MULTISIM DESIGN AND SIMULATION OF 2.2GHz LNA FOR WIRELESS COMMUNICATION

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ABSRACT

This paper presents the work done on the design and simulation of a high frequency low noise amplifier for wireless communication. The purpose of the amplifier is to amplify the received RF path of a wireless network. With high gain, high sensitivity and low noise using Bipolar Junction transistor (BJT). The design methodology requires analysis of the transistor for stability, proper matching, network selection and fabrication. The BJT transistor was chosen for the design of the LNA due to its low noise and good gain at high frequency. These properties were confirmed using some measurement techniques including Network Analyzer, frequency analyzer Probe and Oscilloscope for the simulation and practical testing of the amplifier to verify the performance of the designed High frequency Low noise amplifier. The design goals of noise figure of 0.52dB-0.7dB and bias conditions are V_{cc} = 3.5 V and I_{cc}= 55 mA to produce 16.8 dB gain across the 0.4–2.2GHz band.

KEYWORDS

Amplifier, Bipolar Junction Transistor, Stability, LNA, Fabrication, Multism

1. INTRODUCTION

The function of low noise amplifier (LNA) is to amplify low-level signals so that very low noise could be achieved. Additionally, for large signal levels, the low noise amplifier will amplify the received signal without any noise or distortion hence eliminating channel interference. A low noise amplifier plays an important role in the receiver and it is the major reason LNA is located next to detection device, which made it to have major effect on the noise performance of the general system. It amplifies extremely low signals without adding noise, therefore, protecting the Signal-to-Noise Ratio (SNR) of the entire system. In LNA design, the major factor to put into considerations are its simultaneous requirements for stability, low noise figure, high gain, good input and output matching.[1]

The LNA should not add much noise to the analog signal thereby reducing the bit error rate when the signal is decoded. After the LNA, the signal is typically filtered and down converted to an intermediate frequency using a down converter mixer.

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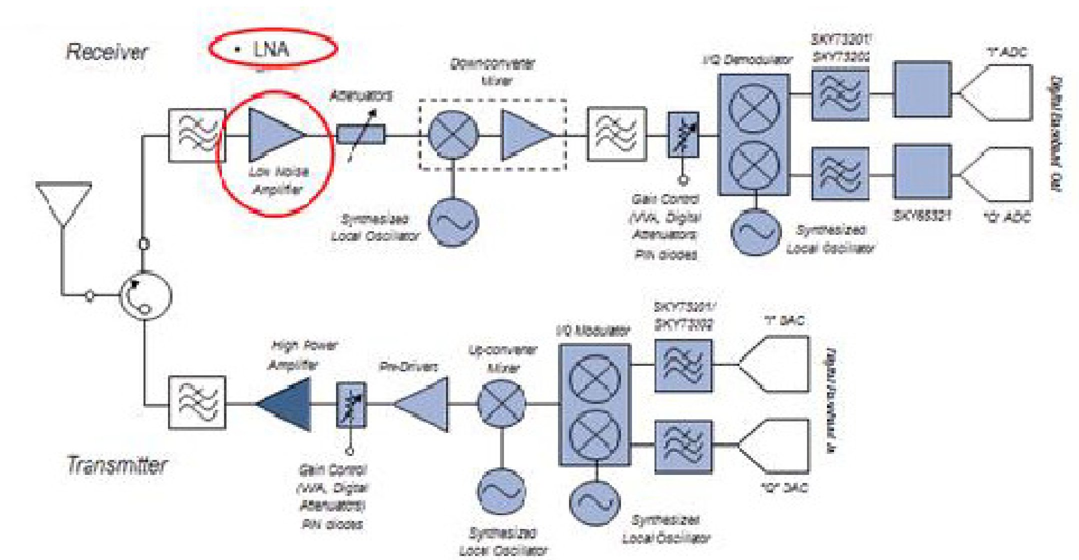

Fig.1 RF front-end architecture for generic infrastructure transceiver

Low Noise Amplifier (LNA) in any communication system provides the first level of amplification of the signal received at the system's antenna. The sensitivity of the receiver is majorly determined by smallest possible signal that can be received by the receiver. The largest signal that can be received by the receiver establishes an upper power level limit that can be handled by the system while preserving voice or data quality [2]. The dynamic range of the receiver, which defines the quality of the receiver's chain is the difference between the highest possible received signal level and the lowest possible received signal level. Additionally, for high signal levels, the LNA amplifies the received signal without introducing any distortions, thus eliminating channel interference [3,4]. It is equally important to consider additional design parameters because of the complexity of the signals in today's digital communications.[5]

Wireless communications signals are very noisy such that signals travelling from far away normally suffer from a lot of degradation. Hence, the LNA is located next to the antenna.[9]. An LNA is the combination of low noise, stability and high gain across the entire range of operating frequency.

