Design and Simulation of LNA using Advanced Design Systems (ADS)

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Abstract

In modern RF and microwave communication systems, amplification plays an important role. A low noise amplifier (LNA) is used in various aspects of wireless communications such as wireless LANs, satellite transponders, cellular communications, etc. At the receiver part, the receiving antenna receives the information signal along with noise. This noise is the unwanted component which needs to be minimized. For this purpose, a low noise amplifier is designed. LNA is the major critical building block in the radio receiver. It amplifies the received signal and boosts its power above the noise level produced by subsequent circuits. The main goal of the paper is to design a low noise amplifier operating at 10 GHz using Advanced Design System (ADS) simulation software which provides high gain with low noise figure. This proposed LNA is designed and its S-parameters and the noise figure are calculated.

Keywords- Advanced Design Systems, Low Noise Amplifier, Noise Figure, Input Return Loss, Output Return Loss

I. INTRODUCTION

A low noise amplifier (LNA) is an electronic amplifier that amplifies a very low- power signal without significantly degrading its SNR. LNAs are designed to minimize the additional noise generated by the amplifier. It decreases the incoming noise and amplifies the desired signal within a certain frequency range in order to increase the signal to noise ratio (SNR) of the communication system and improve the quality of received signal as well. Most of the applications likesatellite communication, broadcasting satellite, radio astronomy, and radar applications, require low noise receiver for system sensitivity consideration.

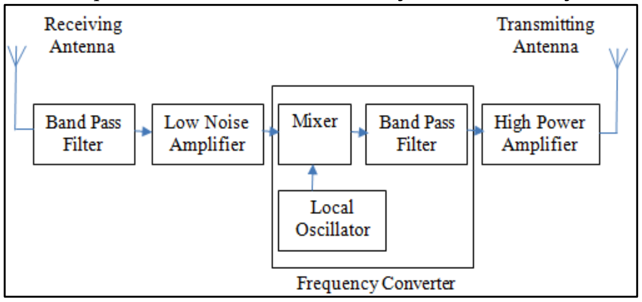


Fig. 1: Block diagram of RF receiver in Satellite Communication

Fig.1 represents the block diagram of receiver used in satellite communication. The design of the LNA results in the trade-offs between noise figure, gain, adequate bandwidth, linearity, voltage supply, and power consumption. These parameters determine the performance of LNA. A key challenge of such radars is the development of highly integrated, highly efficient, T/R modules in an affordable integrated circuit technology platform. Hence, it is important for an LNA to have high gain and low noise figure. Matching networks are mainly used to increase the gain and are designed using inductors and capacitors because it helps in achieving flatter pass band for wide bandwidth [1]. For improving the stability and performance of LNA, the L type impedance matching technique is proved to have good characteristics [2]. Resistive impedance matching technique is not used because it reduces the gain of the LNA [3].

The design parameters that should be considered while designing an LNA is discussed in the following section and the design of LNA in Agilent ADS software is performed and corresponding simulated results are noted.

II. DESIGN CONSIDERATIONS

A. Selection of Device

Selecting the transistor is the first step in designing LNA. There are many transistors which can be used in different frequencies due to the structure and by which process they are manufactured. In this proposed method, ATF-36077 which is an ultra-low noise pseudomorphic high electron mobility transistor (PHEMT) and ATF-10100 is a high performance Gallium Arsenide Schottky barrier gate field effect transistor (GaAs FET)

B. DC Biasing Network

The use of this biasing network is to find the operating point of the transistor and also it makes the parameter values fixed while temperature changes. A resistor bias network can be used over moderate temperature changes but an active bias network is usually preferred for large temperature changes. Resistor divider network is used in this proposed method.

C. Noise Figure

Noise figure (NF) and noise factor (F) are the measures of degradation of the signal to noise ratio (SNR). Noise factor is defined as the ratio of SNR at input to the SNR at output. Noise figure is the noise factor measured in dB.

$$F = \frac{SNR_{input}}{SNR_{output}} \quad (1)$$

$$NF = 10 \log_{10}(F) \quad (2)$$

NF can also be expressed as,

$$NF = \frac{F - F_{min}}{\frac{4R_n}{Z_0}} \left|1 + \Gamma_{opt}\right|^2 = F_{min} + \frac{R_n}{G_s}[Y_s - Y_{opt}]^2 \quad (3)$$

From equation (3), F_{min} is the minimum noise figure of the two-port network, $Y_s = G_s + jB_s$ is the source admittance, $Y_{opt} = G_{opt} + jB_{opt}$ is the source admittance that results in the optimum NF, R_n is the equivalent noise resistance of the two-port network, G_s is the real part of the source admittance

In general, NF of LNA should be found below 5 dB in order to avoid introducing noise in successive stages of the receiver.

