Performance Analysis of Cascode and Inductive Regenerative Low Noise Amplifier for Wireless Applications

Namratha K.R, Nagarathna G Goudar, Nandish M.R, Vishwananth Patil, Thangadurai N

Abstract: ***The present world is ruled by wireless communication. From a telephone communication to satellite communication, the word "wireless" plays a major rule. In the recent years, the modem wireless communication in broadcast and microwave radio demands the properly designed Low Noise Amplifier (LNA) in receiver front ends for proper communication. The paper presents the design of high performance low noise amplifier at radio frequency regime. The LNA is implemented at operating frequency of 1.6 GHz and 2.6 GHz has been implemented at .18um CMOS process. LNA are regularly used in wireless communication receiver leading-ends due to their equity to intensify shaky Radio Frequency (RF) signals without summing additional noise. Cadence virtuoso tool has been used to implement the LNA design and the performance parameters are analyzed at operating frequency.***

Index Terms: CMOS, Noise Figure, SNR, S-Parameters.

I. INTRODUCTION

Radio Frequency (RF) receiver performance requirements are the basic essential for the wireless communication technology where RF receiver makes use of LNA in receiver front-ends due to their wealth to boost weak, RF signals in the absence of additional noise. Industrial, Scientific and Medical (ISM) band are accessible license free which makes them popular in the field of wireless communication. Therefore engineers are showing interest to design devices compatible with this band. Noise, gain, and linearity and power consumption are the basic parameters of LNA. The LNA's main parameters, i.e., noise figure and gain have an important role in the receiver sensitivity. Input impedance and output impedance also adds to the important parameters of LNA. While the LNA is a comparatively Simple design compared to other RF components in a cellular receiver chain, the execution tradeoffs challenge the LNA design engineer.

A. LOW NOISE AMPLIFIER (LNA)

LNA, an electronic amplifier secures the SNR without its degradation while amplifying a very low power signal. It increases both power signal and noise. For a communication, when we send a signal from transmitter to receiver, part of its power gets distorted as noise gets added due to which the signal amplitude gets low and it becomes unable to get the true data. To retrieve the data that we had sent from transmitter, we need to amplify the signal at receiver. Hence there is a need of LNA at receiver front ends. The note to be made is even the noise that adds to the signal gets amplified which decreases the SNR which can be explained by below equation (1),

$$SNR = \frac{Signal\ Power}{Noise\ Power} \qquad \dots (1)$$

SNR and amplifier noise are inversely proportional. Hence amplifier noise needs to be low. Hence the name low noise amplifier. SNR is defined as ratio of signal power to noise power. If the amplifier noise gets decreased, SNR gets improved which enables proper communication which is described in below equation (2)

$$SNR_{out} = \frac{Gain \times Signal\ Power}{Gain \times Noise\ Power + Amplifier\ Noise} \qquad \dots (2)$$

A good LNA needs to have the following parameters

- low noise figure
- linearity
- low power consumption
- low area consumption
- gain(s21)
- matched to the antenna or filter

II. BLOCK DIAGRAM AND WORKING PRINCIPLE

ANTENNA

Antenna is a vital component for any communication system at both transmitting ends and receiving end. Antenna is basically made up of long conductor. At the transmitting end it converts electrical energy into electromagnetic energy and radiates into free space and at receiving end it receives electromagnetic waves and then transforms it into electrical energy which acts as an input or receiver. Then the signal is amplified in LNA.

A. INPUT MATCHING NETWORK

Impedance is measure of opposition to the flow of current that is present in the circuit whenever voltage signal is applied. It is frequency independent. The degradation of signal occurs at transmitting end due to signal reflection if input mismatch comes into a play. Hence mismatch needs to be avoided by equalizing source and load impedance.

B. GAIN

A good low noise amplifier must have a high gain to boost the signal. The main identity of LNA is to boost the low power signal by adding gain to the signal and noise gain needs to be less or else it degrades the SNR.

