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# Design of High Gain Wideband Low Noise Amplifier based on Matching technique for Multiple Applications

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**Abstract**— Increasing demands of portable wireless devices have motivated the development of CMOS radio frequency integrated circuits (RFIC). In wireless system Low Noise Amplifier is the first stage of any RF Receiver design. Performance of RF receiver mainly depends on the effectiveness of LNA. The main objective of the LNA design is to get good gain with minimum noise generation for the entire operating frequency range. With proper matching, Wideband LNA would be one with approximately or exactly the same operating characteristics over a very wide passband and would be used for multiple applications. An efficient LNA design has to manage trade-off between Gain, Noise Figure, Input-Output Losses, power consumption and device's stability. The LNA would be designed and will be simulated on Agilent's ADS.

**Keywords**— Gain, Impedance Matching, Noise Figure, Power Consumption, Wideband, Reflection Coefficient, Stability

## INTRODUCTION

With rapidly increasing technology, wireless communication is evidencing introduction of various communication standards. Despite the fact that digital circuits currently offer an impressive performance, pure digital signal processing of radio signals remains limited for relatively low frequencies below a few hundred MHz On the other hand, frequency bands used in current mobile applications span from around 800MHz up to 6 GHz and hence demand the use of analog circuits to down-convert the radio signals to lower frequencies that are suitable for digital processing. The group of circuits that form this part of the receiver is known as the radio receiver front-end. The rapidly increasing applications for wireless communication systems demands for wideband multiple standard wireless system. It is therefore, desirable to develop a single mobile terminal compatible with several standards. To cope up the growth of technology need's a Multiband/wideband Receiver that would support multiple standard applications. In Wireless communication systems, Low noise amplifier is the chief component of any RF receiver design. Low Noise Amplifier (LNA) is an electronic amplifier used to amplify possibly very weak signals and is placed at the front end of a receiver. LNA's performance has direct impact on the overall receiver performance.

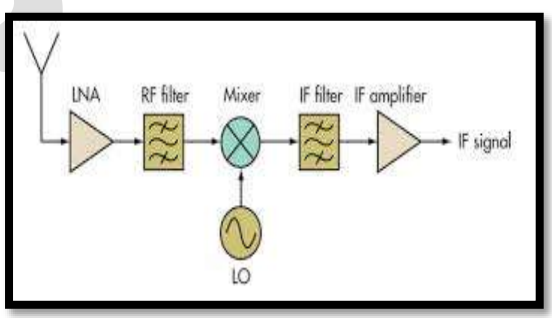


Fig 1. RF Receiver with LNA

When the signal couples from antenna into a LNA circuit, signal is amplified and transmitted to a mixer system including the reduction of the noise coming from outside or circuit inside. LNA is usually located very close to the detection device to reduce losses in the feed line. As LNA is the Key component of RF Receiver it's prime requirements are high gain, lowest possible noise figure (NF), minimum power consumption and system's stability.

The LNA placed at the front-end of a radio receiver circuit determines the performance of sensitivity, linearity and power consumption. A wideband LNA basically is one with approximately or exactly the same operating characteristics over a very wide passband. For Wideband LNA a single, wide-band, RF front-end can satisfy the requirements of any standard in a wide frequency range and thereby support multiple applications. In RF receiver an antenna in combination with wideband LNA is an ideal solution for supporting multiple applications.

## DESIGN PARAMETERS

### *A. Noise Figure*

Noise figure (NF) is a measures of degradation of the signal-to-noise ratio (SNR), caused by components in a radio frequency (RF) signal chain. The overall noise figure is mainly determined by the first amplification stage, provided that it has sufficient gain. It is the ratio between SNR at input to the SNR at output, and is expressed in decibels (dB). NF specifies the noise performance of a circuit or device.

$$NF = 10 \log (SNR_{in} / SNR_{out}) \text{ dB}$$

### *B. Stability*

It is the chief parameter of LNA design. Stability requires to design an LNA circuit that is unconditionally stable for the complete range of frequencies. Achieving stability over entire range of frequency requires to manage trade-off between LNA's gain and noise figure. Stability of the device depends on it's stability factor K and $\Delta$;

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

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

### *C. S-Parameter*

These are also known as Scattering Parameter. S-Parameters are derived from the port parameter analysis of two port network as it describe the electrical behaviour of linear electrical networks when undergoing various steady state stimuli by electrical signals.

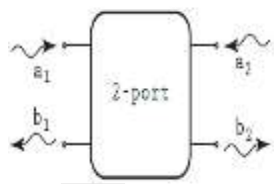


Fig. 2-Port Network

S-Parameter analysis determines the Gain S21 (forward voltage gain), Input Matching S11(input return loss ), Output Matching S22(output return loss ), Reverse Isolation S12(reverse isolation ). While Gain is defined as the ratio between the signal outputs of a system to signal input of a system. Gain basically is the measure of how well the signal from input of any system is routed to the output of the same system.

