Design and Simulation of Power Amplifier at Ka Band

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Abstract— Communication industry is currently in continuous growth. In recent time for satellite communication, spectrum at C-band and Ku band is almost congested and for various new applications Ka band is being explored. In particular the Very Small Aperture Terminal [VSAT] networks have gained wide use for business and private applications. Power Amplifier [PA] is important block in transmitter section. Various amplifier configuration were studied and suitable configuration was selected. Also design steps for power amplifier were understood. After Literature survey and studying different transistor, a suitable for Power Amplifier at centre frequency 29.5 GHz over 100 MHz bandwidth for Very Small Aperture terminal at Ka band is designed. Its performance will be evaluated based on certain parameters like Gain, Efficiency, 1 dB compression point [P1dB], 3rd order intercept point [TOI] and it will be simulated using Advance Design System [ADS].

Key words: VSAT, PA, P1dB, TOI, ADS

I. INTRODUCTION

An amplifier get a signal from some pickup transducer or other input source and provide a larger version of the signal to some output device or to another amplifier stage. An input transducer signal is mostly small and need to be amplified sufficiently to operate an output device. In small signal amplifier, the main factors are usually amplification linearity and magnitude of gain. Because of signal voltage and current are small in small-signal amplifier and the amount of power handling capacity and power efficiency are of little concern. On the other side Large-signal amplifiers or power amplifiers used to provide sufficient power to an output load to drive output device typically few watts to ten watts. The main feature of power amplifier is the circuit's power efficiency, the maximum output power that the circuit is capable of handling and the impedance matching to the output device. [7].

PA is designed to meet a number of indicators such as efficiency, gain and input VSWR. Because of the calculation process is more complex, we usually make it by CAD technology. In this paper, we make the simulation and optimization of the circuit through the ADS microwave circuit simulation design software which greatly help us shorten the design cycle and improve design efficiency. Due to significant R&D funding, innovations, processing advancement and electronic circuit developments, the Microwave Monolithic Integrated Circuit(MMIC) has now become commonplace, replacing many discrete circuits with individual transistors, resistors, capacitors, inductors and element interconnections. MMIC circuits show reduced size and cost with higher reliability to meet the needs of today's markets. The pHEMT has outstanding high-frequency characteristics, power characteristics and low-noise characteristics, and it is one of the most competitions in the field of microwave and millimeter-wave monolithic integrated circuits.

The power amplifier is the key component in transmitter section, which dictates the dynamic range of the transmitter. PAs with high gain, good return loss, low power dissipation, high reliability and compact size are required aggressively for many system applications [2].

Parameter	Value
Centre frequency	29.5GHz
Bandwidth	100MHz
Output power	1 watt
Gain over the bandwidth	10-12dB
3rd order IMP	>15dB
Input/output impendence	50Ω
Input/output port RL	>15dB

Table 1: Target Specification

II. DESIGN AND SIMULATION OF POWER AMPLIFIER

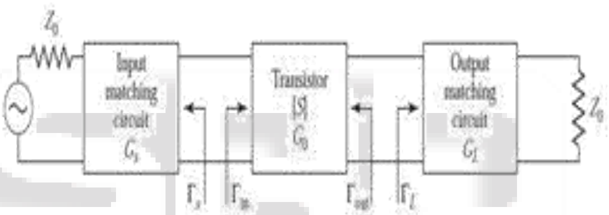


Fig. 1: Block dia. of Amplifier[2]

A Power Amplifier required maximum gain and maximum efficiency so it can deliver maximum power at output.1 dB compression point should be as high as possible to amplify large signal.

We can design Power Amplifier by following steps using ADS tool.

- Selection of transistor
- Checking stability
- Impendence matching
- Result simulation

A single-stage microwave transistor amplifier can be modeled by the fig 1. Here matching network is used on both sides of the transistor to transform the input and output impedance Z0 to the source and load impedances ZS and ZL. Matching circuit is used to avoid unnecessary loss of power. Reflections are eliminated on the transmission line, this procedure is referred to as tuning.

A. Selection of Transistor

Transistors are three-terminal semiconductor devices, and can be categorized as either junction transistors or field effect transistors. Junction transistors include bipolar junction transistors (BJTs) that use a single semiconductor material (usually silicon), and heterojunction bipolar transistors (HBTs) that use compound semiconductors.

Both npn and pnp configurations are possible, but most RF junction transistors are usually of the npn type due to higher electron mobility at higher frequencies.

