Rudimentary Study and Design Process of Low Noise Amplifier at Ka Band

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***Abstract* - This paper presents the fundamental study and literature survey on LNA and Advance Design System (ADS). Low noise amplifier (LNA) is one of the basic building blocks of a communication system. The purpose of the LNA is to amplify the received signal to acceptable levels while minimizing the noise it adds. The low noise amplifier is used in communication systems to amplify very weak signals captured by an antenna. It is often located very close to the antenna thereby making losses in the feed-line less critical. .Gain, noise figure, return loss, P1dB, third order intercept point are most the important parameter in LNA. Here design procedure for LNA is included. The most important task in the design is to establish a tradeoff between the noise figure and gain of the amplifier. Advanced Design Software (ADS) is used to carry out simulations for the design and to see how the design is comparable to the specifications.**

***Keywords*- LNA, Gain, Noise figure, ADS**

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1. INRODUCTION

Millimeter wave band is the main band in military electronic technology, which is mainly used in precision guided, secure communication, radar, electronic warfare and electronic testing and other aspects. A millimeter wave low noise amplifier which is the core circuit of a millimeter wave system is usually applied to the distal end of the millimeter wave receiving system, and it is the key to the receiver to obtain a high sensitivity. Therefore, the development of suitable high frequency band, low noise, high performance amplifier that has become one of the core technology in the design of millimeter wave systems[1].

LNA is designed to meet a number of indicators such as noise figure, gain and input VSWR. Because of the calculation process is more complex, we usually make it by CAD technology. In this paper, we make the simulation and optimization of the circuit through the ADS microwave circuit simulation design software which greatly help us shorten the design cycle and improve design efficiency. Due to significant R&D funding, innovations, processing advancement and electronic circuit developments, the Microwave Monolithic Integrated Circuit(MMIC) has now become commonplace, replacing many discrete circuits with individual transistors, resistors, capacitors, inductors and element interconnections. MMIC circuits show reduced size and cost with higher reliability to meet the needs of today's markets. The pHEMT has outstanding high-frequency characteristics, power characteristics and low-noise characteristics, and it is one of the most competitions in the field of microwave and millimeter-wave monolithic integrated circuits.

The low noise amplifier is the key component in any front end receive chain, which dictates the dynamic range of the receiver. MMIC LNAs with Low noise, high gain, good return loss, low power dissipation, high reliability and compact size are required aggressively for many system applications[2].

2. THE PRINCIPLES OF LNA DESIGN

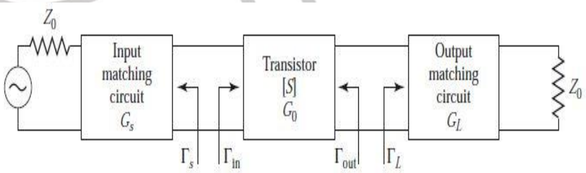

Fig. 1 Block dia. of LNA[4]

A single-stage microwave transistor amplifier can be modeled by the fig 1. Here matching network is used on both sides of the transistor to transform the input and output impedance Z_0 to the source and load impedances Z_S and Z_L. Matching circuit is used to avoid unnecessary loss of power. Reflections are eliminated on the transmission line, this procedure is referred to as tuning.

A. DC BIASING

Biasing a Transistor amplifier is the process of setting the dc (Biasing) operating voltage and current to the correct level so that any ac input signal can be amplified correctly by the transistor. That is by setting its Collector current (Ic) to a steady state value without an input signal applied to the transistors Base, and by the values of the dc supply voltage (Vcc) and the value of the biasing resistors connected the transistors Base terminal. The goal was to select an operating point that would give sufficient output power, have relatively low noise, and operate in the class A region. The correct bias Operating point of the transistor is generally somewhere between the two extremes of operation, that is halfway between cutoff and saturation. This mode of operation allows the output current to increase and decrease around the amplifiers Q-point without distortion as the input signal swings through a complete cycle.

B. STABILITY FACTOR

Amplifier is not reliable when it is instable condition. The stability of a circuit is characterized by stern stability factor. The circuit is stable only when $K > 1$ and $\Delta < 1$. When the input and output reflection coefficients are less than one then we determined the absolute stability factor:

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

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

C. IMPEDANCE MATCHING

Impedance matching at input and output port done by using smith chart technique, by properly adjusting the value of inductance and capacitance at input and output side, we have managed to match impedance with the terminating resistance of 50 Ω. Γ_S and Γ_L is the source and load reflection coefficient respectively. Input and output reflection coefficient is Γ_{in} and Γ_{out} respectively shown in following equations:

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \qquad (3)$$

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1 - S_{11}\Gamma_s} \qquad (4)$$

D. S-PARAMETERS

It is refers to RF output voltage verses input voltage in the RFIC and describes the relationship between the two or more port network.

In the term of RFIC, S_{11} and S_{22} is called reflections coefficient. S_{21} and S_{12} are called transmission coefficient. S_{11} and S_{22} are used to calculate the input and output reflection in the circuits. S_{21} and S_{12} are used to calculate the forward and reverse voltage gain in dB as shown in the figure 2.