### *D. Input-output Matching*

Impedance matching is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load. Also the input and output matching of low noise amplifier determines the frequency response. Wideband LNA requires matching for supporting operation over wideband frequencies.

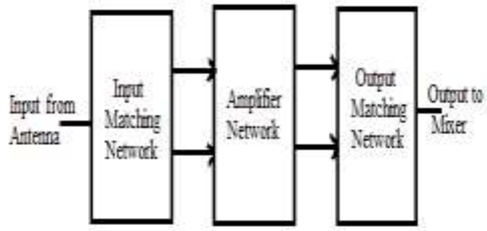


Fig 3. Concept of Matching

## LITERATURE SURVEY

Few papers presents a high gain, low power, high linearity wideband low noise amplifier (LNA) targeting multiple (multiple standard) applications. These few papers have used different techniques to achieve optimum characteristics for LNA. Xusheng Tang et. Al. in [4] presents the design of a low noise amplifier in 0.13μm CMOS technology. The conventional inductive degeneration is applied to reduce the noise figure and the amplifying stage uses the cascode structure to increase the gain and achieve a better isolation. Chang-Tsung Fu et.Al. in [7] have analysed simultaneous noise and impedance matching (SNIM) condition for a common-source amplifier. A dual reactive feedback circuit along with an *LC*-ladder matching network is proposed to achieve the broadband simultaneous noise and impedance matching. Hira Shumail et.Al. [8] have mentioned the design of a highly linear, fully integrated, wideband low noise amplifier. The transistors have been biased in weak/moderate inversion to achieve better linearity and employs a three stage distributed topology along with input and output matching networks. Chun-Chieh Huang et. Al. in [9] stated the designing of LNA using the gate-inductive gain-peaking technique to boost the gain; the proposed LNA achieves a good figure of merit (FOM) with less power consumption. gives one option to use a wideband resistive load cab be used to load inductor for bandwidth extension.

Work done by Jigisha Sureja et.Al. [12] Proposed a technique to attain the wide bandwidth LNA using 0.18μm CMOS technology for a single stage 0.1-3GHz wideband LNA. The paper analyzes cascode common source structure of LNA where a T-coil network can be implemented as a high order filter for bandwidth extension. Vu Kien Dao et. Al. in [14] proposed a multi-band low noise amplifier (LNA) which can operate at frequencies supported by multiple standards. Input matching, noise matching and gain are achieved by adopting a switched output load and a resistive shunt-feedback circuit.

TABLE 1
COMPARISON OF VARIOUS LNA TOPOLOGIES

| Topology | Gain | Noise Figure | Power Consumption |
|---|---|---|---|
| Common gate (CG) | Low | High | moderate |
| Common Source (CS) | High | Low | High |
| Cascode CS | High | Moderate | Moderate |
| Resistive feedback | Moderate | Low | High |
| Current reuse | High | High | Low |

## PROPOSED LOW NOISE AMPLIFIER DESIGN

An LNA is a key component which is placed at the front-end of a radio receiver circuit which determine the performance of sensitivity, linearity and power consumption. As the received signals are processed first though LNA and then to other blocks of receiver. The main function of LNA is to amplify the signal without adding extra noise to the received signal. The LNA schematic shown below is simulated in TSMC RF CMOS 0.13μm technology. Voltage supply of 1.3V is given to transistor (NMOS). The design consists of lumped dc components (R, L, C) with different value at input and output side of circuit. The design below uses common source topology of LNA which either grounded or common to both input and output side. LNA designing includes managing it's parameters like high gain, stability, good input and output matching, low noise figure and linearity. These Design parameters are interdependent, therefore managing trade-off between them is essential. The LNA is designed in Agilent's ADS as it's provides an integrated design environment for the circuit design at RF frequency.

The amplifier is designed using 0.18μm CMOS (Complementary Metal-oxide Semiconductor) based technology. This technology gives low power consumption, strong reliability and also support Multi-dimensional and Multi-standard applications. The Common source topology is used in the design of LNA as it requires low bandwidth of operation. Common source topology also provides high gain and corresponding low noise figure with moderate power consumption. It also has good impedance matching and linearity to lower the distortions.

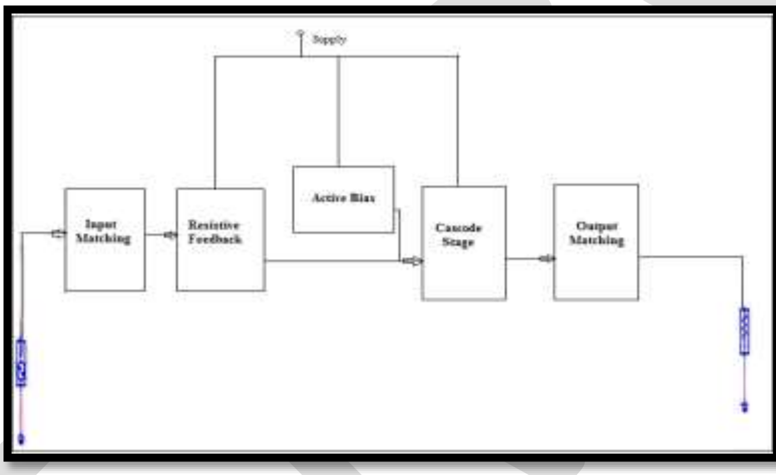


Fig.4. Low Noise Amplifier Circuit

## SIMULATION RESULT

The designed circuit is simulated under **Advanced Design System (ADS)**. It is a leading electronic design automation software for RF, and also microwave and signal integrity applications. Scattering parameter, harmonics, stability and noise figure of the circuit over the frequency range of 0.5GHz to 6GHz have been simulated with 1.3V of voltage supply.