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C. OUTPUT MATCHING NETWORK

Consider there is a load connected at output terminal, and circuit is giving some output. Ideally the same output should occur at the two terminals of load. But from load perspective, there is some finite resistance in series with output voltage .This resistance is output impedance of the circuit. The load is supposed to be smaller than internal resistance or else degradation in efficiency of the system is observed.

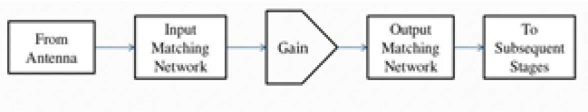

Fig.1 Block diagram of a system

III. RF RANGE

Radio frequency is described as electromagnetic wave frequencies that lie in the range starting from around 3 KHz to 300 GHz. Using antennas, transmitter and receiver, an RF field can be used for various types of broadcasting and communication. The ultra high frequency which ranges from 300 MHz to 3 GHz are extensively used in wireless devices like cell phone, radio, TV broadcast station, wifi, Bluetooth, and satellite communication system [5]. The designed cascode topology at 2.3 GHz and inductive degenerated topology at 1.6 GHz is discussed in design section and its results are discussed in simulation and results.

IV. PARAMETERS OF LNA

S-Parameters: S parameters are applicable to all frequencies, they are particularly relevant to radio and microwave frequencies where signal power and energy considerations are more easily quantified than currents and voltages-parameters are different from other network parameters such as z-parameters, y-parameters, h-parameters, t-parameters and so in the sense that s-parameters do not use open or short circuit conditions to characterize a linear network.S-parameters can be very conveniently used or determining signal low conditions where a device is inserted in a microwave circuit. The scattering parameters can be used to determine various transmission and reflection coefficient.

Noise figure: The noise performance of a RF amplifier is represented by its noise figure. The noise figure indicates the corruption of a signal. Higher the noise figure, the more the signal gets distorted. Hence always a lower noise figure is considered while designing a LNA. It is expressed in decibels. The noise figure can be described by below equations

$$NF = 10 \log_{10} F \quad \ldots (3)$$

Where SNR_{in} and SNR_{out} are the SNRs at the input and output of the amplifier respectively.

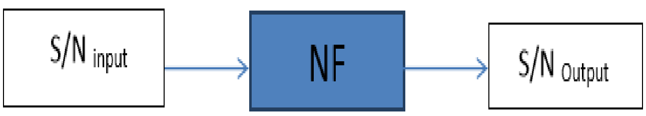

Fig.2 Noise figure of a system

Power consumption: The power consumption of an amplifier has no dependence on the gain, or input signal level. It has dependency on power output. As present world runs mostly on battery powered devices, the main challenge is to design a amplifier with low power consumption.

V. BACKGROUND

There are many types of LNAs available in the market such as inductive degenerated and cascode LNA. These two can make a new architecture that contains excellent input output impedance matching and high gain. When looking for the right low noise amplifiers, filter results by various attributes: nominal gain bandwidth, maximum supply voltage and nominal slew rate at suitable design for a low noise power amplifier for wireless application can be constructed.From the past survey following information has been gathered:

Fathima janisha et. al., used LNA, achieved in the year 2016, the frequency of 1.6 GHz, gain of 46 dB, voltage 5mv, with a noise figure of 259mdB [4].

Iman farjamtalab et. al., used LNA and achieved in 2015, gain of 13.8 dB, voltage of 0.7 V, current of 10 mA, SNR of 2.6 dB. Stability area has been focused on this paper [4].

M.I. Idris et. al., used LNA and achieved in the year 2014, 14.7 dB, extremely lower power consumption of 0.8mw, noise figure of 7dB and small chip area 0.26mm^2. Consequently, this modified LNA is appropriate for low-voltage applications especially in wireless communication system [2].

D. Senthilkumar et. al., used LNA and achieved in 2013, the frequency of 6 GHz, gain of 1.254 to 11.808 dB, voltage of 3 V, current of 10ma and SNR of 3.94dB. From his study the stability is improved from 0.41 to 1.3 with transmission coefficient 23.5dB which is better than matching section. The challenges faced are the different low noise amplifier is used for different matching circuit [6][7].

