CONCLUSION AND FUTURE WORK PLAN

This paper represents how RF oscillator works in low power applications. We have designed the circuit of RF oscillator and simulated in TINA software, then its parameters are calculated. And also described why tube can be selected for this RF application. Further design aspects will be designed and its parameters will be calculated in CST software for high power applications.

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