

Design Of Low Noise Amplifier At 4 Ghz

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Abstract. In first stage of each microwave receiver there is Low Noise Amplifier (LNA) circuit, and this stage has important rule in quality factor of the receiver. The design of a LNA in Radio Frequency (RF) circuit requires the trade-off many importance characteristics such as gain, Noise Figure (NF), stability, power consumption and complexity. This situation forces designers to make choices in the design of RF circuits. In this paper the aim is to design and simulate a single stage LNA circuit with high gain and low noise using GaAs FET for frequency of 4 GHz. The design simulation process is done using ANSOFT designer. A single stage LNA has successfully been designed with 8.53 dB forward gain and 1.26 dB noise figure at frequency of 4GHz.

Keywords. LNA, S-Band, Ansoft, GaAs FET

1. Introduction

Amplification is one of the most basic and prevalent microwave circuit functions in modern RF and microwave systems. Microwave transistor amplifiers are rugged, low cost, reliable and can easily be integrated in both hybrid and monolithic integrated circuitry. Transistor amplifiers can be used at frequencies in excess of 100GHz in a wide range of applications requiring small size, low noise figure, broad bandwidth and low to medium power capacity. The design techniques used for BJT and FET amplifiers employ the full range of concepts developed in the study of microwave transmission lines, two-port networks and Smith chart presentation. Our discussion of transistor amplifier design will rely on the terminal characteristics of transistors as represented by S-parameters. To amplify the received signal in a microwave system, a low noise amplifier (LNA) is required. Because any noise injected by components in a system is amplified by later gain stages along with the signal, it is essential that the signal be amplified early in the receiver chain while adding as little noise as possible. The goal of this is to design an LNA with lowest noise figure possible, with gain as high as possible for the given FET and information.

The operating frequency of the design is 4 GHz. Substrate used is Duroid 5880 with $\epsilon_r = 2.20$, 0.020 inch, 0.5 oz copper. The design utilizes one high-performance low noise GaAs FET transistor. The design is simulated and optimized in ANSOFT.

1.1. Single Stage Amplifier

A single stage microwave transistor amplifier can be modeled by the circuit in Fig. 1, where a matching network is used both sides of the transistor to transform the input and output impedance Z_O to the source and load impedance Z_S and Z_L . The most useful gain definition for amplifier design is the transducer power gain, which accounts both source and load mismatch. Thus, we can define separate effective gain factors for the input (Source) matching network, the transistor itself and the output (load) matching network as follows:

$$G_s = \frac{1 - |\Gamma_s|^2}{|1 - \Gamma_s \Gamma_{IN}|^2} \quad (1)$$

$$G_o = |S_{21}|^2 \quad (2)$$

$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2} \quad (3)$$

Then the overall transducer gain is

$$G_T = G_S G_O G_L \quad (6)$$

The effective gains from G_S and G_L are due to the impedance matching of the transistor to the impedance Z_0 .

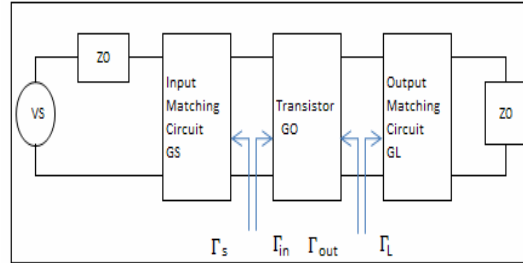


Fig1: General transistor amplifier circuit.

1.2. Stability Consideration

The stability of an amplifier, or its resistance to oscillate, is a very important consideration in a design and can be determined from the S parameters, the matching networks, and the terminations. The stability condition of an amplifier circuit is frequency dependent. In the circuit Fig. 2, oscillations are possible when either the input or output port presents a negative resistance. This occurs when $|\Gamma_{in}| > 1$ or $|\Gamma_{out}| > 1$. This is because Γ_{in} and Γ_{out} depends on the source and load matching networks. The stability of the amplifier depends on Γ_S and Γ_L as presented by the matching networks. Alternatively, it can be shown that the amplifier will be unconditionally stable if the Rollet's necessary and sufficient conditions are met :

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{11}S_{22}|} > 1 \quad (7)$$

1.3. Noise Figure Considerations

Besides stability and gain, another important design consideration for a microwave amplifier is its noise figure. In receiver applications, it is often required to have a preamplifier with as low a noise figure as possible, as the first stage of a receiver front end has the dominant effect on the noise performance of the overall system. The noise figure parameter, N, is given by

$$N = \frac{F - F_{min}}{4R_N/Z_0} |1 + \Gamma_{opt}|^2 \quad (9)$$

Where, the quantities F_{min} , Γ_{opt} and R_N are the characteristics of the transistor being used and are called the noise parameters of the device.

1.4. Matching Network

The impedance matching network is lossless and is placed between the input source and the device. The need for matching network arises because amplifiers, in order to deliver maximum power to a load, or to perform in a certain desired way must be properly terminated at both the input and the output ports.

