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Design and analysis of LNA for RF Wireless Communication at 2 Ghz

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***Abstract*- Progress in the area of RF communication has increased the for low cost, low power and more efficient low noise amplifiers In this paper we present the design of LNA which operates ta a frequency of 2Ghz. This LNA consists of printed circuit board, lumped elements and HiRel K-Band GaAs super low noise High Electron Mobility Transistor (HMET). This circuit is designed in Advanced Design System (ADS) and the analysis shows similar results for the theoretical values and for the simulated values.**

***Keywords*-** *low noise amplifiers, RF, gain, noise figure*

I. INTRODUCTION

The RF industry has seen a drastic change since the days of Marconi. Almost all the mobile communication systems today use radio as a key element. RF application ranges from small devices like cellular phones to huge satellites orbiting around the earth.

Low Noise Amplifier is a basic building block of modern communication and it is the first stage amplifier of radio frequency module. The strength of a signal from an antenna is very weak in practical systems and hence it needs to be amplified before its demodulation. The most common characteristic of LNA is maximum gain with minimum Noise Figure to deal with the above mentioned problem.

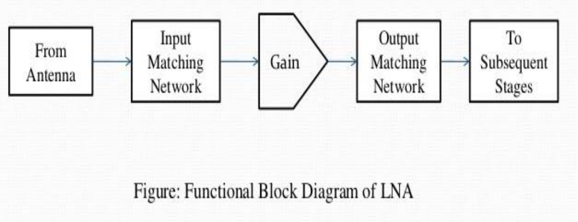

Figure 1: Functional block diagram of LNA

In this paper we design and analyze a single stage LNA using Advanced Designed System (ADS). This LNA comprises of printed circuit board, a High Electron Mobility Transistor (HMET) and lumped elements.

II. DESIGN AND MATHEMATICAL ANALYSIS

In this design, we consider a K-Band GaAs Super Low Noise HEMT as it can amplify small signal at operating frequency around 2 GHz. Before we start designing the LNA, we have set the following requirements so that our LNA design meets the target.

i. Operating range = 1.5 to 2.5 Ghz
ii. Gain > 10 dB
iii. Noise Figure < 3 dB
iv. Return loss for source > 0.1 dB
v. Return loss for load > 1 dB
vi. Power supply = 15V

Before using the HEMT, it needs to be biased at proper operating point. This is done in order to ensure that the HEMT works under the values considered and achieves less power consumption.

By referring to the data sheet we choose V_{ds}=2V, I_{ds}=10mA and choosing V_{gs}=0.52V and I_{BB}=2 mA. Taking V_{dd}=15V.

$$R_3 = \frac{V_{gs}}{I_{BB}} = 260\Omega \tag{1}$$

$$R_4 = \frac{V_{dd} - V_{ds}}{I_{ds} + I_{BB}} = 108.3\Omega \tag{2}$$

$$R_1 = \frac{(V_{ds} - V_{gs})}{V_{gs}} R_3 = 740\Omega \tag{3}$$

Let Z_L=Z_S=Z_0=50Ω

Referring the data sheet we get the S parameters at 2 Ghz as follows:

$$S_{11} = 0.960\angle -39$$
$$S_{21} = 4.282\angle 144$$
$$S_{12} = 0.0460\angle 61$$
$$S_{22} = 0.623\angle -29$$

The reflection coefficient to source, τ_S and reflection coefficient to load, τ_L are given by

$$\tau_S = \frac{Z_S - Z_0}{Z_S + Z_0} \qquad \tau_L = \frac{Z_L - Z_0}{Z_L + Z_0} \tag{4}$$

Since we know that Z_L=Z_S=Z_0=50Ω, $\tau_S = \tau_L$ =0.

The source and load reflection coefficients in order to achieve the maximum power gain of LNA are as follows:

$$\tau_{in} = S_{11} + \frac{S_{12}S_{21}\tau_L}{1 - S_{22}\tau_L} = S_{11} = 0.960\angle -39 \tag{5}$$

$$\tau_{out} = S_{22} + \frac{S_{12}S_{21}\tau_L}{1 - S_{11}\tau_L} = S_{22} = 0.623\angle -29 \tag{6}$$

Power Gain is given by

$$G = \frac{[S_{21}]^2(1-[\tau_L]^2)}{(1-[\tau_{in}]^2)(1-S_{22}\tau_L)} = 233.871 = 23.68dB \tag{7}$$

Another important parameter to be kept in mind during the design is stability of an amplifier. The stability of the LNA can be determined using the equation