According to our VSAT application at Ka which transistor is suitable for designing Power Amplifier is decided from its different parameter like gain efficiency etc. after studying different transistors datasheets of different manufacturer comparing it's parameter with specification requirement, VMMK1225 pHEMT transistor is selected from Avago Technologies.

B. Stability Factor

Amplifier is not reliable when it is unstable condition. The stability of a circuit is characterized by term stability factor. The circuit is stable only when K > 1 and Δ< 1. When the input and output reflection coefficients are less than one then we determined the absolute stability factor:

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{|S_{12}S_{21}|} > 1 \qquad (1)$$

$$|\Delta| = S_{11}S_{22} - S_{12}S_{21} < 1 \qquad (2)$$

we can check stability using ads as shown below figure.

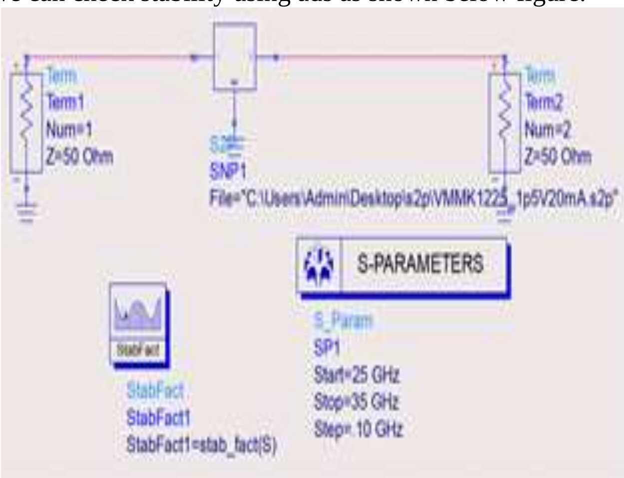


Fig. 2: Stability check of Transistor schematic

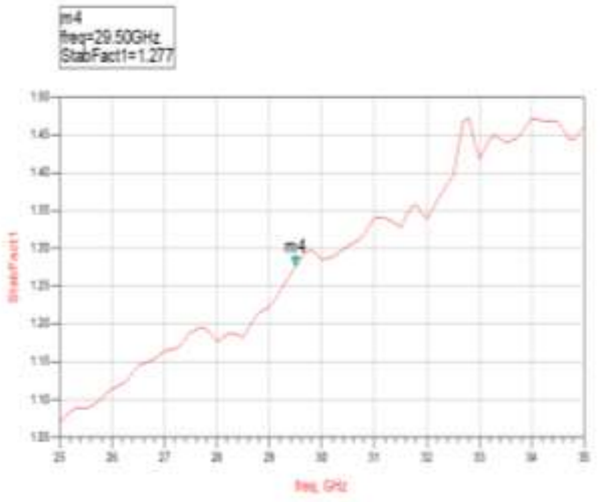
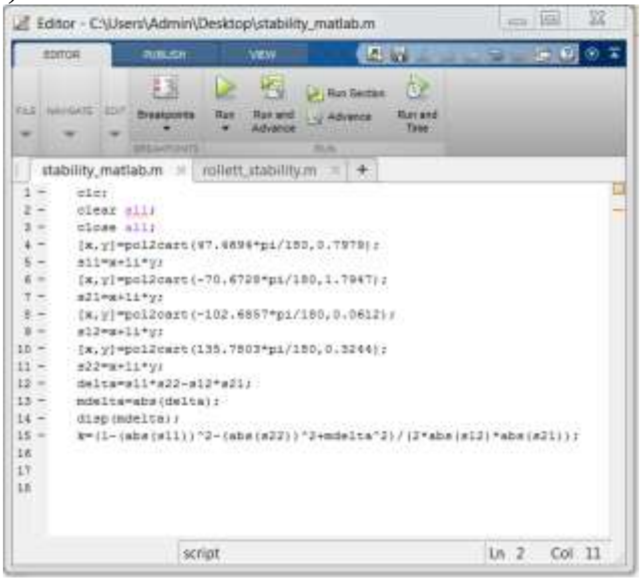


Fig. 3: Stability Results

C. Stability Check Using Matlab:

1) Code:



2) Result:

D. Source -Load Stability Circle:

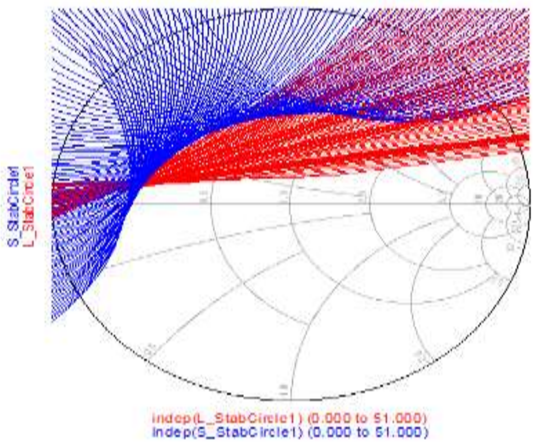


Fig. 3: Source-Load Stability Circles

Here require to put outside this source and load lines from the smith chart for that purpose schematic will be improved as shown below.

