Design and Simulation of Low Noise Amplifier at 10 GHz By Using GaAs High Electron Mobility Transistor

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Abstract : *This paper presents the design and simulation of a 10 GHz Low Noise Amplifier (LNA) for Wireless communication systems. The simulation result has been performed by using the Agilent Advanced Design System (ADS) software. The High Electron Mobility Transistor (HEMT) based on GaAs is used for decreasing of Minimum Noise Figure (NFmin) of LNA. Also, for more decreasing NFmin of LNA radial stub elements are implemented in biasing network. We have designed a 10 GHz LNA based on three design manner basing on the lumped, the distributed and radial stub elements. The designed amplifier offers forward gain of 14.77 dB with the noise figure of 0.775 dB at 10 GHz. The input return loss (S11) is equal to -17.35 dB at 10GHz. The output return loss (S22) is equal to -10.24 dB at 10GHz. Also, the isolation (S12) of proposed structure is equal to -18 dB at 10 GHz. The simulation result have shown that the forward gain and noise figure of 10 GHz LNA are optimized Substantially with respect to the pervious works.*
Keywords: *forward gain, Low Noise Amplifier (LNA), noise figure, radial stub element, lumped element*

I. Introduction

Low Noise Amplifiers (LNA) are the building blocks of any wireless communication system. LNA is used to amplify very weak signals for example signal captured by an antenna [1]. The four most important parameters in LNA design are: gain, noise figure, and non-linearity and impedance matching. Noise figure is also one of the main factors which determines the efficiency of a LNA. Hence, we can decide which LNA is suitable for a particular application. Low noise figure results in better reception of signal [2]. With the low noise figure LNA must have high gain for the processing of signal into post circuit. According to requirement high gain LNA are designed for application by manufacturer. If the LNA doesn't have high gain then the signal will be affected in by noise in LNA circuit itself and maybe attenuated so high gain of LNA is the important parameter of LNA [2, 3]. Input and output matching circuit is used for improving noise figure, gain, gain flatness and input voltage standing wave ratio (VSWR) [1, 4].

The gain, Noise figure and stability circle of the circuits information have been achieved by the scattering parameter analysis. For low noise, the amplifier needs to have a high amplification in its first stage. Therefore, MESFETs and HEMTs are often used. For microwave high power and low noise application AlGaAs/GaAs HEMT attracted consideration because of their excellent microwave characteristics, low noise and high power microwave performance and high current drive capability [5].

LNA at 10 GHz has demonstrated a noise figure of 1.18 dB and forward gain of 13.14 dB [1]. HEMT technology and distributed and radial stab element is used for designing LNA in [1]. LNA with noise figure 1.38 dB and forward gain of 13.53 dB was reported [2]. LNA at 10 GHz has demonstrated a Noise figure of 3.5 dB and forward gain of 13 dB [6]. The RF-CMOS 65nm technology and cascode topology is implemented in its design. The LNA showed a noise figure of 2.29 dB and forward gain 9.11 dB at 10 GHz [7]. GaAs high frequency transistor and common source topology has been implemented for designing circuit in [7]. LNA with a noise figure of 2.72 dB and forward gain of 11.040 dB at 11 GHz were reported [8]. 180 nm RF-CMOS technology and two stage cascode topology is used for designing circuit in [8].

Three different structures are using for designing of LNA at 10 GHz. Lumped, distributed and radial stub elements are implemented for preparing these structures. LNA has demonstrated a noise figure of 0.775 dB and forward gain of 14.77 dB.

The main task of this paper is explained completely in the following manner. The first part of this paper explains the performance of a 10 GHz LNA. In this section, the lumped and distributed elements are implemented for designing input and output matching networks. Also, radial stub elements are used for designing biasing networks. In the second part of this paper, the 10 GHz simulation results are explained. In the final part, the complete conclusion of this paper is explained.

II. 10 GHz LNA Design

Agilent ATF-36077 has been implemented for designing LNA at 10 GHZ. Hewlett-Packard's ATF-36077 is an ultra-low-noise Pseudomorphic High Electron Mobility Transistor (PHEMT), packaged in a low parasitic, surface-mountable ceramic package. Properly matched, this transistor will provide typical 12 GHz noise figures of 0.5 dB, or typical 4 GHz noise figures of 0.3 dB. Additionally, the ATF-36077 has very low noise resistance, reducing the sensitivity of noise performance to variations in input impedance match, making the design of broadband low noise amplifiers much easier [9].