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}.S_{21}|} = -0.378 \tag{8}$$

$$\Delta = S_{11}.S_{22} - S_{12}.S_{21} = 0.401 \tag{9}$$

From the data sheet, at 2 Ghz we have the following data for calculation noise figure

NF_{min}=0.31dB, $|\tau_{opt}| = 0.720$

$\angle\tau_{opt} = 30$ R_n=16.55Ω

$$NF = NF_{min} + \frac{4R_n}{Z_0}\frac{[\tau_s - \tau_{opt}]^2}{[1-\tau_{opt}]^2(1-[\tau_s]^2)} = 2.761dB \tag{10}$$

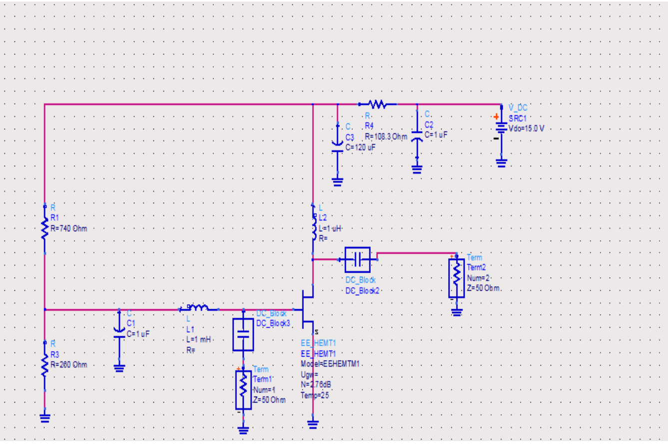

Figure 2: Circuit Diagram of LNA

III. RESULTS AND DISCUSSION

The LNA circuit designed above is simulated in Advanced Circuit Design (ADS) and the results are analyzed at an operating frequency of 2 Ghz.
The table below shows the results of the simulation:

Table I: Parameter and Results

S.NO	Parameter	Result
1	S(1,1)	0.5 dB
3	S(1,2)	-11 dB
4	S(2,1)	14.2 dB
5	S(2,2)	-1.8 dB
6	NF	2.76 dB

The diagrams below show the results of the simulation.

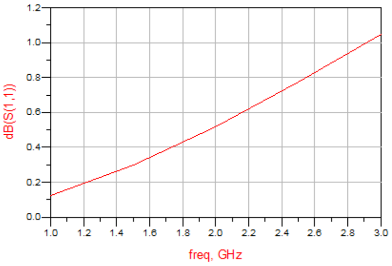

Figure 3: S(1,1) vs Frequency

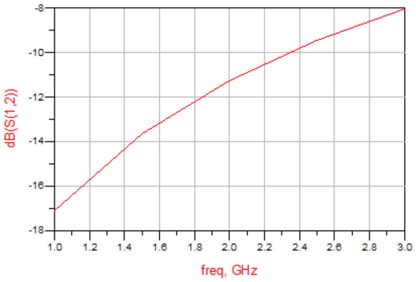

Figure 4: S(1,2) vs Frequency

Figure 5: S(2,1) vs Frequency

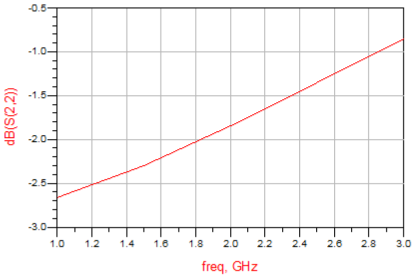

Figure 6: S(2,2) vs Frequency

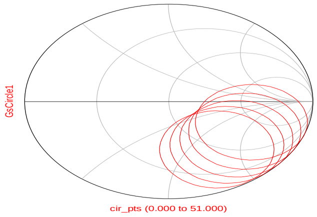

Figure 7: Gain Circle

As K<1 and IΔI<1, this LNA is potentially stable at our frequency of operation which is 2 Ghz. Another important aspect of an LNA design is its gain. It is observed that a maximum gain available on simulating the circuit is 14.2 dB (S2,1) while the theoretical gain is 23.68 dB. S11 parameter which is known as reflection coefficient at source is 0.5 dB, S(1,2) is -11 dB and S(2,2) is -1.8 dB. All the results meet our design specifications which were made prior to the design.

IV. CONCLUSION

In this paper, a low noise amplifier is designed with the required characteristics. A difference in theoretical gain and simulated gain is seen from the comparison of results. Rest of the results of the simulation meet our specifications.

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