M. Meloui and et al. used LNA has achieved in 2009, the frequency range of 1.8 to 4 GHz , gain of 10 dB, voltage of 1v, current of 6ma, SNR of 3 to 1.5 dB [1][3]. From his study low noise figure of 3dB at 1.8 GHz and 1.5dB at 4 GHz and the flat gain of 10 dB at 1.8 to 4 GHz is achieved. And the design challenges are the circuit topology consists of one gain stage.

VI. PROPOSED LNA

Cadence is a wide availability of highly specified popular industrial tool that provides designers an all- in -one tool for designing and verification of IC. Fig.3.depicts the design and verification flow of cadence.

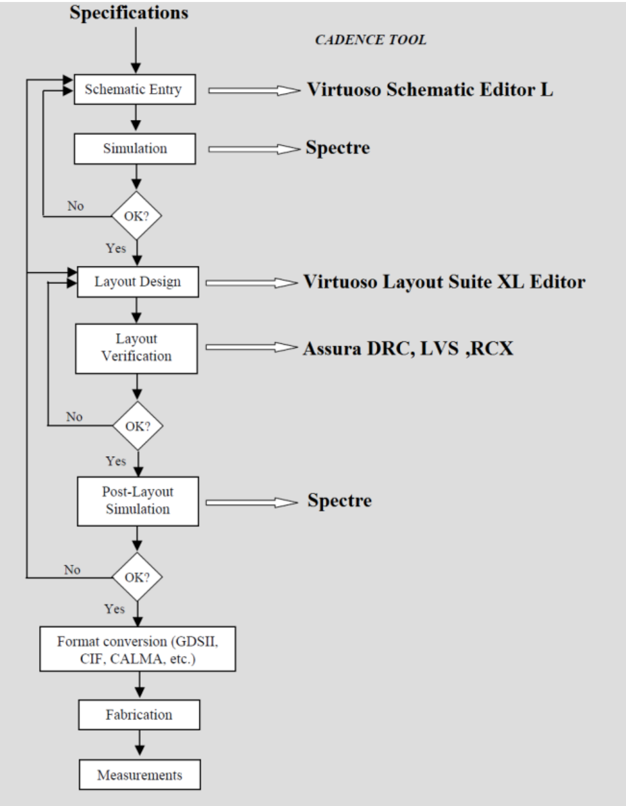

Fig.3. Analog flow OF CADENCE

Cascode and inductive degenerated LNA are the proposed topologies for the design of wireless applications and has been implemented with cadence tool as shown in Fig. 4

A. *CASCODE LNA*

The cascode architecture has been implemented for wireless application at 2.3GHz.Wireless applications in narrow band commonly make use of cascade topology which is a combination of common source and common gate. Cascode is basically a 2 stage amplifiers.Higher input output isolation, higher input output impedance, and higher gain with bandwidth make the cascode a stronger topology.Signal source drives the input stage for the m1 transistor connected of type common source. This drives the transistor M0 of type common gate as output stage. The inductors L0 (Source inductance) and L2 (Gate inducatnce) of transistor M1 becomes responsible for input impedance matching. The drain inductor L1 of transistor M0 becomes responsible for output impedance matching. The schematic of cascode is depicted in Fig.4

