

Design of Low Noise Amplifier at 3.4GHz for Ranging Transponder (IRNSS)

Patel Mehul D

Department of Master Engineering in Communication System Engineering
L.J. Institute of Engineering and Technology, Gujarat Technological University, Ahmedabad, Gujarat, India

Abstract— This paper describes the design and simulation of a single stage Low Noise Amplifier (LNA) at 3.4 GHz frequency. The single stage amplifier is designed by using MGF4941AL super low noise InGaAs HEMT. This low noise amplifier (LNA) is design for application of Receiver Ground Station in Ranging Transponder of Indian regional navigation satellite system (IRNSS). The key points are analysis device's stability with Stability factor and the input and output impedance matching with Smith Chart and Tuning. Finally, the performance parameters of LNA were obtained with the simulation of S parameters. The target simulation are gain (S₂₁) with >15dB, noise figure with <2dB, Input and output return loss <-10dB. A single stage LNA has successfully designed with 18.025dB forward gain (S₂₁), 1.750dB noise figure, -11.040dB input return loss (S₁₁), -10.201dB output return loss (S₂₂) by ADS software.
Key words: low noise amplifier (LNA); ADS software; noise figure; optimization design; IRNSS

I. INTRODUCTION

The low-noise amplifier (LNA), one of the most important blocks in a receiving system, governs the receiving sensitivity of the entire system. Most of the radio frequency (RF) and microwave LNAs are designed in CMOS, BiCMOS, GaAs FET and p-HEMT technologies, and are used in a variety of applications including wireless communication, radio astronomy, RADAR etc.

The requirement of the LNA originates mainly to have the lowest possible noise figure (NF) with a reasonable gain. The general topology of an LNA consists of three stages: the input matching network (IMN), the amplifier itself and the output matching network (OMN). In addition to selection of the appropriate active component, the IMN and OMN are the critical factors in achieving the specified overall amplifier performances.

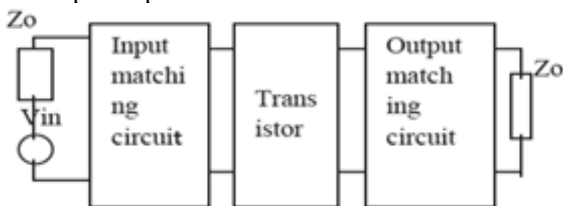


Fig. 1: Block diagram of single stage LNA

This paper presents the design of a single stage LNA working at 3.4 GHz. The circuit design starts with the selection of proper active device for the frequency band of interest. For design and simulation purposes, Advanced Design System (ADS) provided by Agilent Technologies, is used. The S-parameters and noise parameters of the device are included in simulation file.

II. LNA DESIGN

In the designing of low noise amplifiers, the important goals are minimizing the noise figure of low noise amplifier, producing higher gain, lower power consumption and providing good input and output matching.

A. Transistor Selection

In this paper, InGaAs HEMT transistor has been chosen for designing the low noise amplifier. Gallium arsenide is preferred over silicon due to its superior performance at microwave frequencies. It has low noise provides enough amplification and minimum degradation of signal-to noise ratio (SNR).

LNAs are used in various applications like, Cellular Handsets, GPS Receivers, Cordless Phones, and Wireless LANs, Wireless Data, and satellite communications etc. Low noise amplifiers are used in many systems where low-level signals must be sensed and amplified.

In LNA design it is necessary to compromise its simultaneous requirements for high gain and low noise figure, stability, good input and output matching. The proposed low noise amplifier design is carried out with a systematic procedure and simulated by Advanced Design Systems (ADS) designed by Agilent.

MGF4941AL	
Company Name	Mitsubishi
Technology Used	Low noise GaAs HEMT
Frequency Band	S-Band(3.4GHz)
Gain(S ₂₁)	14.618dB
Noise Figure	0.916dB

Table I. Selection Of Transistor

B. Stability Consideration

Before LNA design, it is important to determine the stability of the transistor. The stability of an amplifier is very important in the design and if not taken care, can create self-oscillation of the device due to reflected wave.

Amplifier is not reliable when it is unstable condition. The stability of a circuit is characterized by stability factor. The transistor is stable when $K > 1$ and $\Delta < 1$.