The impedance matching networks can be either designed mathematically or graphically with the aid of Smith Chart. Several types of matching networks are available, but the one used in this design is open single stubs whose length is found by matching done using Smith chart manually.

2. Analytical Analysis of the LNA

The device used here to design the LNA is a GaAs FET whose S-parameters at 4GHz ($Z_0=50\Omega$) is given below

	Magnitude	Angle
S_{11}	0.6	-60°
S_{12}	0.05	26°

S_{21}	1.9	81°
S_{22}	0.5	-60°

Table 1. S-Parameters of GaAs FET for 4GHz

The noise parameters are $\Gamma_{opt}=0.62 \angle 100^\circ$, $F_{min}=1.6\text{dB}$, $R_N=20\Omega$.

The stability calculations below show that this transistor is unconditionally stable since $K>1$ and $|\Delta|<1$.

From calculations using equation (7) and (8), $K=2.86$ and $\Delta=0.392 \angle -116^\circ$. $K>1$ and $|\Delta|<1$, hence the transistor is unconditionally stable.

The noise figure parameter N is calculated as 0.0986 from equation (9).

In order to obtain minimum noise figure, the reflection coefficient Γ_S looking into the source is matched to Γ_{opt} and is found to be

$$\Rightarrow \Gamma_S = 0.62 \angle 100^\circ$$

With Γ_{IN} is set to be the conjugate of Γ_S the reflection coefficient looking into the load is shown below.

$$\Rightarrow \Gamma_L = 1.55 \angle -282.66^\circ$$

The value of Γ_S and Γ_L is then used for the design of the input and output matching networks using smith chart. They are designed using open shunt stubs.

Thus the Transducer Power gain is equal to the available Power gain and its value is observed to be 8.53 dB. This is a reasonable high gain. As a conclusion, with minimum noise level achieved at the input, the transistor can still produce high gain at the operating frequency.

3. Simulation Results

The calculation done in the previous section are checked with simulations using Ansoft Designer SV.

The schematic of the design is shown in Fig.2.

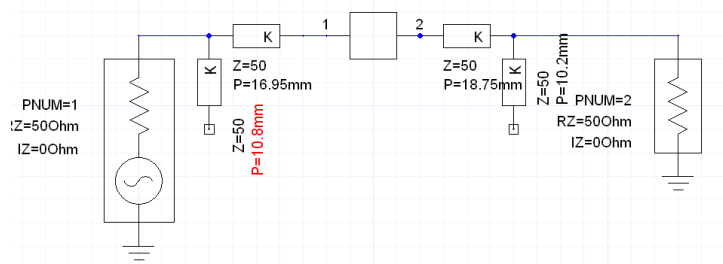


Fig.2. Schematic of Amplifier In Ansoft Designer SV

The forward gain is plotted in Fig.3 which shows the gain to be 8.4 which agrees well with the design.

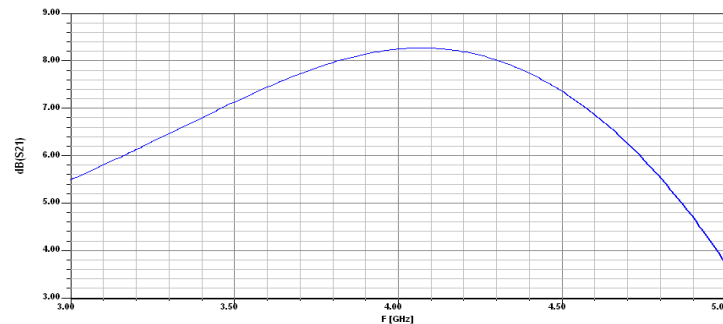


Fig 3. Gain of the amplifier

The reflections at the input(S11) and output(S22) are plotted in Fig.4.

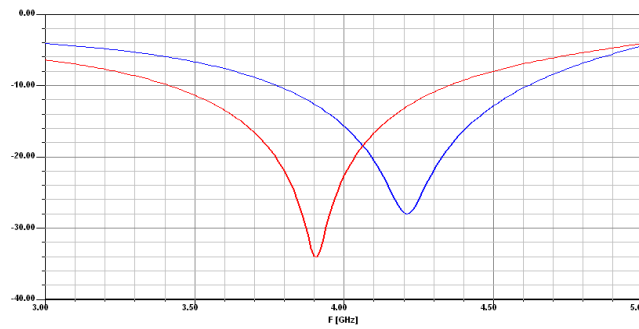


Fig.4.reflections at the input(S11) and output(S22)

4. Conclusion

In this paper, a new Low Noise Amplifier (LNA) circuit design for frequency of 4 GHz is presented and circuit simulation were done in Ansoft Designer SV. LNA has successfully developed with 8.36 dB gain and 1.6 dB noise figure at frequency 4GHz.

5. References

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