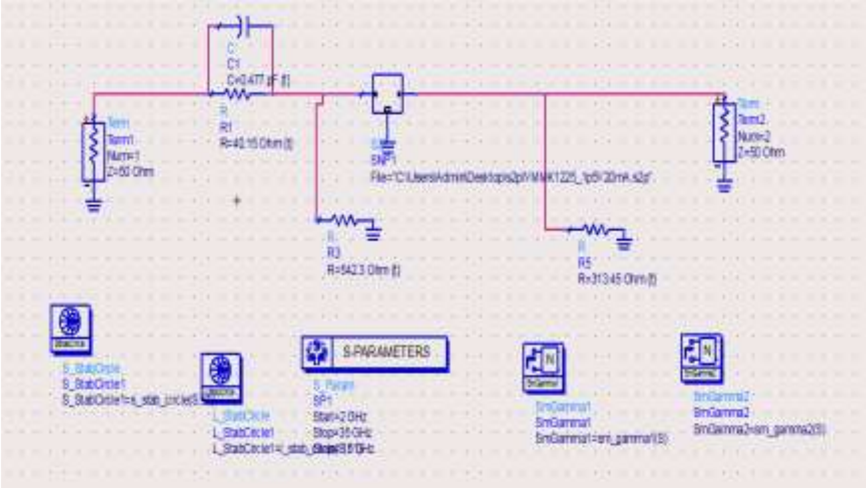


Fig. 4: Improve Schematic for Stability Circle

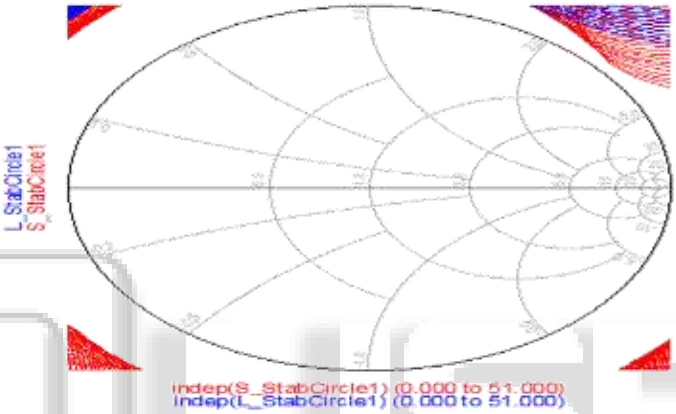
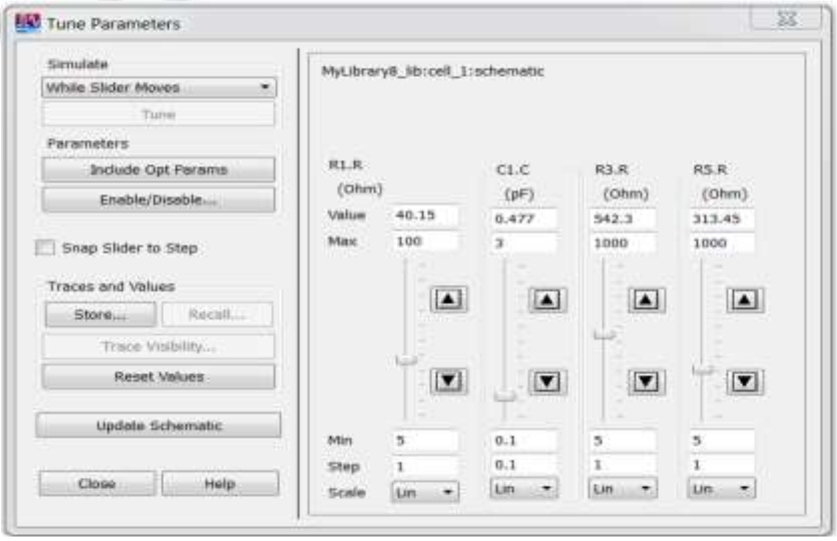


Fig. 5: Improved Source Load Stability Circles

Result will be improved by tuning in ads tool as shown in below.



