

Parametric Performance Analysis of 2-GHz Low Noise Amplifier

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ABSTRACT

In this paper designed, implemented and simulated LNA is divided into two parts. In the first part, LNA is based on lumped elements and in second part LNA is based on distributed elements. Two designed methods have been compared and best performance is obtained with lumped elements. The designed amplifier provides a noise figure of 0.358 dB, gain of 16.778 dB, input return loss is -4.917dB and output return loss is -10.045 dB. LNA is simulated at 2 GHz by employing active device like MESFET sp_hp_ATF34143_4_19990129. Parametric performance analysis is carried out using Advanced Design Simulation (ADS) tool of Agilent Technologies. This paper highlights or shows the all necessary steps or different performance parameters for LNA design.

Keywords – ADS (Advanced Design System), LNA(Low Noise Amplifier), Smith Chart, S-parameters

I. INTRODUCTION

The amplifier is probably the most fruitful of all electronic circuit building blocks in a microwave/radio-frequency (RF) system. For amplification of microwave signals both vacuum tubes and solid state devices (Transistors) are used. Tubes such as klystron and Travelling wave tube (TWT) amplifiers are exclusively used for high-power applications, whereas solid state amplifiers are very suitable for low-noise and medium power levels. Solid state devices generally require low voltage for operation and they are very compact and light weight. These characteristics are particularly useful for space and military applications where weight and size can impose severe limitations on the choice of components and systems [5]. While microwave tube amplifiers are still sometimes required for very high power and/or very high frequency applications, continuing improvement in the performance of microwave transistors is gradually reducing the need for microwave tubes. BJT is used up to certain frequency due to their structure and manufacturing process but FET can be used for higher frequencies. several GHz [3]. Also FET consumes or dissipates less power and requires less area rather than BJT also having better noise immunity than BJT's [8]. There are several kinds of FETs distinguished by the type of gate isolation shown in table 1.1.

Table 1.1 Types of EFTs

Device	Gate Isolation
MOSFET	Oxide (SiO ₂)
JFET	P/n-Junction
MESFET	Schottky barrier diode

When you applied high frequency to MESFET, offers better simulation results also second order effects are less as compared to JFET [9]. The Metal-Semiconductor-Field-Effect-Transistor (MESFET)

consists of a conducting channel positioned between a source and drain contact region. The carrier flow from source to drain is controlled by a Schottky metal gate. The control of the channel is obtained by varying the depletion layer width underneath the metal contact which modulates the thickness of the conducting channel and thereby the current between source and drain. The key advantage of the MESFET is the higher mobility of the carriers in the channel as compared to the MOSFET. Fabrication process of MESFET and JFET is also easy or simple than MOSFET. Hence MESFET sp_hp_ATF-34143_4_19990129 is used in this project to implement and simulate the LNA. Lumped elements (Inductor and Capacitors) and Microstrip, which containing distributed elements (MLIN-Microstrip line and MLOC- Microstrip Open-Circuited Stub) are used to overcome the drawbacks of other methods [4].

II. CIRCUIT DESIGN

In this paper or project circuits is designed and implemented using lumped element and distributed element.

2.1 Lumped elements

Meaning of lumped element is, discrete object that can exchange energy with other, An object whose internal physics can be combined into terminal relations, Whose size is smaller than wavelength of the appropriate and signals do not take time to propagate [15-19].

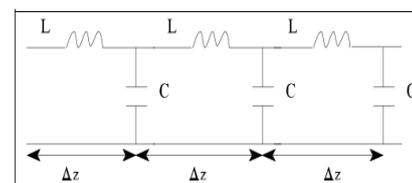


Fig.1 Lumped model [7]

Fig.1 illustrates lumped model where as the L and C are the inductance and capacitance of actual circuit elements. L is in units of inductance per unit length and C in units of capacitance per unit length. Each infinitesimal element of length Δz along the line is a circuit with a total inductance in each Δz of $L\Delta z$ and a total capacitance of $C\Delta z$ [18].