While designing any amplifier, it is important to check the stability of the transistor chosen, or the amplifier may function as an oscillator. For determining stability, calculate Rollet's Stability factor, (represented as variable K) using S-parameters at a given frequency. The adequate and essential situation for being unconditional stability are in the following manner [1]:

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

$$|\Delta| = |S_{11}.S_{22} - S_{12}.S_{21}| < 1 \qquad (2)$$

There are three parameters in ADS software for calculation stability factor of LNA such as Stab Meas, Stab fact, and mu. Where,

$$Stab\_fact = K \qquad (3)$$

$$Stab\_meas = 1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2 \qquad (4)$$

$$MU = \frac{1 - |S11|^2}{|S_{22} - conj(S_{11}).\Delta| + |S_{12}.S_{21}|} \qquad (5)$$

For being unconditional stable: Stab_fact>1 and Stab_meas>1 or MU>1

The simulation result indicate in Fig. 1. According to the Fig. 1 stab fact and MU are smaller than 1, so the transistor is conditional stable in working frequency.
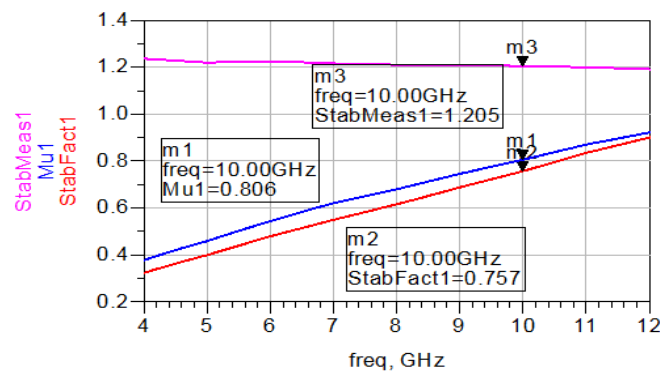

Fig. 1. Stability figure for active part of 10 GHz amplifier

The feedback resistor between drain and gate is used for improving stability of circuit. Optimization and tuning tools of ADS software have been used for calculating of feedback resistor. Fig. 2 indicate transistor with feedback resistor. The simulation result indicate in Fig. 3. According to the fig. 3 stab fact and MU are improved noticeably in working frequency.
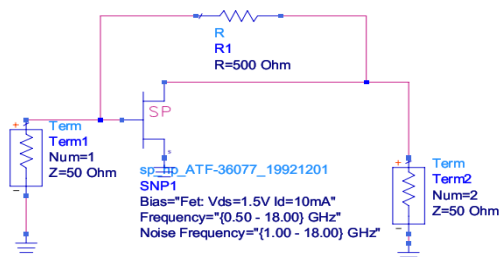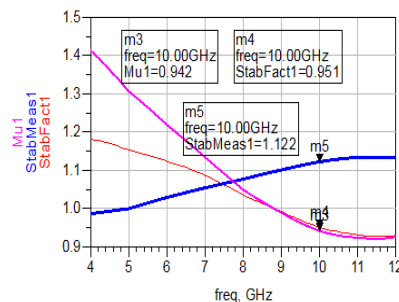

Fig. 2. Transistor with feedback resistor

Fig. 3. Stability figure

III. Structures Of Lna With Simulation Results

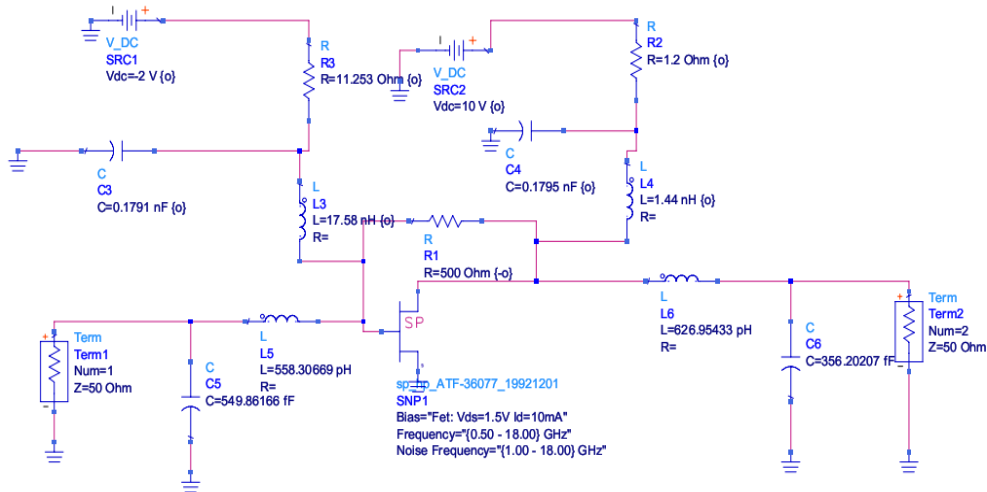The first LNA, design is based on lumped element for matching and bias networks as shown in Fig. 4.

