Methods and steps required for the development of a RF Power Amplifier

[1]Ms. Shwetal N Patel, [2]Mr. Sunilkumar

[1]Student, [2]Scientist-GIPR Gandhinagar
[1]L.D. College of Engineering,
Ahmedabad, India

Abstract: **Amplifiers play a vital role in the development of high performance and low-cost solutions for front end of the RF and microwave systems. Early RF &microwave amplifiers were the exclusive province of vacuum tube devices such as triodes, tetrodes, Klystrons,TWT amplifiers and magnetrons but today amplification is dominated by solid state amplifiers except for application at high output powers i.e. More than 100W for microwave and more than 1KW for RF. The usefulness and methods to design a SSPA are discussed. The functionality of proposed design of solid state power amplifier will be verified for parameters like Bandwidth, Gain, Output power and high efficiency. [1]**

***Index Term*- DC Biasing, Impedance matching, L section network, MOSFET, Solid State Power Amplifier**

1. INTRODUCTION

Amplifier applications include electromagnetic compatibility (EMC) testing, defence components, communications testing and medical diagnostics. RF power amplifiers can be used as driver to another high- power source, RF heating etc. They can also be used for driving a transmitting antenna where the transmitter and receivers are used for voice and data communications as well as for weather sensing. Microwave or RF heating is used in industrialapplications as well as in microwave ovens. Particle accelerators also use RF sources.This project is meant for initially understanding the requirements and then explore the conceptual design of the CWRF amplifier. RF amplifier strengthens a weak signal using a direct current power supply, the device along with its matching and biasing circuitry. The DC power is converted into RF power to enhance the incoming signal strength. Basic constituents are a device, input and output matching networks, bias circuitry and input and output RF connections. The requirement is to develop transistor based CWRF output amplifier operating in common emitter class B mode of operation by using readily available MOSFET that can withstand a load mismatch at all phase angles with minimum VSWR of 30:1.

1.1 STEPS FOR DESIGNING AN AMPLIFIER

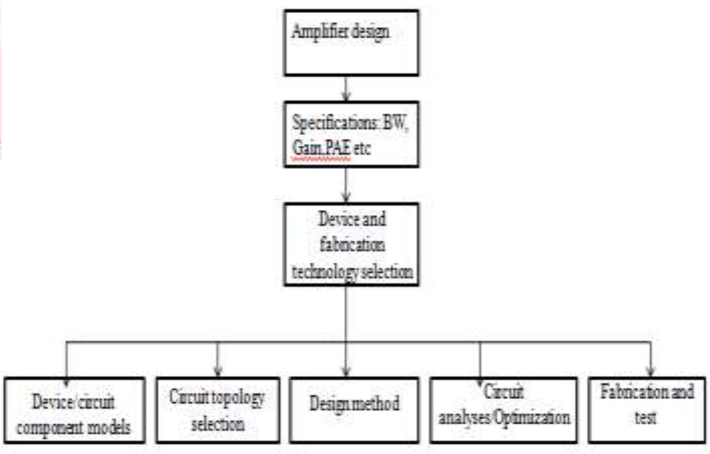

Figure 1.1 Hierarchy for the designing of an amplifier.

The design of an amplifier for a particular application and frequency range is quite complicated in the sense it has to meet physical, electrical, thermal and cost requirements. Hierarchy of an amplifier design has been given in fig. 1.1. The amplifier performance requirements in terms of frequency band, gain, noise figure, power output, Power added efficiency, linearity and input & output VSWR are determined by the device specifications, the circuit design topology, matching networks, the number of gain stages, the aspect ratio for the devices between the stages, design methodology, fabrication technology and packaging.
Design of amplifiers in a broad sense, falls into two categories: low noise and power. In a low-noise amplifier, the transistor's output is conjugately matched to 50Ω system impedance for maximum gain and return loss. In a power amplifier, the 50Ω system

impedance is matched to a required load at the transistor's output for maximum gain and return loss. In linear amplifiers, the input and output are matched for better linearity. Thus, in an amplifier, the device's input is either matched for minimum noise or maximum gain or linearity and output is matched for maximum gain or optimum power and Power added efficiency or linearity.