The forward gain S21 is measured to be in the range of 21.37-19.64 db at the frequency range of 0.5-6GHz. The input reflection coefficient ($S_{11}$) is in the range of -11.19 - -15.12 db, the output reflection coefficient ($S_{22}$) is in the range of -7.44 - -7 and the noise figure is in the range of 1.97 - 2.01 db for the same frequency range.

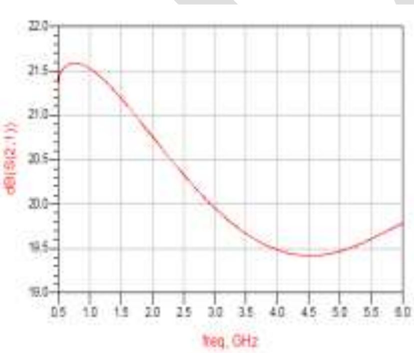


Figure 5: Gain ($S_{21}$)

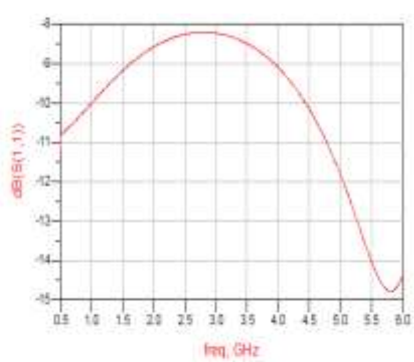


Figure 6: Input reflection coefficient ($S_{11}$)

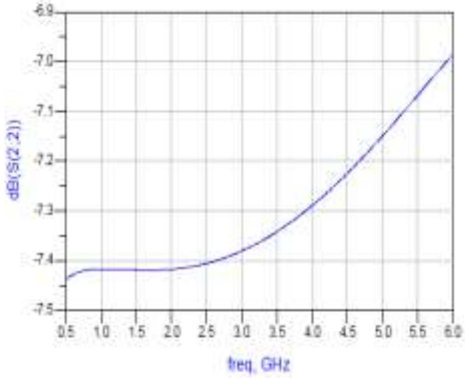


Figure 7: Output reflection coefficients ($S_{22}$)

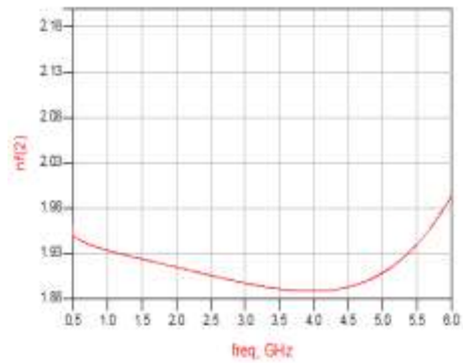


Figure 8: Noise Figure of LNA

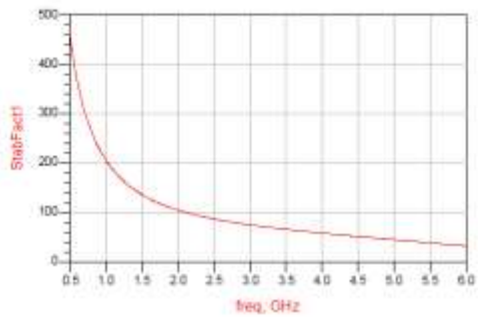


Figure 9: Stability of LNA

TABLE 2
COMPARISON OF SIMULATION RESULTS

| Paper | Frequency (GHz) | Gain (dB) | Noise Figure (dB) | S11 (dB) | S22 (dB) |
|---|---|---|---|---|---|
| Ref 15 | 1 | 19.5 | 3.81 | <-5.0 | NA |
| Ref 16 | 3.1-10.6 | 12.25 | <3.8 | <-10 | <-8.2 |
| Ref 17 | 0.8-2.5 | 15.1 | 1.63 | <-10 | <-5.0 |
| This Work | 0.5-6 | 21.37-19.64 | 1.97 - 2.01 | -11.19 - -15.12 | -7.44 - -7 |

## CONCLUSION

The paper describes the concept and designed circuit of Low Noise Amplifier. This paper gives the details information about LNA design parameter and the comparison between different LNA design topologies. The Complete LNA schematic is simulated in Agilent's ADS through 0.13μm CMOS technology. The simulations results obtained has high gain and optimal noise characteristics with good stability. This LNA would be used in RF receiver for good quality reception.

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