Fig. 4. LNA with lumped elements for matching and bias networks.

The simulation results of LNA with lumped element for matching and bias networks indicate in Fig. 5.
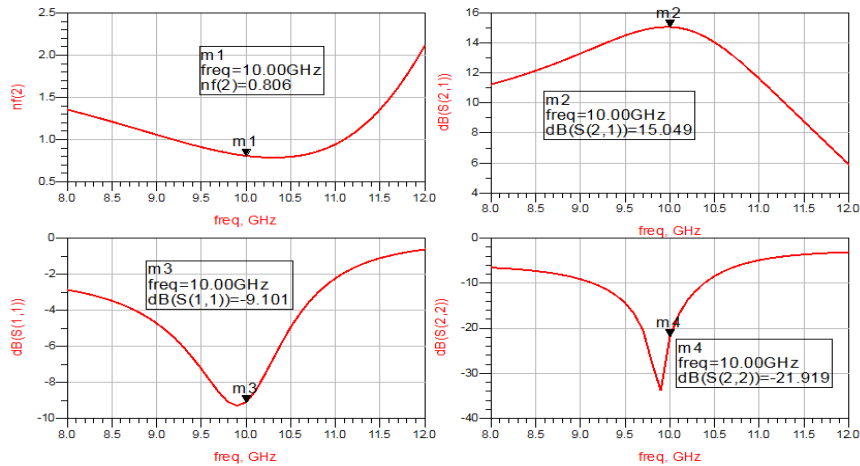

Fig. 5. Simulation results of LNA with lumped element for matching and bias networks.

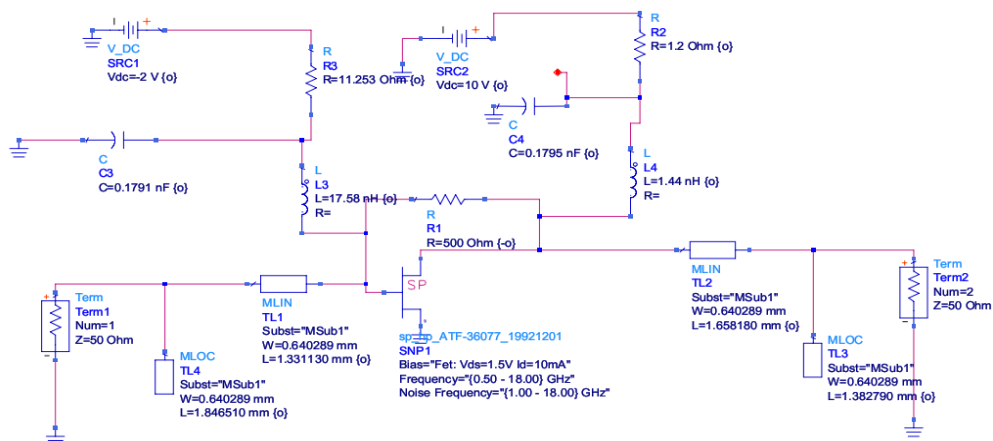The second LNA, design employs distributed element for matching network and lumped element for Biasing network.

Fig. 6. LNA with distributed element for matching network and lumped element for biasing network
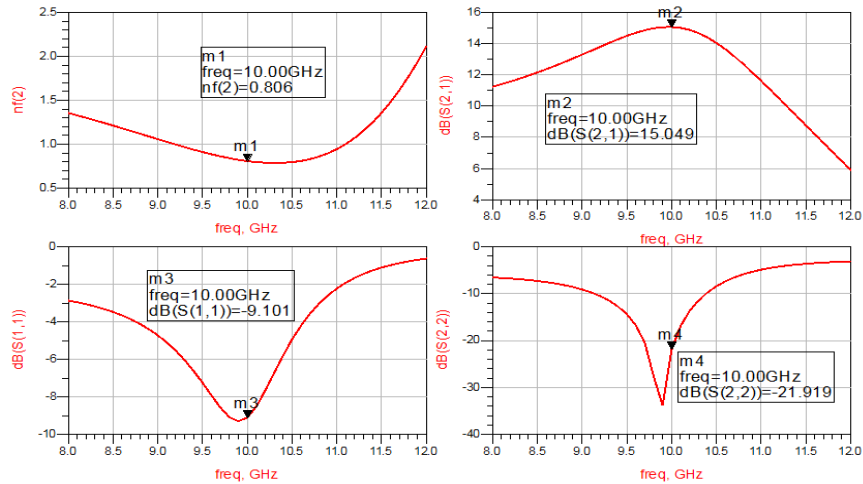
Fig. 6. Simulation result of LNA with distributed element for matching network and lumped element for biasing network