D. Linearity

Linearity is a key requirement in the design of an LNA because the LNA must be able to maintain the linearoperation in the presence of a large interfering signal. Linearity is measured from the third-order intercept point (IIP3). Linearity is the criterion that defines the upper limit of detectable RF input power and sets the dynamic range of thereceiver. The linearity of an amplifier is described in terms of 1-dBcompression point and IIP3.The 1-dBcompression point is defined as the level at which the gain drops by 1dB.

E. Matching Network

The input matching network is designed for minimum NF and output matching network is designed for maximum gain. Fig.2 represents the simple block diagram of an LNA. Impedance matching minimize the signal reflected from load to source and another matching network deals with maximum power transferred from source to load. There are different types of matching networks.

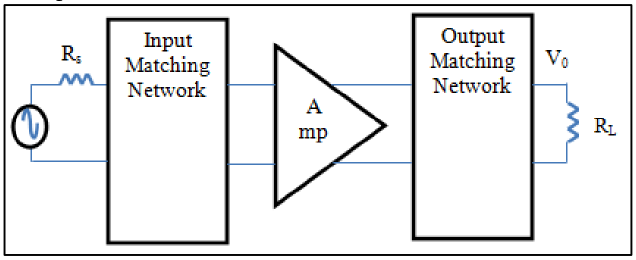


Fig. 2: Block diagram of low noise amplifier

They are,

- LC matching network
- Stub matching network
- T and Pi - matching network

In this proposed method, LC matching network is used.

F. Stability

The Stability analysis is the important parameter in LNA design. Stability of an amplifier is determined by the S-parameters.If the real part of the inputand output impedances of the amplifier is greater than zero then the amplifier is said to be conditionally stable or potentially unstable. The condition for stability is that $|\Delta| < 1$, $K > 1$ and $\mu > 1$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \quad (4)$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} \quad (5)$$

$$\mu = \frac{1-|S_{11}|^2}{|S_{22}-S_{11}^*\Delta|-|S_{21}S_{12}|} \quad (6)$$

In equations (4), (5) and (6), Δ value corresponds to the determinant of the two port S-parameter matrix, S_{11} is the input return loss, S_{12} is the isolation, S_{21} *is* the gain, S_{22} is the output return loss, S* is the complex conjugate of the corresponding S-parameter.

III. PROPOSED METHOD

In RF receiver, LNA is the crucial component and designing it is a great challenge. To amplify the received signal in a communication system, an LNA is required. LNA reduces the noise in the signal received from the BPF and amplify the gain. Here the inductively degenerated topology is used to achieve narrow band for 10GHz. The input matching network consists of the source inductors and the gate to source capacitance. Cascode amplifier with inductive source degeneration is the most commonly used LNA topology.

A. Cascode LNA Design using ATF-36077

Fig.3 represents the schematic diagram of LNA design using ATF-36077 (PHEMT) in the ADS software.