Stability	Criteria
Unconditionally stable	$K > 1$ & $ \Delta < 1$
Potentially unstable	$K > 1$ & $ \Delta > 1$ or $K < 1$ & $ \Delta < 1$

Table 2. Criteria For Stability

Rollet's condition,

$$\text{Stability Factor } K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|}$$

Delta factor $\Delta = S_{11}S_{22} - S_{12}S_{21}$

Parameter	Magnitude	dB
S_{11}	$0.910 \angle -46.66^\circ$	$-0.817 \angle -46.66^\circ$
S_{12}	$0.044 \angle 58.34^\circ$	$-27.052 \angle 58.34^\circ$
S_{21}	$5.381 \angle 129.6^\circ$	$14.618 \angle 129.6^\circ$
S_{22}	$0.600 \angle -34.86^\circ$	$-4.431 \angle -34.86^\circ$

Table 3. S-Parameters Of Transistor

The value of stability Factor (K) is 0.354(K<1). So, the transistor is unstable.

C. Transistor Stabilization

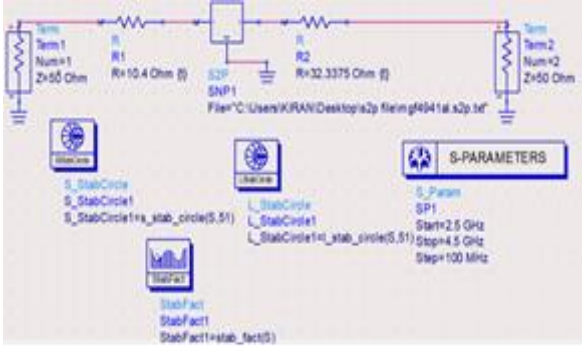


Fig. 2: Transistor stability after connecting source and load resistance

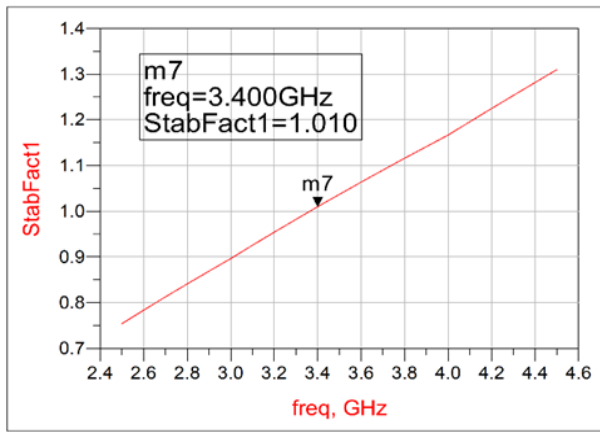


Fig. 3: Stability factor

After connecting source and load resistance at source and load respectively, the value of stability factor (K) is 1.010(K>1). So, now the transistor is in stable region.

D. Impedance Matching Networks

Impedance matching is required to maximize the power transfer and minimize the reflections. Smith chart is used for impedance matching. According to maximum power transfer theorem, maximum power delivered to the load when the impedance of load is equal to the complex conjugate of the impedance of source ($Z_S = Z_L^*$).

A minimum noise figure and maximum gain can never be obtained simultaneously. So constant noise figure circles, together with constant available power gain circles are drawn on the Smith chart, from which reflection coefficients can be selected that compromise between the noise figure and gain performance. In the present communication, the stabilized amplifier is simulated to obtain the best noise matched at the input side and gain matched at the output side. The most critical part is the input stage where a 50 Ω input line has to be transferred into complex impedance varying with frequency. This complex impedance should also be as close as possible to the value

optimized for the best noise performance of the transistor. To reduce the size of the circuit, low impedance shunt stubs and high impedance series stubs have been employed.

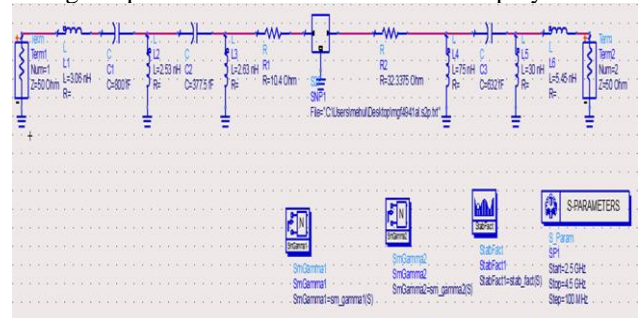


Fig. 4: LNA Circuit

E. Simulation Circuits & Results

By using Advance Design System (ADS) software design a Low Noise Amplifier. The Schematic diagram and simulation results of LNA are shown in figures(4-8).