The third LNA, design is based on distributed element for matching network. The biasing network design based on radial stub, inductor and capacitor is shown in fig. 7. Also, biasing network performance is shown in fig. 8.
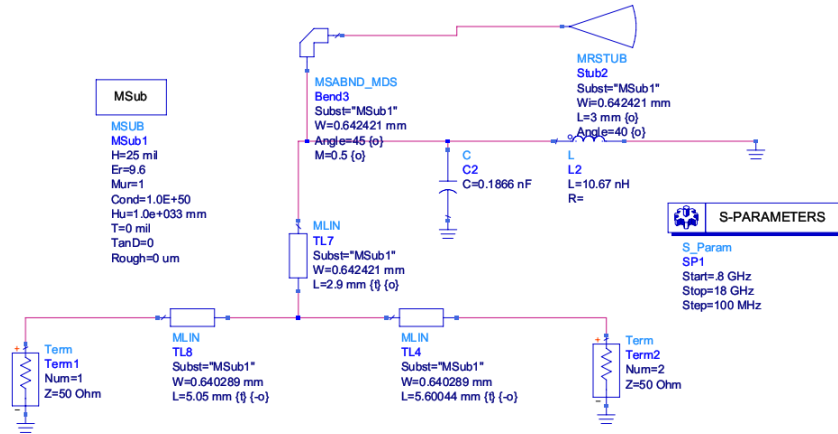

Fig. 7. Biasing network with radial stub elements

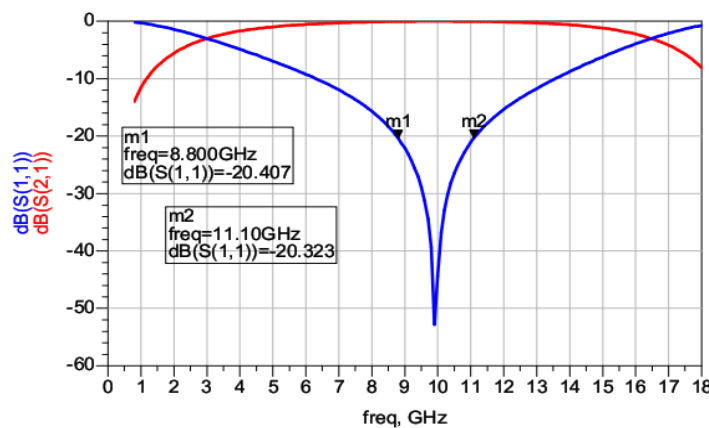**Fig. 8.** Biasing network performance.