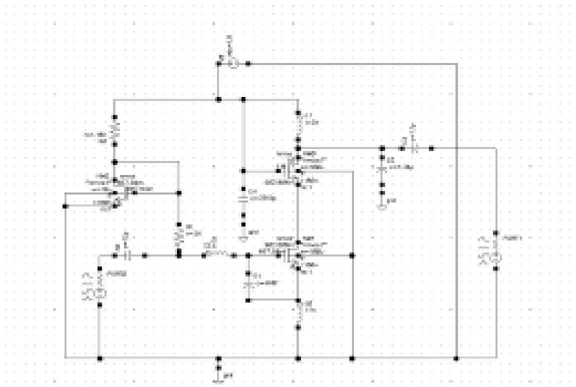

Fig.4. Schematic of cascode LNA

B. *INDUCTIVE DEGNERATIVE LNA*

The proposed schematic of inductive degenerative LNA is shown in Fig 5. To overcome the critical issue of stability caused due to undesired feedbacks, the inductor L0 current passing through it is made to oppose the current over the gate to transistor M1. Due to this fact the proposed amplifier is called inductive degenerative LNA. In the proposed designed transistor M1 and M2 are designed in cascode topology to provide the required isolation between input and output which becomes responsible to decrease the miller's effect caused by Cgd. A biasing circuit is formed by transistor M3 and resistors R0 and R1. A biasing circuit is required to set a dc operating voltage or current conditions to a proper level so that input signal can be amplified correctly by a transistor. L2 and L0 are used to match the output resistance of antenna. The designs of transistors are made in .18um with width of 450u for transistor NM0 and NM1 and NM2 width is around 4.5u. The analysis is done by remaining the capacitor C2 with unknown variable j.

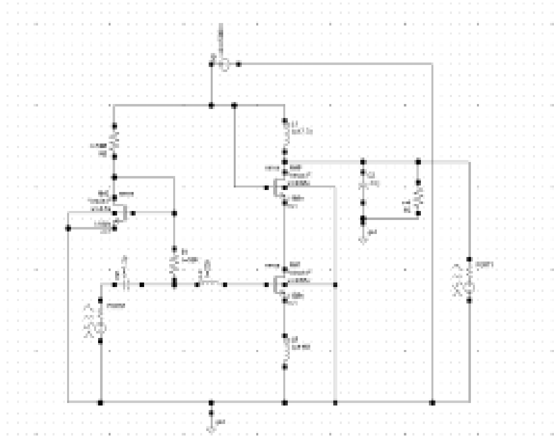

Fig.5. Schematic of Inductive dengerative LNA

VII. SIMULATION AND RESULTS

The results regarding to s parameters, noise figure and power consumption for the proposed designs are discussed below. S parameters: The S parameters results of cascode and degenerative LNA is shown in Fig.6 and Fig.7 respectively and the comparison of both LNAs are depicted in Table.1

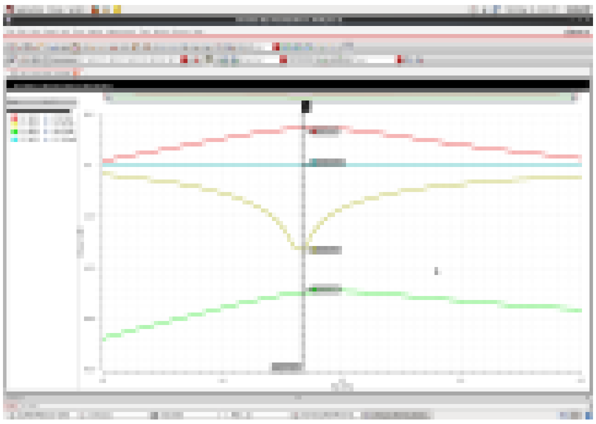

Fig.6. S-parameters plot of Cascode

Table.1. Comparison of S-parameters

Parameters	Cascode at 2.398 GHz	Inductive degenerative at 1.6 GHz
S_{11}	-33.4053dB	-1.8004dB
S_{12}	-49.8735dB	-46.201dB
S_{21}	-14.5281dB	5.363dB
S_{22}	-161.458dB	-933.398mdB