2. BIASING OF THE DEVICE

DC biasing network is essential to provide stable operating point for the device. Biasing circuit must be protected from the high frequency effects.

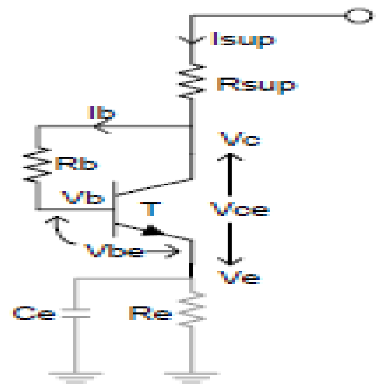

Fig. 2: Typical LNA Biasing Circuit.

3. METHODOLOGY

For low noise system, the input (front-end) stages are very important. For small source resistances, the BJTs are the preferred devices for these stages, and typically they have about 10 times lower level of equivalent input noise voltage than JFETs[7].For this design BJT(transistor) was used because of the above stated reason. The circuit was actualized in Multism 11.0 and simulated to confirm the performance of the circuit by measuring the stability factor, S-parameter, gain and operating frequency using network analyzer ,frequency analyzer and oscilloscope .After the simulations and mathematical calculations has been compared and analyzed, the design was proceed for fabrication using the ultiboard simulator to place all the designs component on a board and a schematic diagram was derived on how the board size will be.

Thereafter, the layout of the design circuit schematic was developed using ultiboard layout software where the size of the design was adjusted and the placement of the components were arranged.

4. STABILITY

The stability of a circuit is characterized by Rowlett's stability factor (K), Circuit is stable when K>1

in addition $\Delta < 1$.

$$K = \frac{1 + \Delta^2 - S_{11}^2 - S_{22}^2}{2S_{11}S_{22}} \quad (1)$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \quad (2)$$

Absolute stability is then determined when the input reflection coefficient is <1 and output reflection coefficient out <1. This must be considered important in the design of LNA and can be determined from the S-parameters, matching networks and terminations [8] .Unconditional stability means that with an arbitrary, passive load connected to the output of the device, the circuit will not become unstable, that is will not oscillate. Two stability parameters K and |Δ| can be calculated to determine as to whether a device is likely to oscillate or whether it is unconditionally or conditionally stable. Where

$$|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| < 1 \quad (3)$$

and

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12} \dots S_{21}|} < 1 \quad (4)$$

The parameters K must satisfy K>1, | Δ |<1 and the parameter b must be greater >0for a transistor to be unconditionally stable.

Where:

$$B = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 > 0 \quad (5)$$

The S-parameter matrix of common 2-port network is shown in figure 3 below;

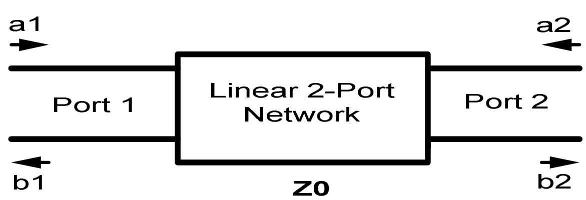

Fig 3: Sketch of a 2-Port Network

Here is the matrix algebraic representation of 2-port S-parameters:

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \times \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \quad (6)$$

Where:

S11 is the input port voltage reflection coefficient, and **S11= b1/a1.**

S12 is the reverse voltage gain, and **S12= b1/a2.**

S21 is the forward voltage gain, and **S21= b2/a1.**

S22 is the output port voltage reflection coefficient, and **S22= b2/a2** [2]

5. NOISE FIGURE CONSIDERATIONS

In wireless communications, lower noise figure shows the efficiency of the LNA which means less noise is added by the LNA. In telecommunications, noise factor is determined by measuring the degradation of signal to noise ratio. [9]

Besides stability and gain, another major factor to consider in the design of LNA is bringing to minimal its noise figure.