2.2 Distributed elements

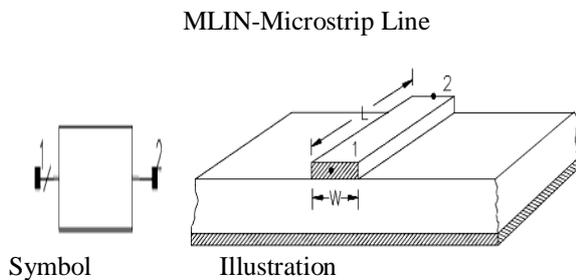


Fig.2 Microstrip Line [7]

MLOC- Micro strip Open-Circuited Stub

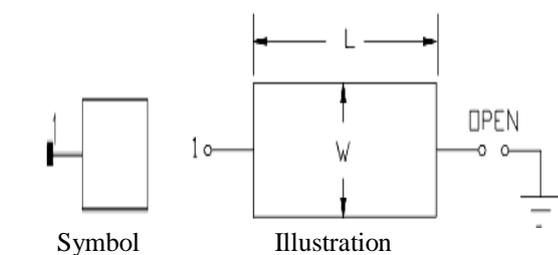


Fig.3 Microstrip Open-Circuited Stub

In microstrips, short-circuit stubs are difficult to realize which means that the open circuit stub often is used.

III. PARAMETRIC PERFORMANCE

We can use the number of parameters to measure the performance of the LNA as per applications or requirements but commonly or generally used parameters are as follows:

3.1 Power Gain (S_{21})

In general gain is a ratio between the output signal and input signal. It shows how much the signal is amplified. LNA is required to achieve a high power gain in order to reduce the effect of noise introduced by the subsequent stages at the receiver front end. Value of the gain should be high. When relation between input-output is linear then it is called as linear gain. However all RF& IF circuits are inherently non-linear [1].

3.2 Noise Figure (NF)

NF is a measure of degradation of the SNR, caused by components in the RF chain. Mathematically, NF is defined as the ratio of the input SNR to the output SNR of the system. NF may be defined for each block as well as the entire receiver [2]. Generally it is not possible to obtain minimum

noise figure and maximum gain for an amplifier, so one compromise must be made. This can be achieved by using smith chart. Fig.4 shows the complete co-ordinate system of the smith chart with proper example. It includes the inductive, capacitive, open and short circuits regions with prime center, resistance axis, reactance axis and resistance circles. The input matching network is designed for minimum NF and output matching network is designed for maximum gain [9-14].

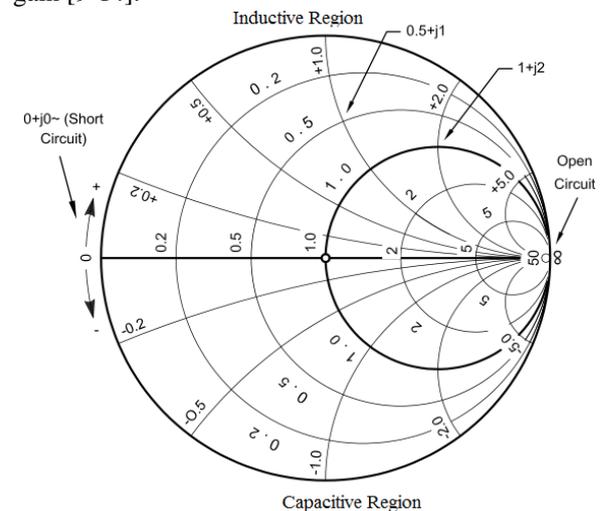


Fig.4 Co-ordinate system of the Smith Chart [17]

3.2.1 Input Return Loss or Input matching (S_{11})

In general, it is difficult to achieve both noise matching and power matching simultaneously in an LNA design, since the source admittance for minimum noise is usually different from the source admittance for maximum power delivery. A simultaneous NF and input matching approach is achieved using a CG input stage along with an inductor to transform the source impedance from 50 ohm to the optimum value for minimum noise. It's typical value should be less than 10dB while maintaining lowest NF. Practical value of the NF should be low. In our LNA minimum NF is achieved 0.358 at 2-GHz frequency.

3.2.2 Output Return Loss or Output matching (S_{22})

It is also required to make sure the output matching network does not change the DC bias of the active device. Since source follower is having very low output impedance, it is very easy to achieve the required output matching without any filter network at the output [14].

3.2.3 Stability

The stability analysis is very important consideration or step in the LNA design or in a microwave circuit design. Stability or resistance to oscillation in a microwave circuit can be determined by the S-parameters. Delta (Δ) is the Intermittent quantity where as k is the rollett stability factor. If $K > 1$ then circuit will be unconditionally stable for any combination of source and load impedance. The K

factor represents a quick check for stability at given frequency and given bias condition [11-13].