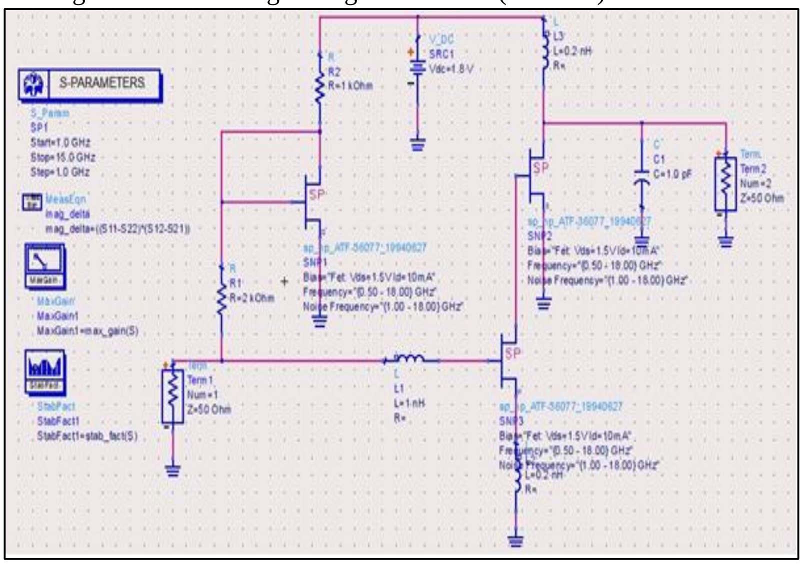


Fig. 3: Schematic diagram of LNA design using ATF-36077 (PHEMT)

B. Cascode LNA Design using ATF-10100

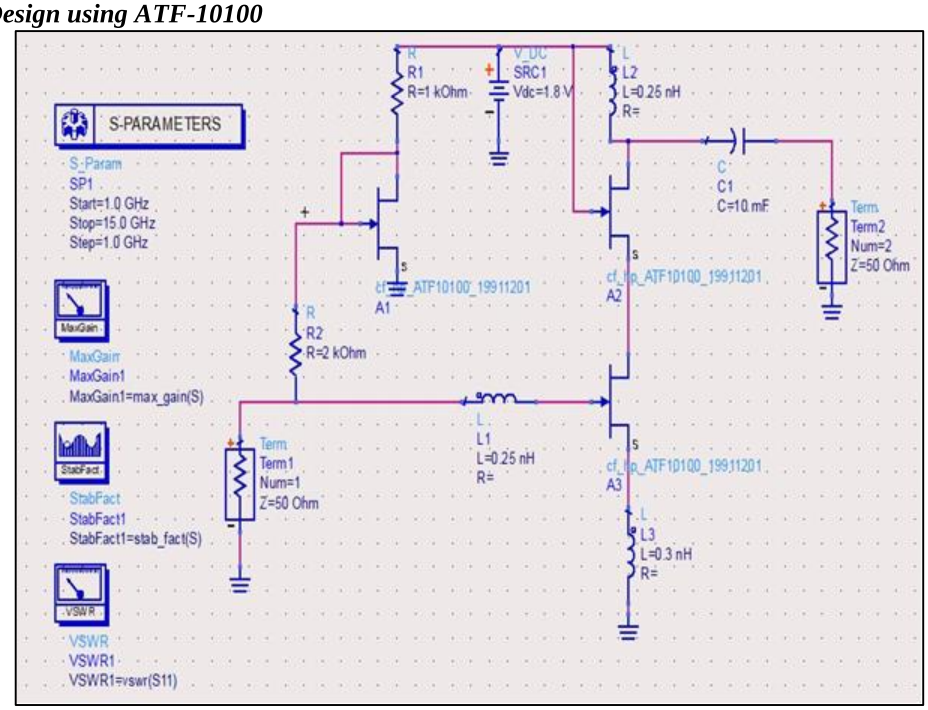


Fig. 4: Schematic diagram of LNA design using ATF-10100 (GaAs FET)

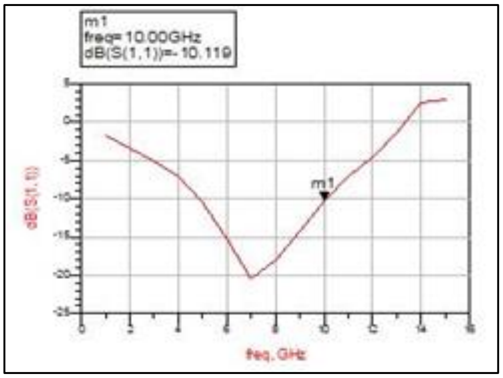
Fig.4 represents the schematic diagram of LNA design using ATF-10100 (GaAs FET) in the ADS Software.