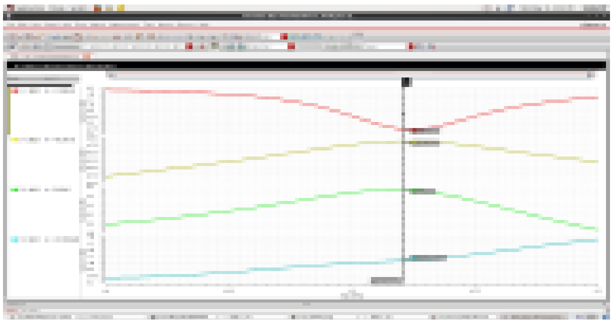

Fig.7. S-parameters plot of inductive degenerated LNA

The noise figure results of cascade and degenerative LNA is shown in Fig.8 and Fig.9 respectively and the comparison of both LNAs are depicted in Table.2

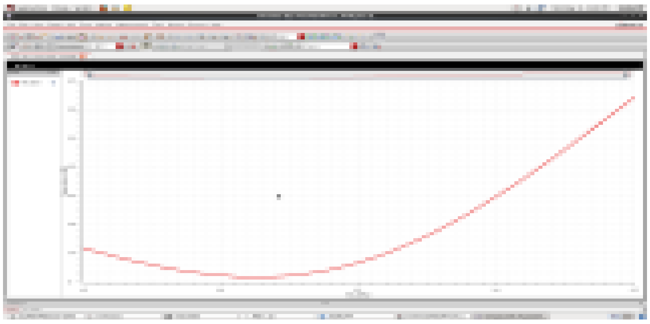

Fig.8. Noise Figure plot of cascade

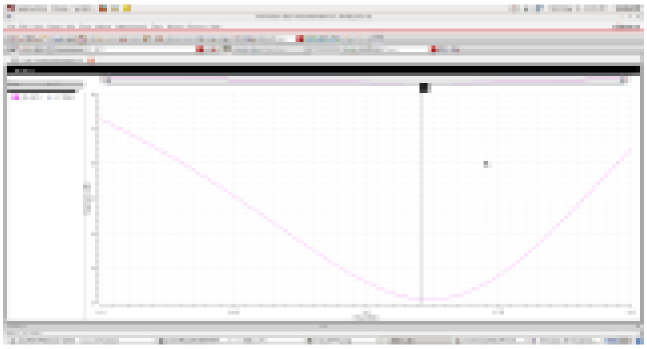

Fig.9. Noise Figure of inductive degenerated LNA

Table.2. Comparison of noise figure

Parameters	Cascade	Inductive degenerative
Noise figure	1.028dB	2.11dB

Power consumption: The s parameters results of cascade and degenerative LNA is shown in Fig.10 and Fig.11 respectively and the comparison of both LNAs are depicted in Table.3

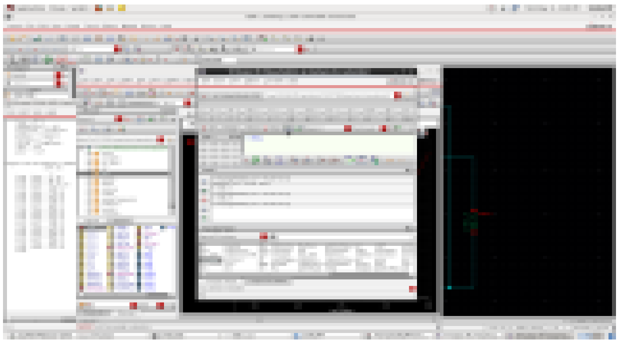

Fig.10. Power consumption of cascade

Fig.11. Power consumption of inductive degenerated

Table.3. Comparison of Noise Figure

Parameters	Cascade	Inductive degenerative
Power consumption	11.95E-3	870.8E-6

VIII. CONCLUSION

A Low voltage CMOS Low noise amplifier was designed at 180nm in cadence virtuoso platform at gpdk180 libraries. The Noise figure, power consumption and gain (S21) for both cascade and inductive degenerative LNA is analyzed. Though the responses are satisfactory, but still there are scopes to improve the performances. Some of the circuits can be improved in design and with more proper optimization to have better responses. Many other parameters of the device can be studied and analyzed. The layout can also be designed with zero errors in both DRC and LVS so that the design can be fabricated without any off-chip components.

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