E. Impedance Matching:

Impedance matching at input and output port done by using smith chart technique, by properly adjusting the value of inductance and capacitance at input and output side, we have managed to match impedance with the terminating resistance of 50 Ω. Γ_S and Γ_L is the source and load reflection coefficient respectively. Input and output reflection coefficient is Γ_{in} and Γ_{out} respectively shown in following equations:

$$\Gamma_{in} = S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22} \Gamma_L} \qquad (3)$$

$$\Gamma_{out} = S_{22} + \frac{S_{12} S_{21} \Gamma_s}{1 - S_{11} \Gamma_s} \qquad (4)$$

For impedance matching finding out the value of Γ_S and Γ_L by plotting below smith chart in ADS.

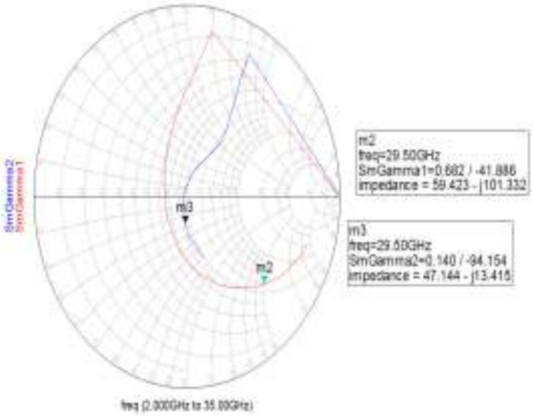


Fig. 6: Gamma1 and Gamma2

Using ADS we can get the value of gamma1 and gamm2 then putting this value in schematic we can match impedance as shown below.

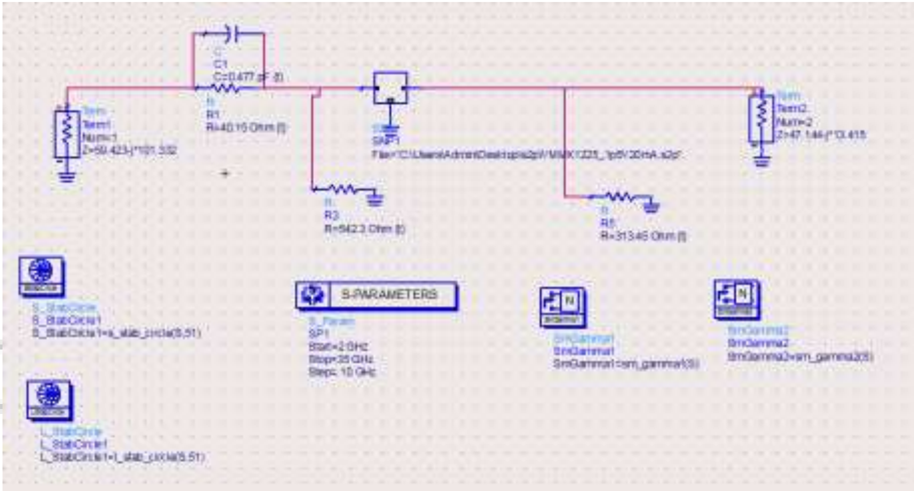


Fig. 7: Putting Value of Gamma in Schematic

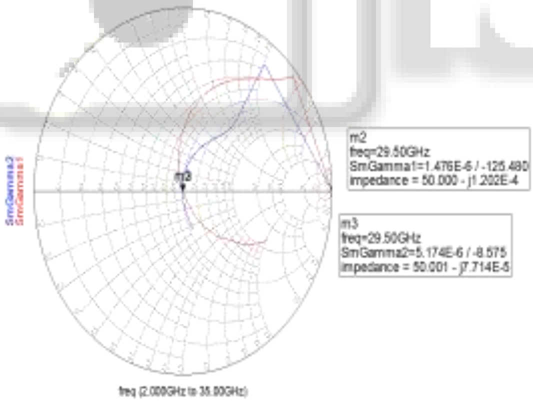


Fig. 8: Matched impedance

F. Simulation of PA:

Simulation is going to be done by using ADS software. The entire simulation of PA is taken out using ADS tool.

