RESEARCH ARTICLE OPEN ACCESS

Stability Analysis of Low Noise Amplifier for S Band Applications

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Abstract:

This work aims to analyze various performance metrics of an LNA and arrive at an optimum values for the real time implementation. The various metrics considered here are, Stability factor, Group Delay, Load Pull Analysis and Reflection coefficient of the output of the Amplifier schematic. A FET based amplifier layout is considered for the performance evaluation, and input power range of 0 to 12 dBm is taken up, to arrive at an optimum input power for the Proposed LNA in the S Band.

Keywords — **Low Noise Amplifier (LNA), FET, S Band, Stability Analysis**

I. Introduction

With the advent of IOT infrastructure, there is a burgeoning demand in Electronic circuits which cater to data exchange within various connected devices, or between the infrastructure networks. The smart devices are capable of sensing various real time parameters like temperature, pressure, moisture, noise levels, fuel levels in a car, human body bio signals ets. So the sensor systems which collect these data over 24/7 period need to be the most efficient in their operation due to the sensitivity of the data monitored. And as we know,, these sensors have an RF Front end, which enable them to connect to the network wirelessly. And the most crucial component of any RF Front End associated with these sensing circuits, is an LNA, as they need to capture the control signals from the remote place, and send back the required data from the point of interest.This work focuses on performance optimization of an LNA schematic for future S Band Applications. Few of the existing works have thrown light upon various topologies of Low Noise Amplifier Design. [1] discuses an LNA implementation for ISM Band using an effective forward biasing techniques , which results in marginal performance improvement of the LNA layout. A low power LNA is for Wideband applications is designed in [2] using 1.8 V input constraint. [3] Discusses the isolation of the RF Amplifier circuit from the attenuator circuit and possibilities of efficiency improvements. LNAs for various bands like W Band [4] and UHF Band [5] have been realized with variation in the active devise used in the layout, and further changes in the matching circuitry. Design rules for various CMOS Based power amplifiers [6] [7] can be used in this work, to study the stability of the proposed LNA schematic. Further, [8] discusses the challenges faced in the real time implementation of the LNA circuit for the S Band applications.

II. LNA Topology

Before realizing the final Low Noise Amplifier Design, it becomes imperative that the design rules for the amplifier design be followed to make the approach more systematic. We use the general amplifier design equations for the buildup of the wave shaping circuit. And the design procedure is as follows:

1. DC Biasing: We know that the biasing is the primary step in any amplifier layout. With the help of the DC load line analysis, it is found out the DC Power required for the proposed amplifier is 7.5dBm for effective amplification at 2.45GHz

2. Amplifier Layout:

A suitable FET is chosen for the proposed stability analysis and performance review of an S Band based Low Noise Amplifier. Figure 1 shows the designed layout of the Proposed LNA.

