Analysis of Tetrode Amplifier

[1]Mitika Acharya H., 2J.V.S. HariKrishna, 3A.C.Suthar
[1]PG Student, [2]Engineer-SD, ITER-INDIA, G.I.D.C., Gandhinagar, India [3]Director, L.J Institute of Engineering &Technology, Ahmedabad, India
[1]Masters in Electronics And Communication [1] L.J Institute of Technology, Ahmedabad, India.

***Abstract*— Vacuum tubes were the earliest of electronics devices and for decades they were the sole basis of the ever-evolving electronics industry. For high power transmission remains only area where vacuum tubes are still used. If we want more power in terms of kW or MW using solid state amplifiers, then much more of the transistors should be connected in parallel which makes circuit more complex. This task can be completed using single vacuum tube. So, here we are going to design vacuum tube amplifier that is tetrode based. This paper is dedicated for design and analysis of narrowband amplifier. It has maximum output power of 10kW which will be used for testing of high power transmission line components. The design of amplifier includes design of input and output matching circuit for amplifier which has to cover the frequency range of 35-65 MHz both input and output matching circuits are coaxial in nature and both are tunable to achieve desired impedance matching at a required frequency.**

Keywords— Tetrode, coaxial, vacuum tube

I. INTRODUCTION

A Variety of power amplifier exists in VHF range. Two main categories are based on solid state devices and vacuum tubes. The former can yield only quite low power and large numbers of transistors must be operated in parallel to reach even a few kilowatts of power levels. The high power stages of radio amplifiers mainly use vacuum tubes. Tetrode is one type of vacuum tube which has four electrodes named cathode, control grid, screen grid and plate (anode).It can be used as an amplifier for higher range of frequencies such as VHF range of frequency. For the generation of 10kW of power, we select EIMAC tetrode 4CW25000B. For designing, we have to find the performance parameters. Here are some technical specifications of the tetrode is given:

Table 1 Technical Specification of tetrode

Filament – Type	Thoriated tungsten
-voltage	6.3V
-current	160A
DC plate voltage(max.)	10kV
DC screen voltage(max.)	2kV
DC grid voltage(max.)	-1.5kV
DC plate current(max.)	6A
Plate dissipation	15kW
Interelectrode capacitances (cathode grounded)	
Cin	160pf
Cout	24.5pf
Cpk	1.5pf

To find the performance parameter of the tube, we use EIMAC tube performance computer which provide 'operating line'. In an amplifier, a varying voltage is applied to control grid of the tube. Simultaneously, the anode voltage will vary in similar manner. Anode voltage is 180 out of phase with grid voltage. As we are going to design class AB1 amplifier (Common cathode) grid current becomes zero. Now, we will show how such variation of anode and grid voltage of a tube appears on constant current curves for the tube.
Point 1 : Intersection of grid bias (-350V)and dc anode voltage(6.5kV)
Point 2: Intersection of max instantaneous anode current and min instantaneous anode voltage
By connecting both the lines we have an operating line.