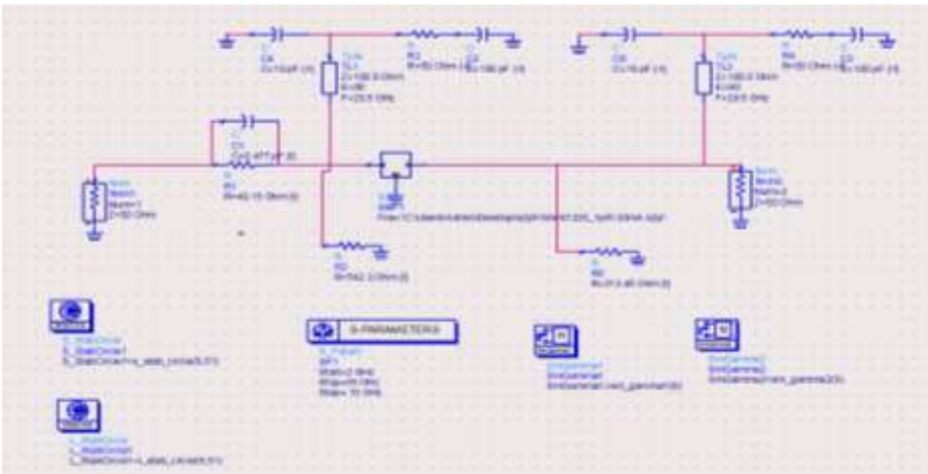


Fig. 9: Schematic Design of PA

G. *Results:*

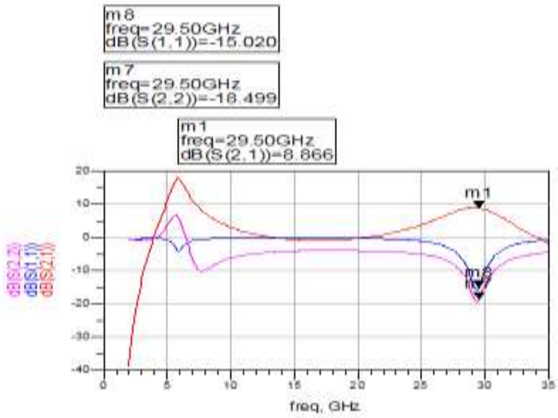


Fig. 10: S parameter

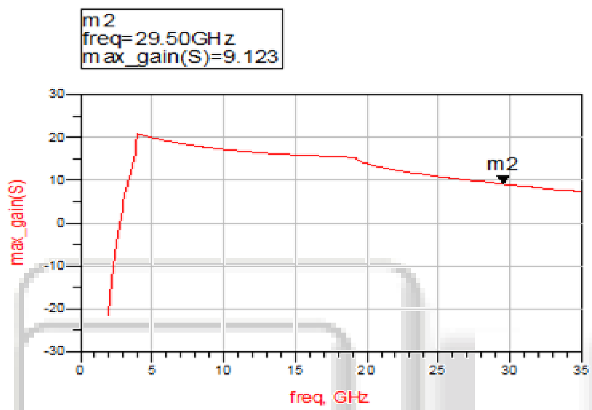


Fig. 11: Maximum Gain

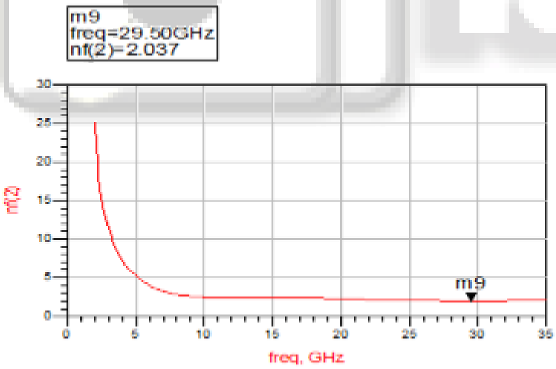


Fig. 12: Noise Figure

III. CONCLUSION

After studying literature of Power Amplifier and its different parameters it can be concluded that Power Amplifier is a device which delivered maximum power at output for this purpose transistor should be selected as its gain, efficiency, 1dB compression point and 3rd order intercept point are as large as possible, for this purpose different manufacturer companies transistor datasheet and its s parameter are compared for VSAT application at ka band then using that design of target specified Power Amplifier is done. Using S parameter stability is checked and simulation is processed for PA .Accordingly gain 9.123 dB, noise figure 2.037 dB, input return loss -15.020 dB, output return loss -18.499 dB is simulated output measured.

IV. FUTURE SCOPE

In future getting nonlinear model of transistor Power amplifier will be developed and utilized for VSAT.

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