2. LITERATURE REVIEW

Huge numbers of studies are conducted related to the development of RF Power Amplifier and its biasing methods as well as its stability but; very few studies are conducted related to its application in the field of ion heating for the generation of plasma.

In the year 2002 IEEE transactions on microwave theory and techniques, Power Amplifiers and Transmitters for RF and Microwave describes the generation of RF/microwave power is required not only in wireless communications, but also in applications such as jamming, imaging, RF heating, and miniature dc/dc converters. Each application has its own unique requirements for frequency, bandwidth, load, power, efficiency, linearity, and cost. RF power is generated by a wide variety of techniques, implementations, and active devices. Power amplifiers are incorporated into transmitters in a similarly wide variety of architectures, including linear, Kahn, envelope tracking, out phasing, and Doherty. Linearity can be improved through techniques such as feedback, feedforward, and predistortion. [2]

In 2003, IEEE transactions on microwave theory and techniques, High linearity and high efficiency of class-B Power Amplifiers in GaN HEMT technology, a 36 dBm high-linearity, single-ended common source class B monolithic-microwave integrated circuit power amplifier is reported in GaN high electron-mobility transistor technology. For class-B amplifiers with fractional bandwidth less than 2:1, the push pull configuration is unnecessary with output filtering. This avoids the difficulty of fabricating balun transformers with correct harmonic termination at microwave frequencies. The single-ended common-source class-B amplifier has shown more than 35 dBc of IM3 suppression at 8 GHz with approximately 34% PAE. The class-B mode of operation can have a similar distortion level as that of class A if biased right at the pinch off point, and can yield more than 10% improved PAE over class A. The common-drain class-B power amplifier has low distortion over a wider range of bias due to its integral negative feedback mechanism. This circuit is simulated with 54% of PAE with 45 dBc of IM3 suppression at 5 GHz at the same output power level. [3]

In 2014, IEEE, Implementation of dual gate and drain dynamic voltage biasing to mitigate load modulation effects of supply modulators in envelope tracking power amplifiers has been published. This paper contains a combination of dynamic gate and drain biasing techniques. It consists in implementing an appropriate dynamic gate bias control of the RF power amplifier. At 38 dBm output power, dynamic load variations of the drain supply modulator versus instantaneous input power level variations have been drastically reduced and maintained to a 40$\boldsymbol{\Omega}$ average value. It has proposed a solution to mitigate load modulation effects of DSM that are inherent to ETPA architectures. The proposed technique can be advantageously used to balance the heat dissipation within DSM and RFPA parts of integrated ETPA architecture. [4]

In the year 2015, International journal of engineering research online, Design and simulation of solid state power amplifier at 400Mhz for radar applications. This paper acknowledges about the designing and simulation of solid state power amplifier by using Advanced Design system(ADS). In this DC simulation is done in order to get the proper operating point, stability factor had been found, load pull & source pull simulation have been carried out and the harmonic balance simulation to verify the harmonic levels of the signals other than desired frequency of operation. It attains 30 dB output power with 17%efficiency and 11 dB gain of amplifier with 10 MHz bandwidth. [5]

In 2005, sadhana vol. 30, part 1, Ion cyclotron resonance heating system on Aditya tokomak has been published. In this an ion cyclotron resonance heating system has been designed and commissioned on Tokomak Aditya. The system has been commissioned to operate between 20 and 47MHz at a maximum power of 200kW continuous wave. The same system feeds the final stage of the 1.5 MW ICRH system being prepared for the steady state superconducting Tokamak for a duration of 1000s. RF power of 225 kW has been generated and successfully tested on a dummy load for 100s at 30MHz.The whole system has been described. [6]

3. OBJECTIVES:

1. The objective of this study is to discuss the design, simulation, fabrication of solid state power amplifier of power more than 25W at 38MHz.
2. To study differentclasses and load line concept to demonstrate how Power Amplifier will work in class B.