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

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

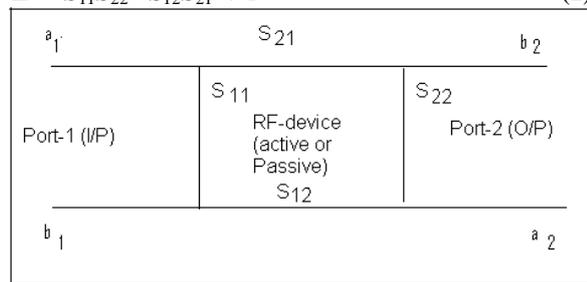


Fig.5 Graphically representation of two-port network

Fig.5 shows graphical representation of S-parameters and representation of two-port network in the form of equations are:

$$b_1 = S_{11}a_1 + S_{12}a_2 \quad (3)$$

$$b_2 = S_{21}a_1 + S_{22}a_2 \quad (4)$$

Where as :

Input Return Loss or Input matching $(S_{11}) = b_1/a_1$

Output Return Loss or Output matching $(S_{22}) = b_2/a_2$

Power Gain $(S_{21}) = b_2/a_1$

Reverse Isolation $(S_{12}) = b_1/a_2$

Each and every transistor having separate S-parameter file for stability analysis of the LNA circuit, designed by the designer's or provided by the manufacturer. Which includes all the parameters mentioned above in proper sequence including frequency, bias conditions (Vds, Id), ratio of R_n/Z_0 , reflection coefficient (Γ) and last updated information [10].

IV. IMPLEMENTATIONS AND RESULTS

In MNDE2 (Matching network distributed element) only exchange of matching networks is done as compare to MNDE1 and performance is carried out.