5.1 The BJT Noise Model

From equation (7) below noise specifications for BJT's are commonly measured as V_n,

$$V_{n1} = \sqrt{4kTr_x\Delta f + 2kT\frac{V_T}{I_C}\Delta f}$$

$$= \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 620.29 \times 2.2 \times 10^9 + 2 \times 1.38 \times 10^{-23} \times 300 \times \frac{0.0259}{4.998 \times 10^{-3}}}$$

$$\times 2.2 \times 10^9 = \sqrt{2.27 \times 10^{-8}} = 1.5 \times 10^{-4} V$$

$$V_{n2} = \sqrt{4kTr_x\Delta f + 2kT\frac{V_T}{I_C}\Delta f}$$

$$= \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 31.45 \times 2.2 \times 10^9 + 2 \times 1.38 \times 10^{-23} \times 300 \times \frac{0.0259}{8.13 \times 10^{-3}}}$$

$$\times 2.2 \times 10^9 = \sqrt{1.2 \times 10^{-9}} = 3.464 \times 10^{-5} V$$

6. CIRCUIT DESIGN OF A HIGH FREQUENCY LOW NOISE AMPLIFIER

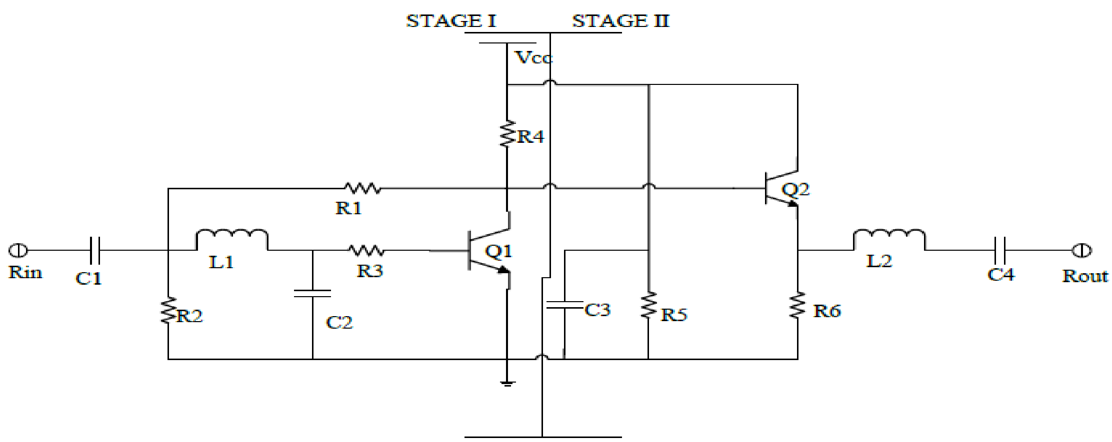

Fig 4. Designed LNA Circuit

7. SIMULATIONS RESULTS

In this section, simulation results from MULTISIM 11.0 are presented. Shown in figure 5 to 9 The simulation result of stability, which determines the effectiveness of the circuit. As stated earlier, for an LNA circuit to be stable and effective, Delta must be lesser than one while Rowlett's stability factor (K) must be greater than one. Other simulations are presented alongside.