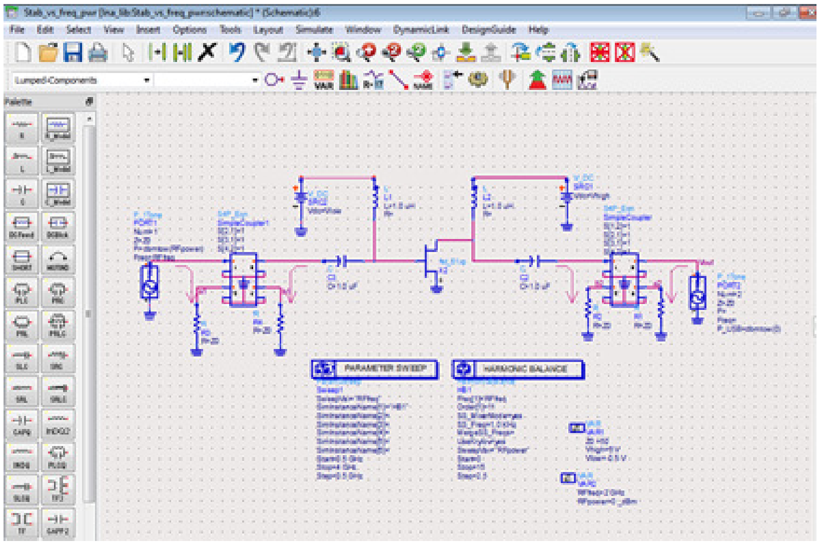

Figure 1: Schematic of the Prosed LNA

3. Stability Analysis: The most important performance metric of an LNA is its own stability under various Load conditions. Stability analysis can be carried out both mathematically (Equation (1) and (2)) and also through simulation engines. The stability of an amplifier confirms the confidence of the design engineer to deliver constant performance over a wide range of frequencies (Equation 3) and load conditions to the maximum possible limit. A lot depends on the choice of the discrete components in the layout and avoiding non linearity in the board design.

a) $K > 1$ …(1)

b) $|\Delta| < 1$ … (2)

Where,

$$K = (1 + |'|^2 - |S_{11}|^2 - |S_{22}|^2) / (2 |S_{21} S_{12}|) \quad \text{.... (3)}$$

4. Matching networks: These networks are the crucial link of any amplifier design procedure. This step gains importance due to the tremendous amount of performance improvements in the real time operation of the designed or proposed amplifier structures. Various input and output matching circuits can be laid out to carry out this most important design step. Simulation Engines provide robust matching network designs solutions and they have largely made the design Engineer's task simpler.

III. Performance Evaluation

The main purpose of this work is to observe the stability and RF power variations over a wide range of frequencies So the Stability, Input Power and Frequency are mapped against each other in the analysis. A wide range of data is correlated to find out the best possible combination and performance of the low noise amplifier in the real time scenarios. Figure 2 shows the plot of RF Power vsforward gain (S21) at the output port of the designed LNA. It can be observed that for the required application in the 2.4 GHz band, the -3dB Gain Compression happens at 12dB RF power input.

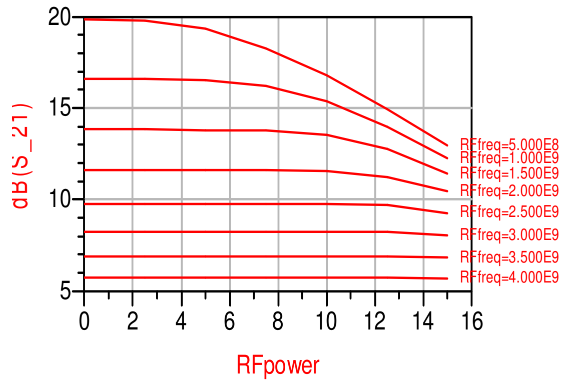

Figure 2: Simulated S21 of the proposed LNA

Further, the stability of the Amplifier circuit can be inferred from Figure 3, and a stability factorof 0.674 is observed in case of and optimum input power of 7.5dB.

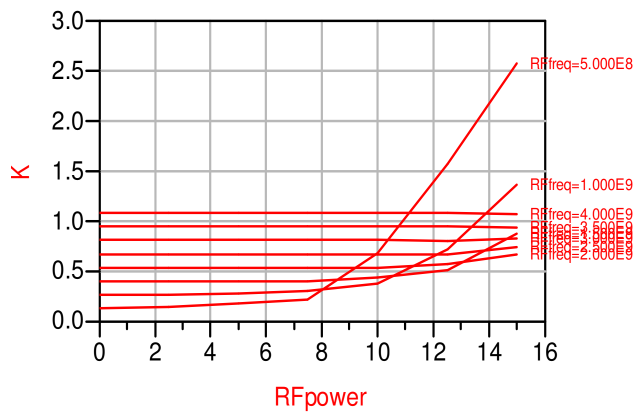

Figure 3: Stability factor vs RF Power plot

Figure 4 and 5 provide various analysis of the required performance metrics of the Proposed LNA circuit design. Firstly the Reflection loss of the output port is mapped with the RF input frequency. A minimum loss of -10.23dB is observed at the said port at the required 2.5GHz band.