According to the Fig. 8 S11 is less than -50 dB and S21 confined to 0 dB, this result indicates that biasing network performance is satisfactory. The designed LNA is shown in Fig. 9. Distributed elements have been used for designing input and output matching networks.
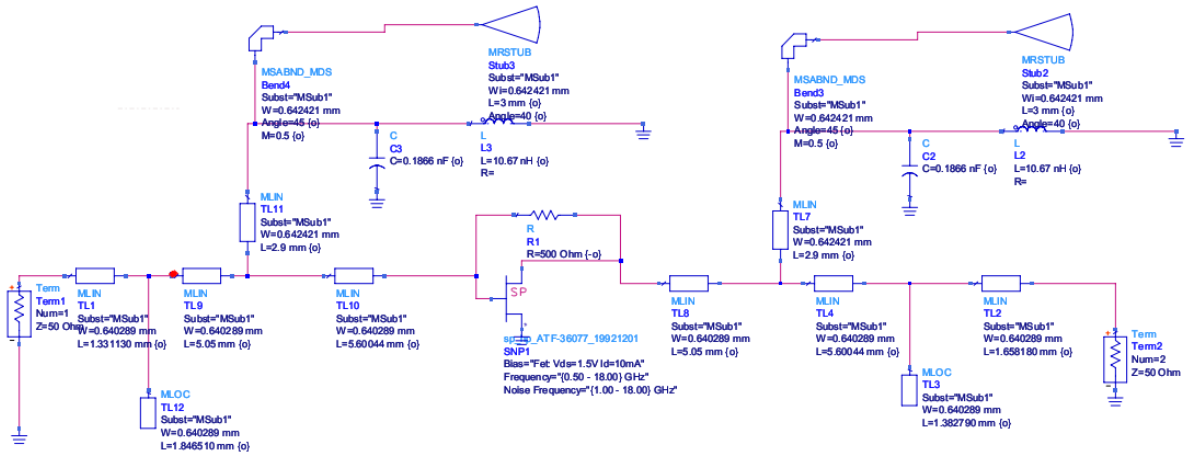
Fig. 9. Designed LNA
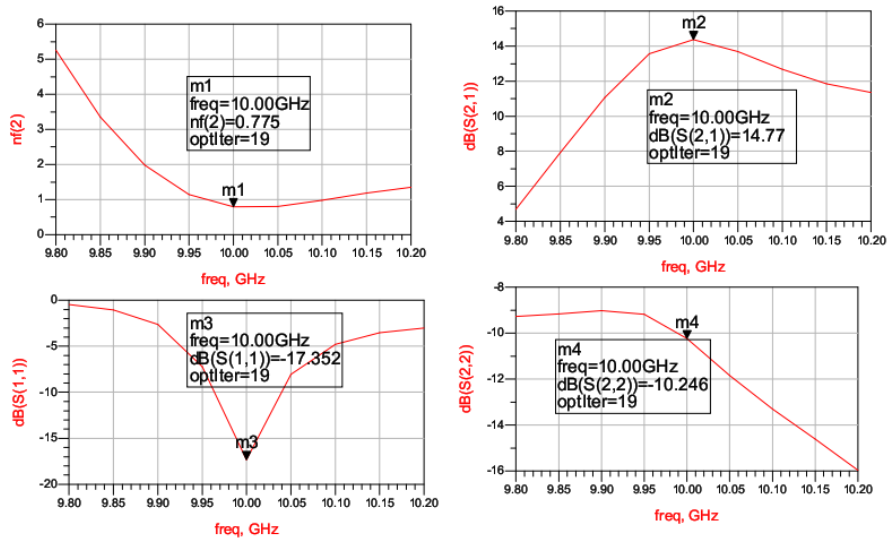
The simulation result of designed LNA is shown in Fig. 10.

Fig. 10. Simulation result of designed LNA

IV. Summary Of Simulation Results

Table I presents the summary of simulation results of a 10 GHz LNAs. The obtained results show that the forward gain and noise figure of these designs is almost 15 dB and 0.775 dB respectively in 10 GHz. Input impedance of these structures are nearly 50 ohm. Since the characteristic impedance is equal to 50 ohm, this result indicates that design of input matching network has been accurate.

Table I. Comparison between the designs of 10 GHz LNAs

LNA types	Gain [dB]	Noise Figure [dB]	Input return loss [dB]	Output return loss [dB]
Fig. 4	15.049	0.806	-9.101	-21.919
Fig. 6	15.049	0.806	-9.101	-21.919
Fig. 9	14.77	0.775	-17.352	-10.246

Table II indicates a comparison between the simulated results with other works. According to table II, Noise figure in [1], [2] and [6] is equal to 1.18 dB, 1.38 dB and 3.5 dB respectively. But noise figure in our study is equal to 0.775 dB. This result indicates noise figure is reduced forty-eight percent in compare with prior literature [1, 2, and 6]. Forward gain (S21) is higher than [1, 2, and 6]. Also, input and output reflection coefficient (S11, S22) of these structures are improved noticeably. To our knowledge, these are the best noise figure performance of any LNAs ever reported at 10 GHZ.

Table II. Comparison with to other reported designs

Reference	F0 [GHz]	Gain [dB]	Noise Figure	Input return loss [dB]	Output return loss [dB]
This work	10	15.049	0.755	-17.352	-21.919
[1]	10	13.14	1.18	-18	-8.78
[2]	10	13.53	1.38	-17.98	-10.016
[6]	10	13	3.5	-16	-27

V. Conclusion

In this paper, LNAs at 10 GHz for communication system have been designed and simulated. We used three different structures for design of LNA at 10GHz. It is observed that the forward gain and noise figure of these designs is almost 15 dB and 0.775 dB respectively in 10 GHz. This results indicate noise figure and forward gain of this structures are improved noticeably with respect to the previous works. The simulation result have good assent with desired demand.

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