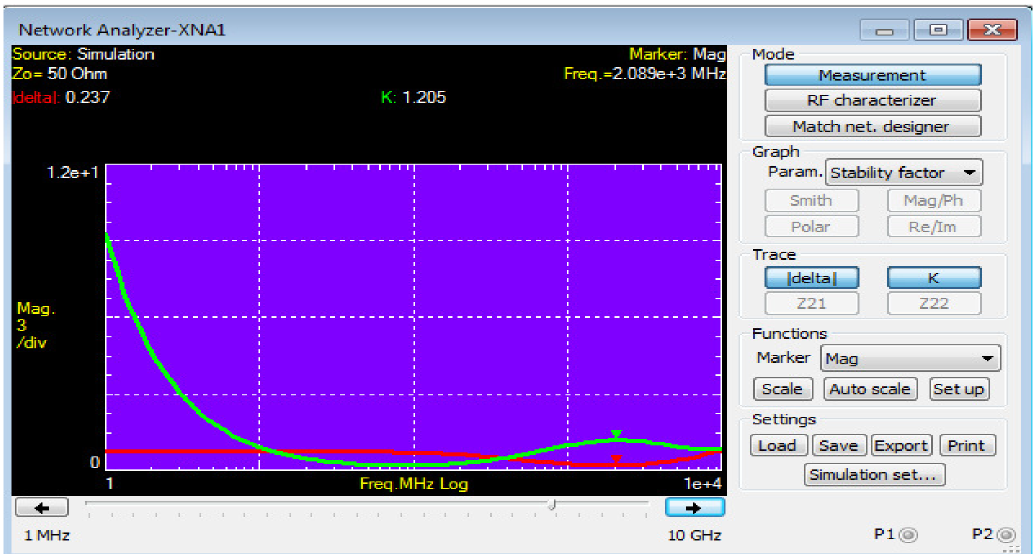

Fig5. Stability at 2.0GHz

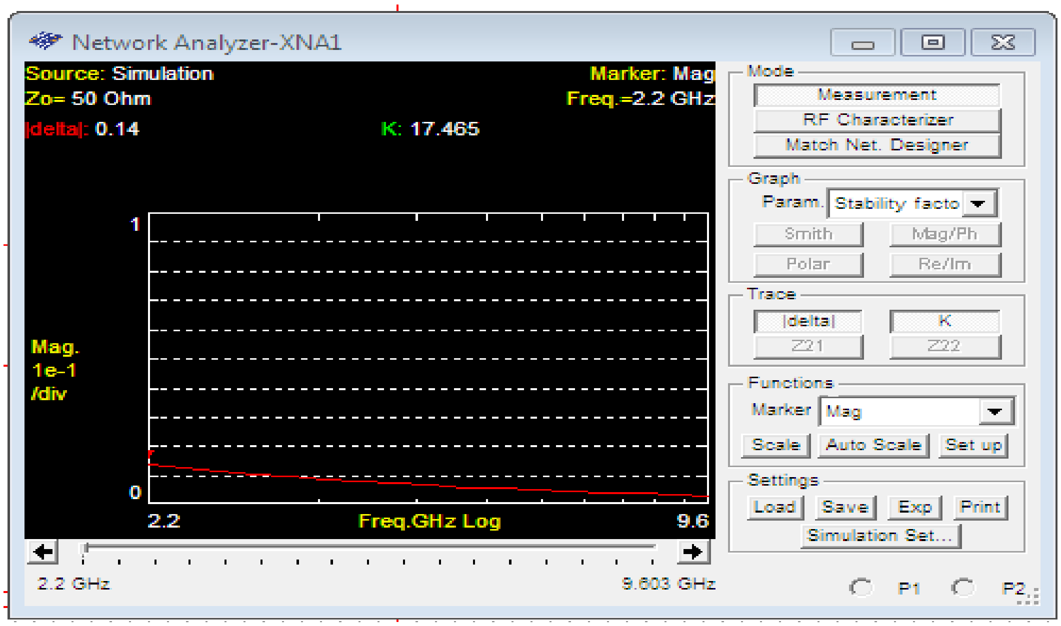

Fig.6: Stability Simulation at 2.2GH