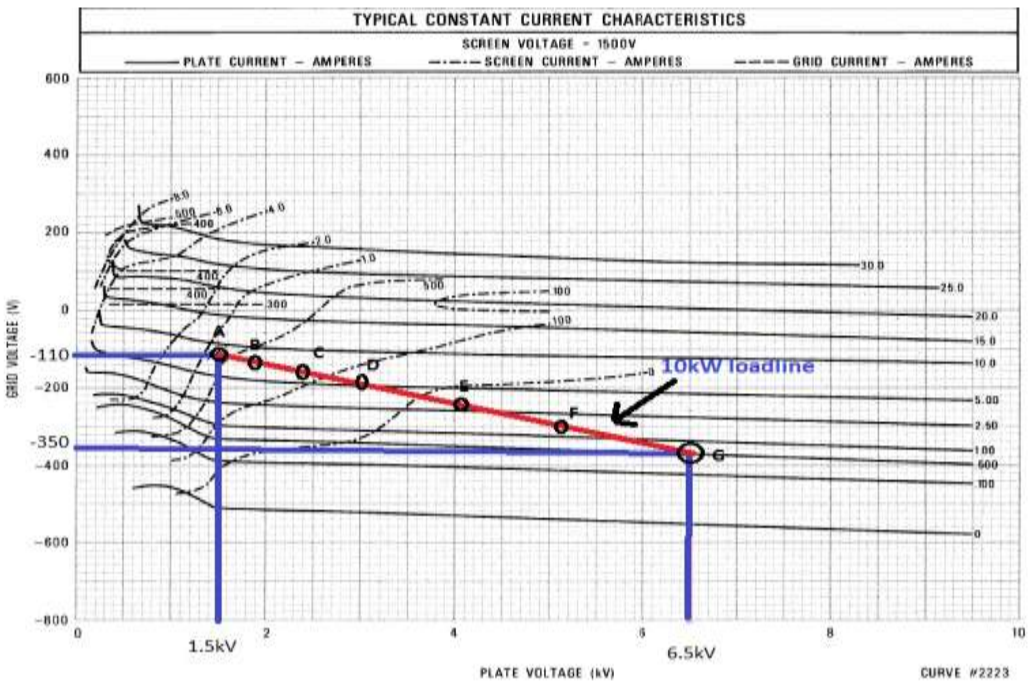

Fig 1. Constant Current Characteristics

Overlay the computer over constant current curve; we have the different values of currents flowing at 15˚ of the electric cycle. Now, Read off the instantaneous anode current values where these lines crossing the operating line; we have instantaneous anode and screen currents. At the point where the line crosses operating line, anode currents are 8.20A, 7.20A, 6.5A, 5A,3A, 1.5A,0.5A respectively for points A,B,C,D,E,F and G. Similarly, Screen currents are 0.6A, 0.3A, 0.2A, 0A, 0A, 0A, 0A respectively for points A, B, C, D, E, F and G.

Table 2- Calculated Parameters from Load line:

Parameters	**Description**	**Values from load line**
DC plate voltage	Input DC voltage	6.5kV
DC plate current	1/12(0.5A + B + C + D + E + F + G)	2.31 A
Peak fundamental plate current	1/12 (A +1.93B +1.73C +1.41D +E +1.5F +0.5)	4.09A
Power output	0.5*Peak fundamental RF current * Peak RF voltage	10.22kW
Resonant load impedance	Peak RF voltage/ Peak fundamental current	1.22kΩ
Efficiency	Output power / DC input power	68%
Plate dissipation	DC input power - RF output power	4.79kW

II. Input Matching Circuit

Input matching circuit is required to match the source impedance with the load so that the reflection of the input signal is minimum and input signal is transmitted with the maximum power. Here, the resistance of the input signal is infinite as the grid current of the common cathode configuration is zero. So, we connect external resistor of value 50Ω to the input capacitance (160pf) of the tube in series. It is matched to the 50Ω. There are many types of techniques for matching such as L-matching network, T- matching network and Pi-matching network. The simplest type of the all is L-match but we are using Pi-match as L-match provide the value of Q that is zero for this match. It is simulated in RFsim99 as shown below. The component values can be derived using following formulas:

$$Q = f / BW$$

$$R_p = (R_d^2 + X_d^2)/ R_d$$

$$X_p = (R_d^2 + X_d^2)/ X_d$$

$$Y_{c1} = 1 / X_{c1} = Q/R_p + 1/X_p$$

$$X_{c2} = R_L \, [(R_p/R_L)/(Q^2 + 1) - R_p/R_L]^{1/2}$$

$$X_L = [QR_P + (R_P\, R_L)/X_{C2}]/Q^2 + 1$$

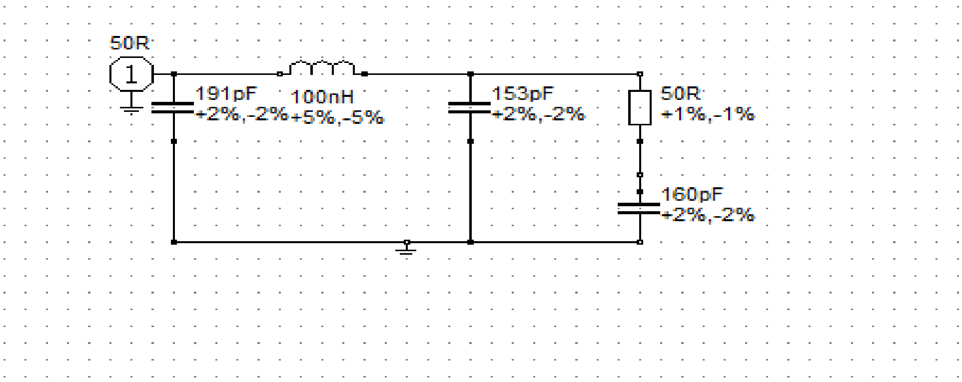

Fig 2. Input matching circuit

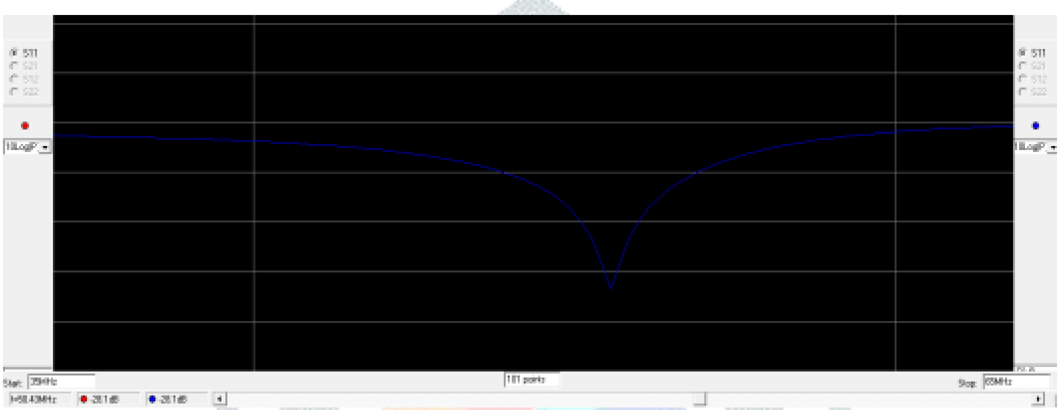

Fig 3. Input matching result

III. Output matching Circuit

As we have designed input matching circuit, similarly we can design output matching circuit. Here, we have to match the plate impedance with the 50Ω. We will also consider the output capacitance of the tube. L- Matching circuit along with the result is shown below. The component values can be found using following equations:

$$Qp=Qs=\sqrt{(Rp/Rs)}-1$$

$$Qs=Xs/Rs$$

$$Qp=Rp/Xp$$

$$L=Xs\ /w$$

$$C=1/wXp$$

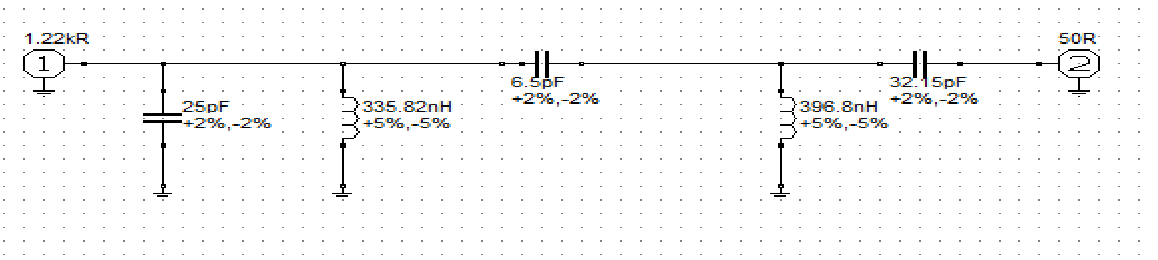

Fig 4. Output matching circuit

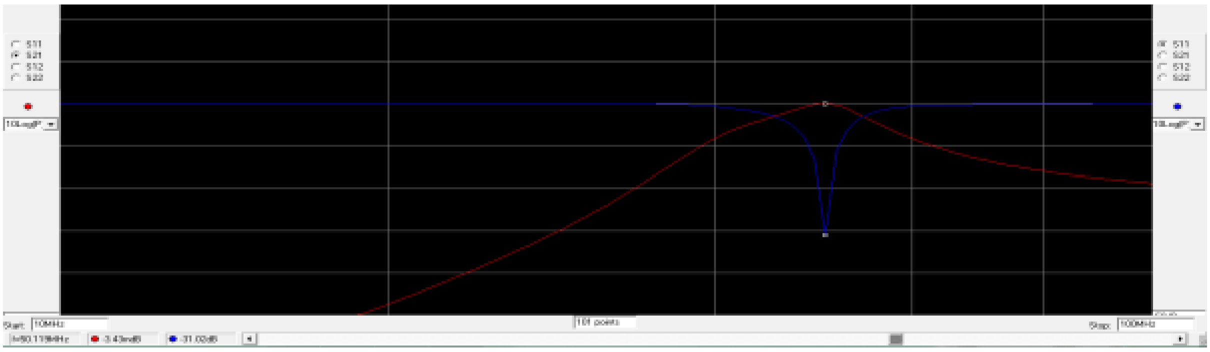

Fig 5. Output matching result

From both the result, we get minimum reflection (indicated by blue line in result) for the input and output about to be -28dB and -31dB respectively.

IV. SUMMARY

We have done the analysis of the tetrode amplifier, its constant current characteristics and load line calculations, input and output circuits with simulation results which requires for the design of tetrode amplifier.

V. ACKNOWLEDGEMENT

I am thankful to Mr. J.V.S. Harikrishna, for sharing his great knowledge with me and guiding me. I also wish to express sincere thanks and deep sense of gratitude to respected Dr. A.C.Suthar for his support. I am thankful to my family for their continuous encouragement to pursue higher studies and my friends for the help and support.

REFERENCES

[1] Trivedi, R. G., Raghuraj Singh, Kumar Rajnish, M. Kushwah, A. Bhardwaj, H. Machchhar, and A. Mukhrjee. "Design analysis of test bed with variable VSWR and variable phase angle for frequency range of 35 to 65 MHz." In Recent Advances in Microwave Theory and Applications, 2008. MICROWAVE 2008.

[2] Elkins, David B., and Robert Heckman. "US Army Beam Power Tetrode Based Broadband Resonant Coaxial Cavity High Power Amplifier System." In Vacuum Electronics Conference, 2006 held jointly with 2006 IEEE International Vacuum Electron Sources., IEEE International, pp. 235-236. IEEE, 2006.

[3] Mukherjee, A., R. G. Trivedi, R. Singh, K. Rajnish, H. Machchhar, P. Ajesh, G. Suthar et al. "Ion Cyclotron Power Source System For ITER." FUSION SCIENCE AND TECHNOLOGY 65, no. 1 (2014): 120-128.

[4] Pande, Manjiri, Sandip Shrotriya, Niranjan Patel, A. Shiju, Sonal Sharma, and P. Singh. "Design and development of 350 MHz, 60 kw RF system in CW and pulse mode for 400 kev deuterium RFQ accelerator." In Microwave and RF Conference, 2013 IEEE MTT-S International, pp. 1-4. IEEE, 2013.

[5] K. Kikkert, RFChapter9,AWRCorp.(2009);http://www.gobookee.net/rf- electronics-kikkert