IV. SIMULATION RESULTS AND DISCUSSION

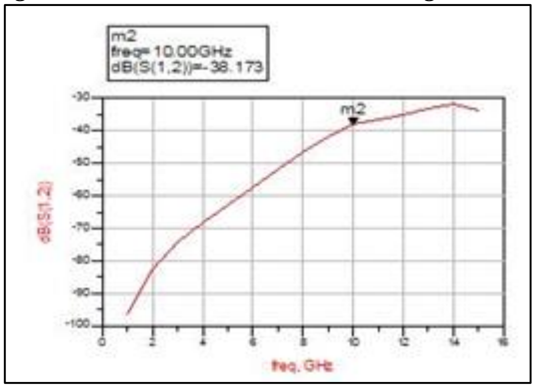
In LNA design, the most important factors are low noise, moderate gain, matching and stability. The noise figure helps to determine the efficiency of LNA and also results in better signal reception.

1) Cascade CS stage LNA using ATF-36077 (PHEMT)
2) Cascade CS stage LNA using ATF-10100 (GaAs FET)

The S- parameters and the noise figure for the designed LNA using PHEMT are obtained as shown in Fig.5.



(a)



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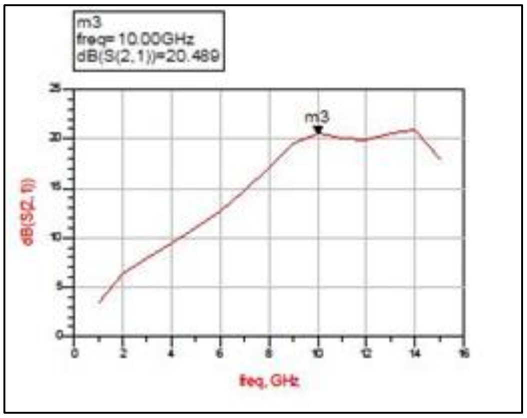

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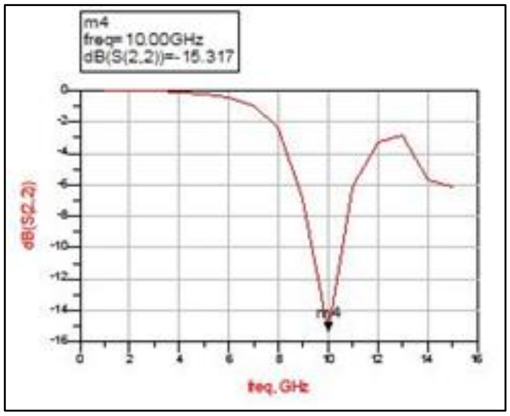

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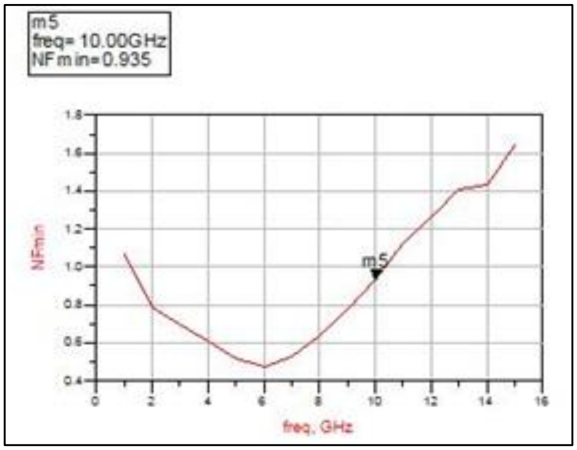
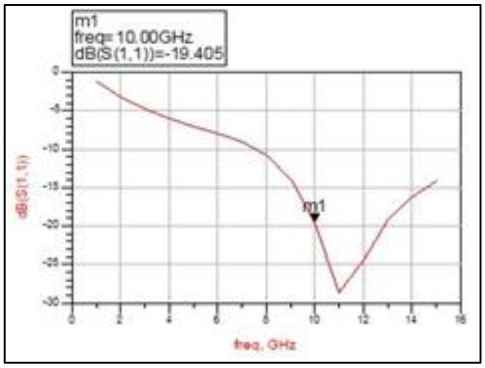


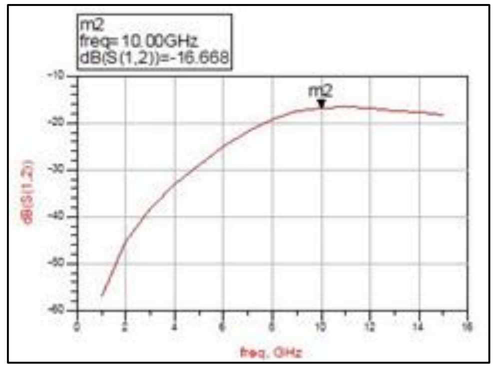
(e)

Fig. 5: Simulated Results for LNA using PHEMT (a) input return loss (b) isolation loss (c) Gain (d) output return loss (e) Noise figure

The S- parameters and the noise figure for the designed LNA using GaAsFET are obtained as shown in Fig 6.