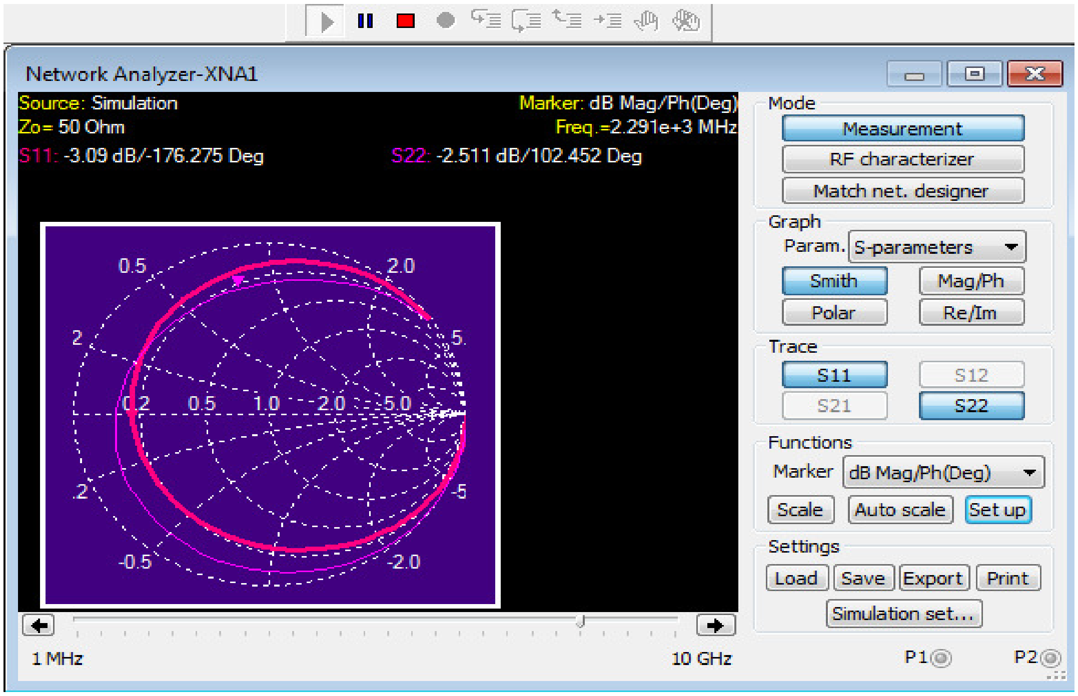

Fig.7: Simulation of S-parameters

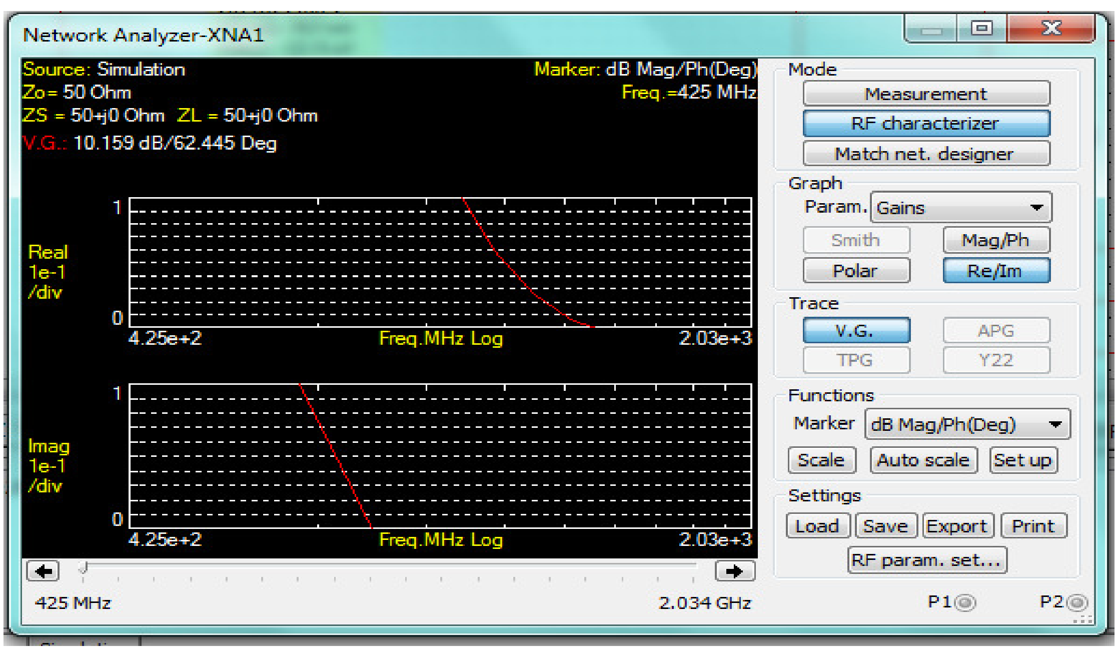

Fig.8: Simulation at 2.2GHz on network analyzer for Gains (Re/Im)