S-parameter is one of the important parameter of low noise amplifier.

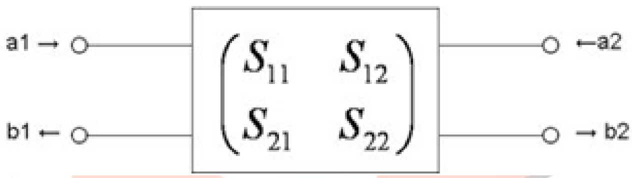

Fig. 2 S-parameters of two port network[2]

E. NOISE FIGURE

Noise figure is the ratio of output SNR to the input SNR.

$$NF\,(dB) = 10\,log NF\,(dB) = 10 \log \frac{SNRi}{SNRo} \qquad (5)$$

In the cascaded form the noise-factor (F) is given as

$$F_{total} = F_{LNA} + \frac{F_{after,LNA} - 1}{G_{LNA}} \qquad (6)$$

F. RETURN LOSS

The characterization of the input and output signal can be shown in more convenient way in the form of return loss when a load is mismatched. This means that all the source power is not delivered to the load. This loss of power is known as “return loss” and can be represented as:

$$RL = -20 \log|\Gamma|\ dB \qquad (7)$$

G. LINEARITY

Linearity of LNA is most important in a wireless receiver to reduce the inter-modulation distortion. The linearity is expressed by the 1 dB compression point and inter-modulation product (IP3). When the input signal is increased, a point is reached where the power of the signal is not amplified by the same amount as the smaller signal at the output. At this point where the input signal is amplified by an amount 1 dB less than the small signal gain, these are called 1 dB compression point. IIP3 (input inter-modulation product) is proportional to the ratio of the first and third derivatives of the transfer characteristic. IIP3 is expressed as:

$$IIP_3 = \sqrt{\frac{4}{3}\frac{g_{m1}}{g_{m3}}} \qquad (8)$$

3. ADS OVERVIEW

Advanced Design System (ADS) is an electronic design automation software system produced by Keysight EEsof EDA, a division of Keysight Technologies. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high speed data links. ADS supports every step of the design process schematic capture, layout, design rule checking, frequency-domain and time-domain circuit simulation, and electromagnetic field simulation.

4. SCHEMATIC AND SIMULATION RESULTS OF LOW NOISE AMPLIFIER

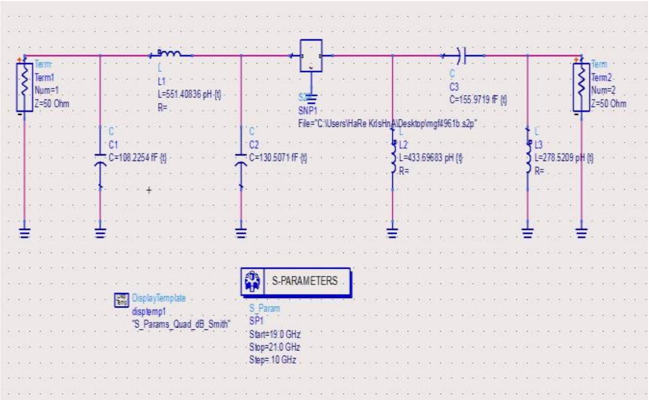

Fig 3. Schematic of LC Matching 1

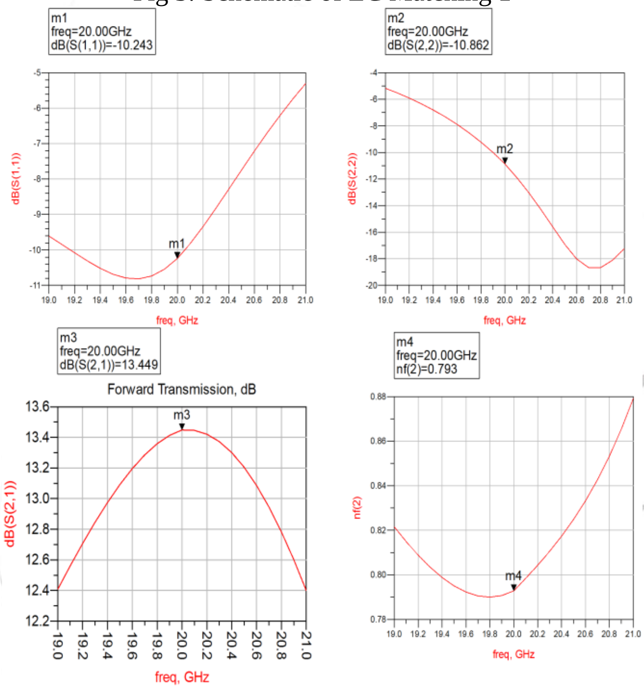

Fig 4. S-Parameter vs. Frequency of LC Matching 1

5. CONCLUSION

Many reference papers for low noise amplifier have been studied and LNA for different types of application at different frequency are designed and simulated. So, finally low noise amplifier is one of the best element in receiver system.

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7. REFERENCE

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