(a)



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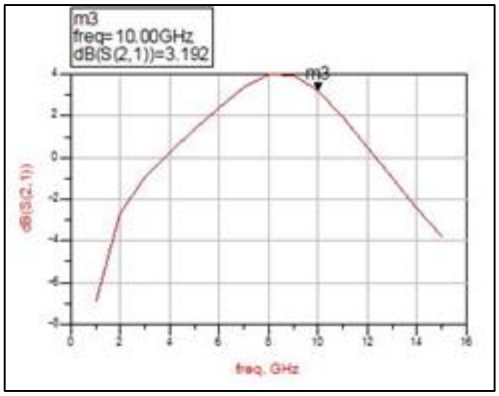

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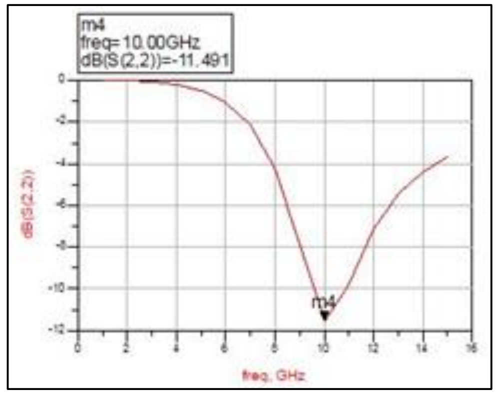

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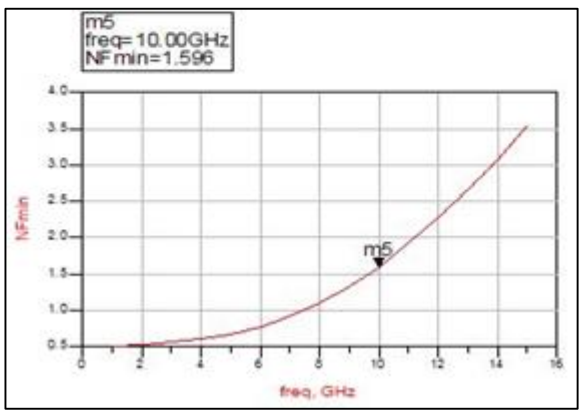

(e)

Fig. 6: Simulated Results for LNA using GaAs FET (a) input return loss (b) isolation loss (c) Gain (d) output return loss

A. Comparison

While comparing the results of both LNA designed, it is found that single stage cascade amplifier with inductive source degeneration using PHEMT has high gain of 20 dB and low noise figure of 0.9 dB than that of using GaAs FET. The comparison of the results are shown in Table 1.

Table 1: Comparison table for the simulated results

Sl.No	*10 GHz*	*S11 (Input return loss)*	*S12 (Isolation loss)*	*S21 (Gain)*	*S22 (Output return loss)*	*Noise Figure (NF)*
1.	*Cascade LNA using PHEMT*	*-10.119*	*-38.173*	*20.489*	*-15.317*	*0.935*
2.	*Cascode LNA Using GaAs FET*	*-22.350*	*-16.713*	*3.146*	*-10.939*	*1.596*

V. CONCLUSION

In this research work, LNA at 10 GHz for communication system has been designed and simulated. Single stage cascade and cascode amplifier with inductive source degeneration is used. It is observed that the noise figure is 0.9 dB and gain is 20 dB for single stage cascade LNA in 10 GHz using PHEMT and it is observed that the noise figure is 1.6 dB and gain is 3 dB for cascaded LNA using GaAs FET. LNAs designed in this paper show low noise figure in compared to previously works. The simulation results have good assent with desired demand.

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