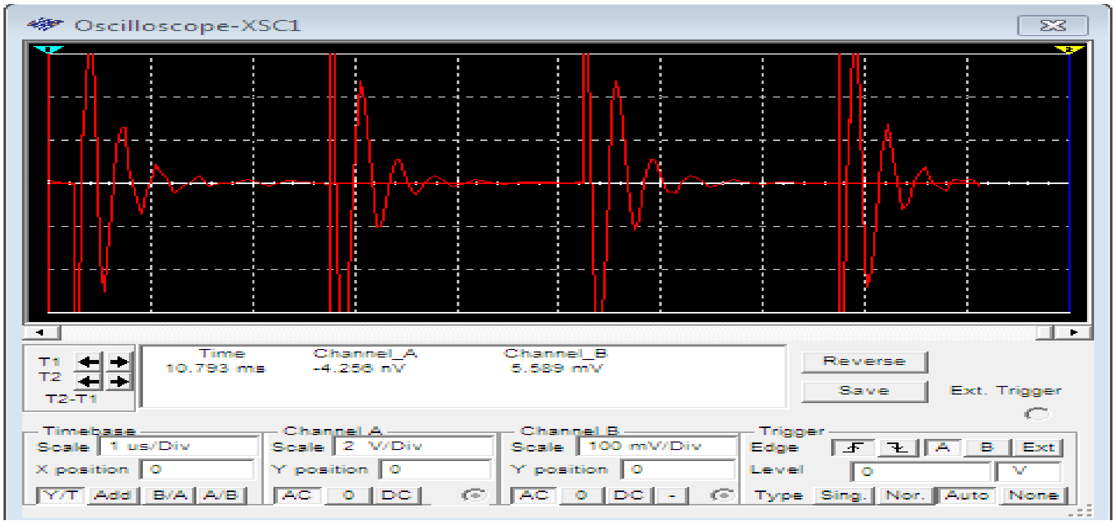

Fig.9: Simulation with an Oscilloscope

8. DISCUSSIONS

The design of an LNA for a wireless mode of operation at a high frequency range of 1.9 GHz - 2.2 GHz with a good gain is determined majorly by the quality of RF transistor used in the design. The results derived after simulation using multism 11.0 were shown in fig5-9.

Fig 5 and 6 are the simulated results on Network analyzer for Rowlett's stability (K), the results obtained for Rowlett's stability (K) over range of frequencies 1.9GHz- 2.2GHz are >1 and delta(Δ) are <1 this shows that the transistors used for this design is said to be unconditionally stable which is good for the design.

Figures7 and 8 are the simulation results for the s-parameters of the design when the mode was on the measurement while the graph parameter was smith and the trace are s_{11} and s_{22}. Fig 8 of the simulation result shows the mode was RF character and the graph parameter is in real/imaginary and the trace is for voltage gain (V.G) of the design, which was done between frequency ranges of 425MHz to 2.034GHz. The gains on simulation results vary within the ranges of 10.15dB and 16.8dB, which is actually good for this design.

Table 1: Simulated results for Delta and Stability factor at 1.9GHz-2.2GHz

FREQUENCY	**DELTA(Δ)**	**STABILITY FACTOR(K)**
1.9GHz	0.423	3.476
2.0GHz	0.237	1.205
2.2GHz	0.14	17.465

Table 2: SIMULATION PARAMETERS ACCROSS 0.4-2.2GHz

AT FREQUENCY 2.2GHz	SIMULATION
Gain(S_{21})	16.8dB
I_{CC}	55mA
V_{CC}	3.5V

This design was based on 50 Ω input and output impedance considering the fact that most RF designs are designed to be 50Ω. The gain and the noise generated which are very essential in LNA designs are analyzed carefully so that adequate signal propagated can be received with minimal signal to noise ratio.

9. CONCLUSION

The designed LNA with matching network at 2.2GHz GHz is obtained. In LNA design, the research goal is to achieve the unconditional stability over the complete range of frequencies along with substantial gain and low noise figure, which was achieved for both stages in the simulation results. Transistor is added for unconditional stability. Therefore, NF and gain are sacrificed. For two stages, mismatch at the output of the first-stage can then be optimized to improve input return loss without adversely effecting noise figure.

This device yields excellent bandwidth, linearity and super low noise figure with high efficiency. The system was simulated using ADS (MULTISIM 11.0), an RF circuit simulator. The design went through a series of tests and measurements for verification. The data from these measurements was recorded, documented, and compared to the simulated predictions.

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