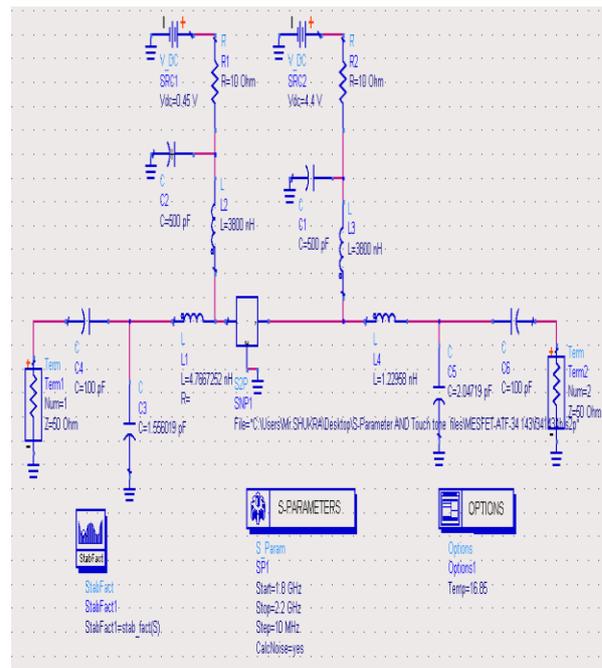


Fig.6 Implementation of LNA using MNLE

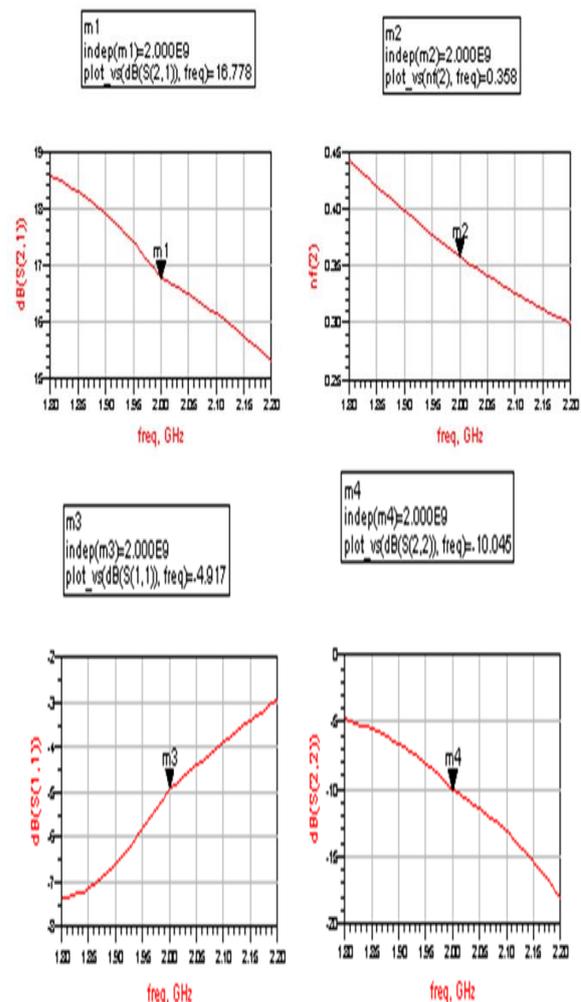


Fig.7 Performance analysis of MNLE-LNA in ADS

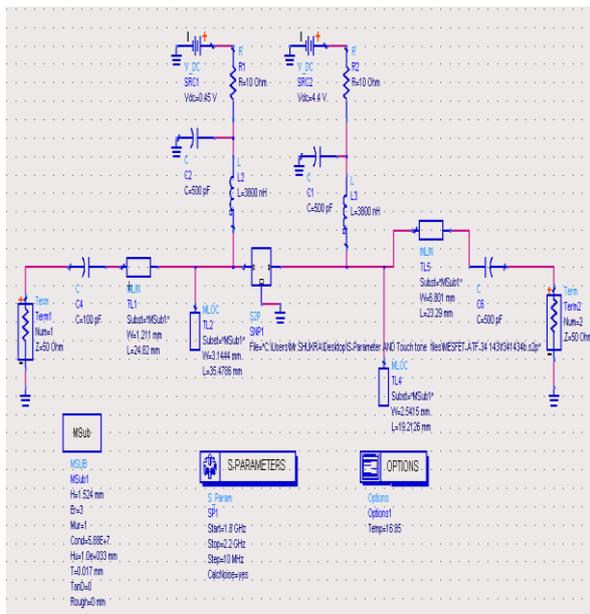


FIG.8 IMPLEMENTATION OF LNA USING MNDE1

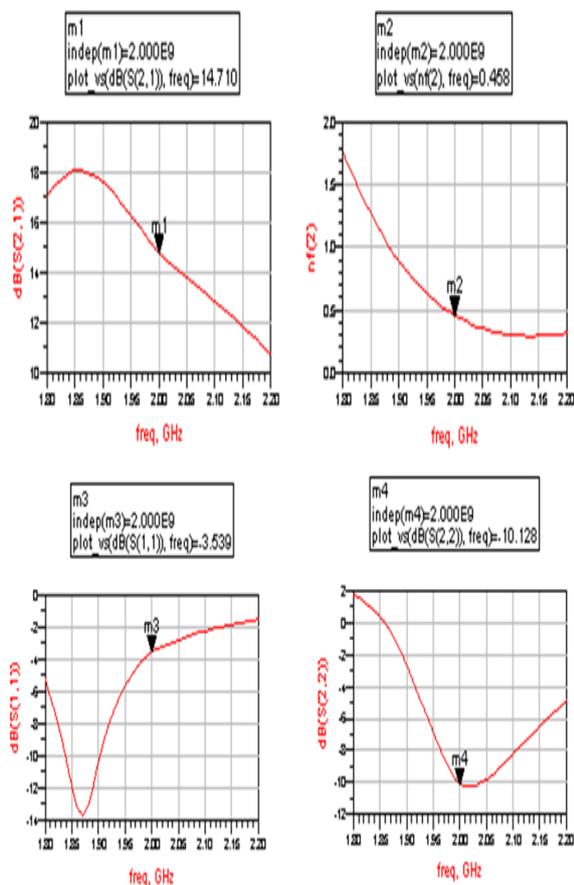


Fig.9 Performance analysis of MNDE1-LNA in ADS

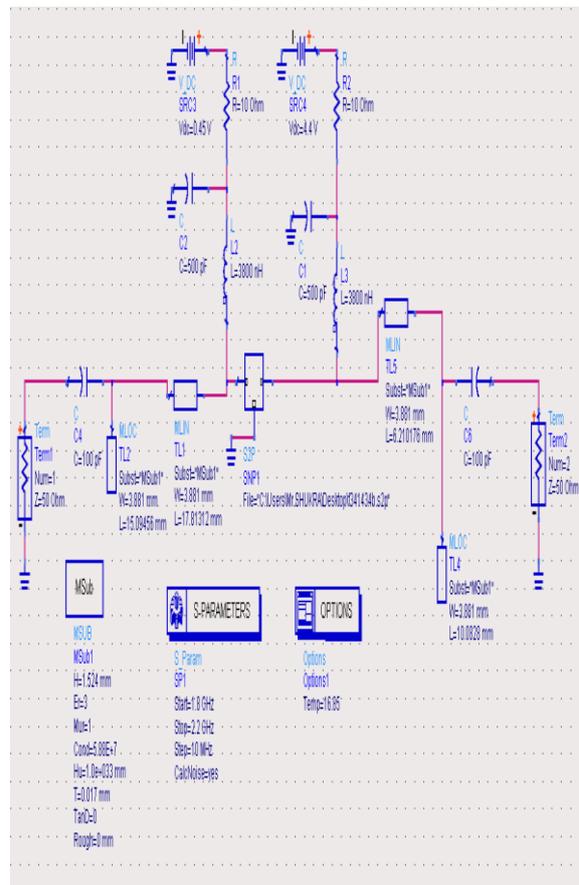


FIG.10 IMPLEMENTATION OF LNA USING MNDE2

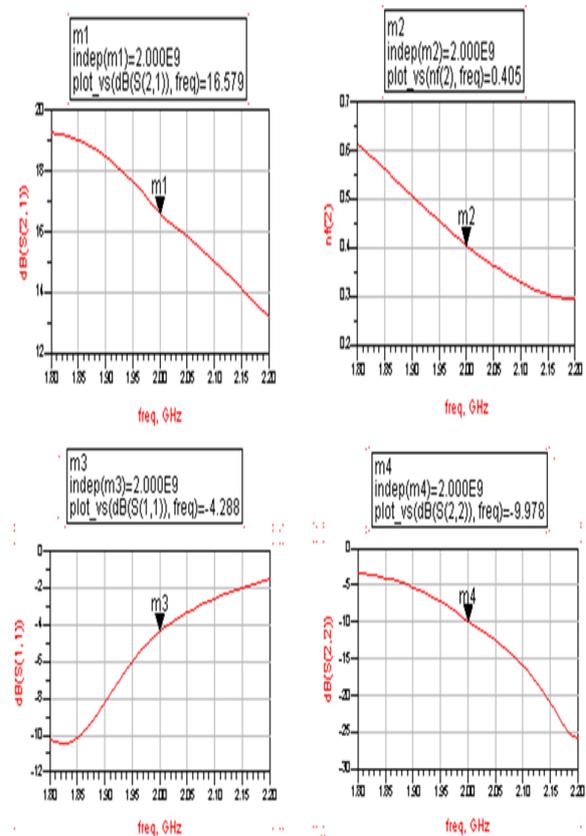


Fig.11 Performance analysis of MNDE2-LNA in ADS

Table-2 Comparison between the designs

Sr. No.	LNA-Parameter's [dB]	LNA-Design Methods		
		MNLE	MNDE1	MNDE2
1	Power gain (S_{21})	16.778	14.710	16.579
2	Noise Figure (NF)	0.358	0.458	0.405
3	Input Return Loss or Input matching (S_{11})	-4.917	-3.539	-4.288
4	Output Return Loss or Output matching (S_{22})	-10.045	-10.128	-9.978

Table-2 indicates two designed methods have been compared and best performance is obtained with lumped elements.

V. CONCLUSION

S-parameters are more applicable at RF due to its ability to express in terms of powers, are suitable for high frequencies and possibility of complete transmission. Smith chart is convenient for circuit calculations and impedance matching circuit design. ADS Simulation tool is best option to implement the RF-circuits. The disadvantages of microstrips like metal's resistivity and dielectric losses in the substrate and also compared with waveguide are the generally lower power handling capacity, and higher losses. Unlike waveguide, microstrip is not enclosed therefore susceptible to cross-talk and unintentional radiation. So we can use waveguide for design of LNA. We can use the HEMT (High Electron Mobility Transistor) or pHEMT (pseudomorphic High Electron Mobility Transistor) to implement the LNA because having some advantages likes ability to increase carrier concentration, channel conductivity, access time. In short Charge mobility of HEMT can attain twice the value of MESFET and frequency of HEMT is almost 100 times fast than MESFET. HEMT find applications up to 60 to 70 GHz. CMOS or SiGe Bi-CMOS technology can be used for fabrication of LNA.

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