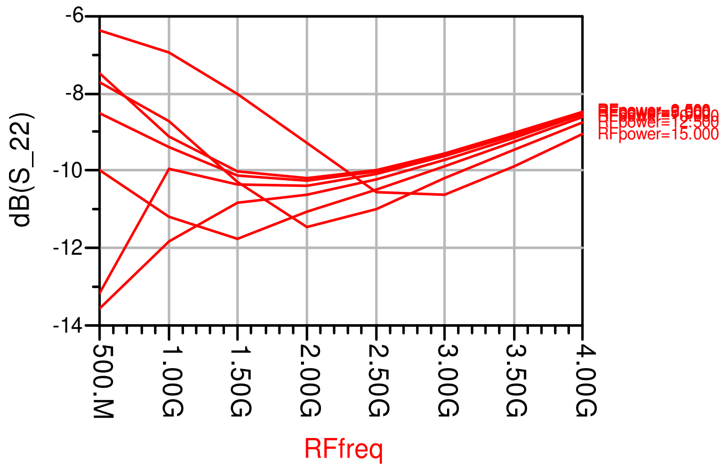

Figure 4: Plot of Output Reflection Loss vs RF Frequency

In Figure 5, the Smith chart is used as tool to evaluate the Impedance of the output port with respect to various load pull conditions. We can note that for the required frequency band the impedance is brought to about 36.991-j24.6, which is pretty good. But to shift the impedance to the 50ohms range, suitable matching networks are todeployed and analyzed for the accuracy. From Figure 6, another very important parameter for the operation of any amplifier is noted. A group delay of ~50ps can be noted for the required frequency of 2.5GHz and optimum power of 7.5 dBm.

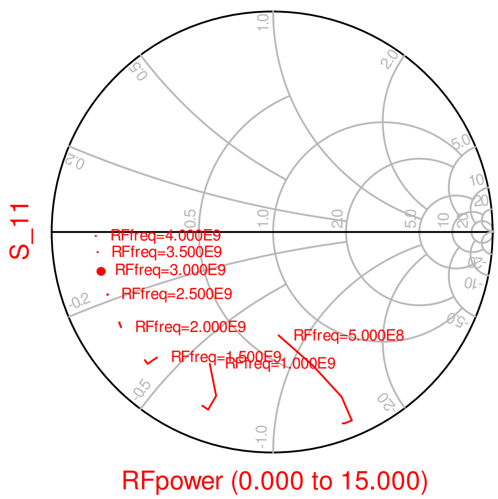

Figure 5: Impedance Analysis of the LNA Deisgn

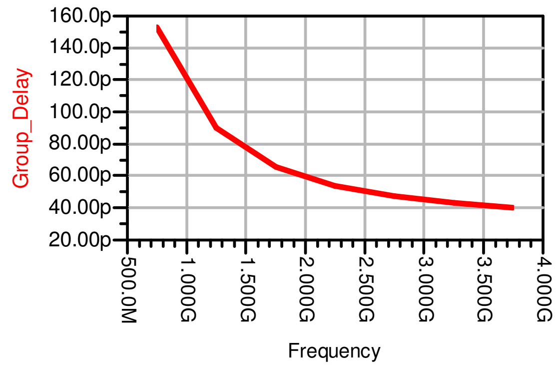

Figure 6: Group Delay Pattern vs Frequency

IV. Conclusion

In depth Stability analysis and performance evaluation is carried out in this work for the said applications. From the various results generatedin the analysis, it can be seen the impedance varies from ~ -29db to ~ -37dB in therequired 2.5GHz range. And further, the output reflection loss of -10.23dB is also needed to be improved in further works. Overall, for an optimum performance of the LNA in the 2.5GHz ranges, we would require 7.5dBm input power to maintain a stability of 0.674 and group delay of ~50ps in real time application scenarios. Improvements can still be carried out in impedance matching and stability factors.

V. References

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