4. METHODOLOGIES:

The main thing in the designing of an amplifier is to do the impedance matching and thus decide the components required in the input and the output circuit. The term "impedance matching" is rather straight forward. It is simply defined as the process of making one impedance look like another. The maximum power-transfer theorem says that to transfer the maximum amount of power from a source to a load, the load impedance should match the source impedance. There are various methods of impedance matching but we will be using L section network. There are four basic versions of the L section network, with two low-pass versions and two high-pass versions Fig.2. The low-pass versions are probably the most widely used since they attenuate harmonics, noise, and other undesired signals, as is usually necessary in RF designs. The key design criteria are the magnitudes and relative sizes of the driving generator output impedance and load impedance.

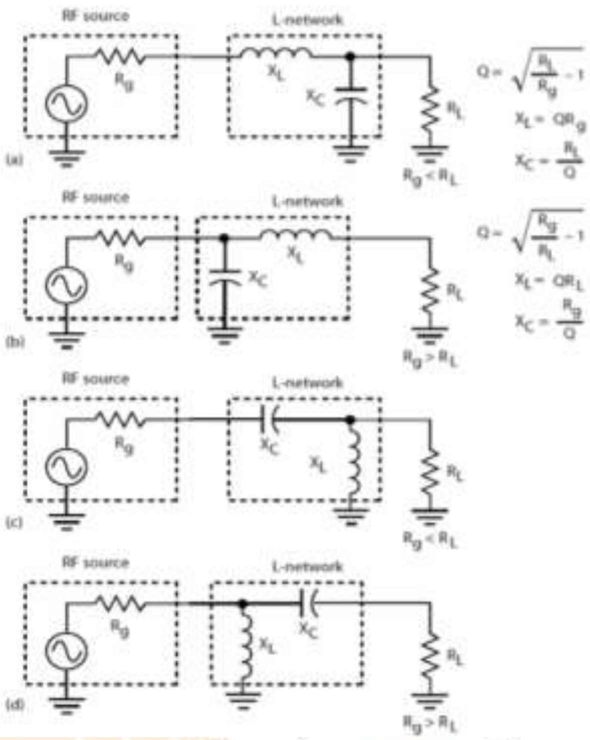

Fig 2 There are four basic L-network configurations. The network to be used depends on the relationship of the generator and load impedance values. Those in (a) and (b) are low-pass circuits, and those in (c) and (d) are high-pass versions.

For finding Q factor we will find out which one is the greater value between the two resistances to be matched then accordingly find the values as per:

$$Q = \sqrt{\{(\frac{R_G}{R_L}) - 1\}}(1)$$

$$X_L = R_L * Q(2)$$

$$X_c = \frac{R_G}{Q} \quad (3)$$

$$L = \frac{X_L}{2\pi f} \quad (4)$$

$$C = \frac{1}{2\pi f X_C} \quad (5)$$

5. FIGURES AND TABLES:

Using Zin = 4-j15 and Zout = 14-j2.5 and matched to 50Ω impedance we get the following values using the above equation:

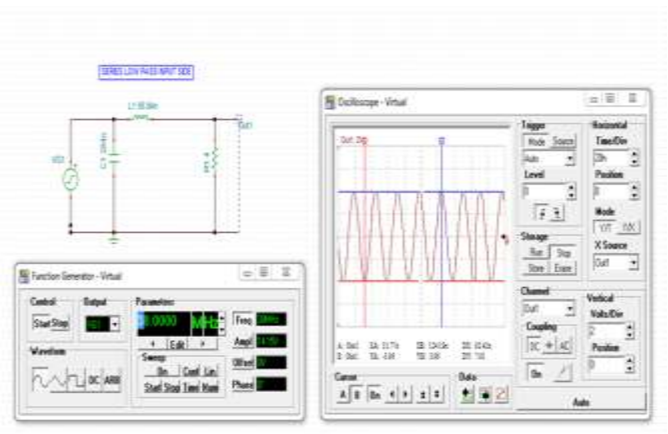

Fig 3 Input side low pass matching circuit

Vpp=7.91

Power=$\frac{Vpp^2}{8*Rl} = \frac{7.91^2}{8*4} = 1.95$

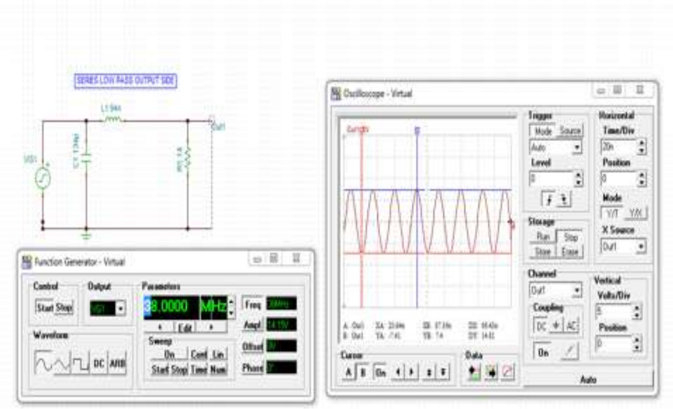

Fig 4 Output side low pass matching circuit

Vpp = 14.83

Power =$\frac{Vpp^2}{8*Rl} = 1.96$

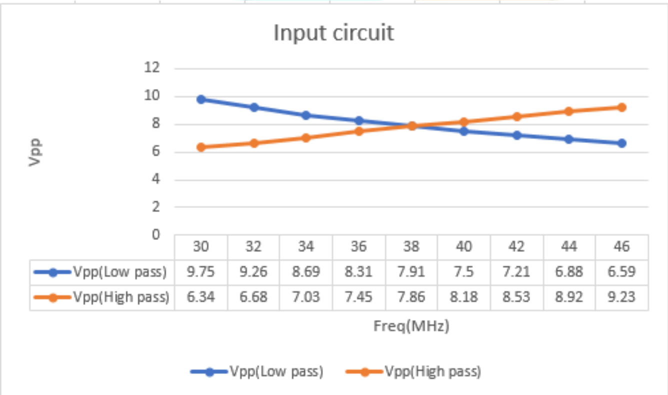

Fig 5 Comparison between high pass and low pass matching circuit of input circuit

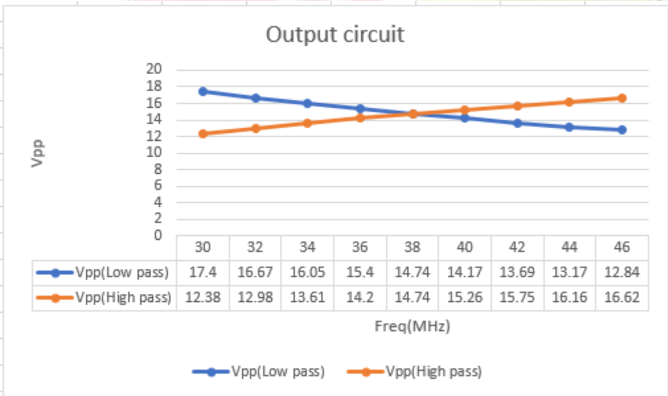

Fig 6 Comparison between high pass and low pass matching circuit of output circuit

The results show that low pass series model gives the better matching.

6. Conclusion and discussion:

We have discussed the different steps that has to be followed in order to develop a solid-state amplifier. We have described different classes of an amplifier and the methods of impedance matching and shown the L section network method is better and T and π network can be used if value of Q can't be changed then we have simulated the input and output circuit in which we have seen the low pass series model gives the better matching result.

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