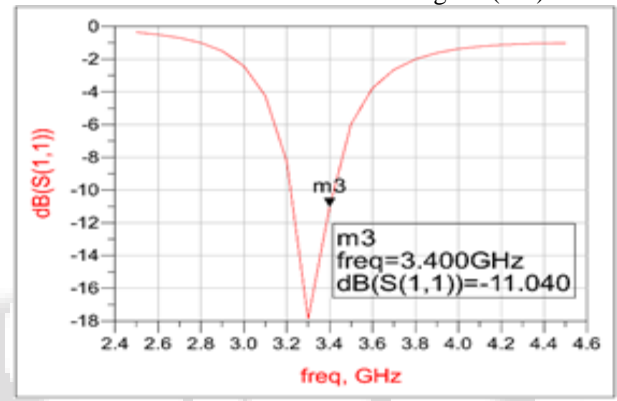


Fig. 5: Input Return loss

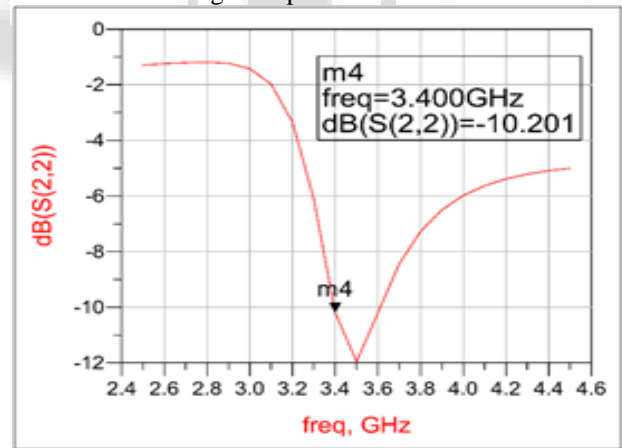


Fig. 6: output Return loss

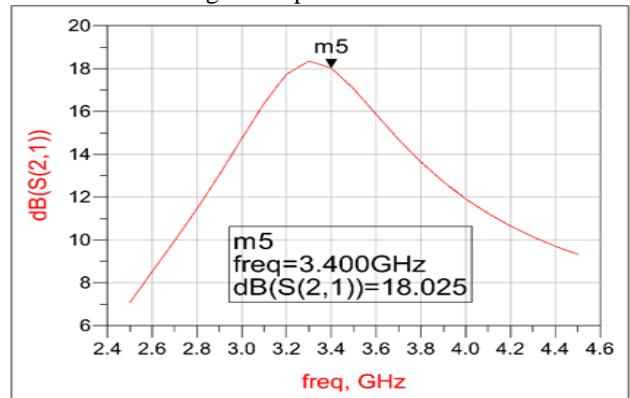


Fig. 7: Gain

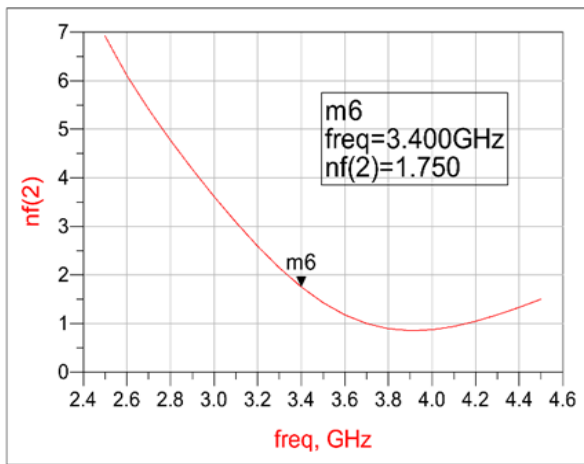


Fig. 8: Noise Figure

III. MEASURED RESULTS

The complete schematic of the Low Noise Amplifier is shown in Figure 4. The performance results are shown in the Figure 5,6,7,8.

PARAMETERS	RESULTS
Input Return Loss(S_{11})	-11.040dB
Output Return Loss(S_{22})	-10.201dB
Gain(S_{21})	18.025dB
Stability Factor(K)	1.010
Noise Figure	1.750dB

Table 4. Measured Results

IV. CONCLUSION

A single stage low noise amplifier working at 3.4 GHz frequency is presented. The noise figure and gain of the prototype LNA is measured as 1.750 dB and 18.025 dB respectively. The measured results are in good agreement with simulated results. While all the target specifications are met, the input return loss is lower than the desired one.

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