Design of X-BAND LNA at 10 GHZ

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Abstract:
This project presents LNA design at X band frequency of 10 GHz for conditionally stable condition and unconditionally stable condition. The gain of 15.121dB and noise figure minimum of 0.593 dB, has been obtained for single stage design. The gain obtained at conditionally stable design is higher when compared to existing systems. The s-parameter analysis and noise figure analysis has been made keeping the impedance of the circuit matched to 50 ohms. The input port reflection coefficient and the output side reflection coefficient of both conditionally stable and unconditionally stable design are very good aspects of the design compared to many of the existing systems. The X band LNA at 10GHz are present in receiver circuits of amateur radio, amateur satellite, motion detectors, radars and missile guiding systems. Best example of X-band application is DRDO’s Battle field Search Radar (BFSR) which works at 10GHz to 20 GHZ. The demand of LNA increases due to the development of the modern technologies such as RADAR, Black-box of airplanes, GPS, Bluetooth, cell phones etc.

Keywords: X-band, LNA, 10GHZ, Noise figure, S-parameters, Unconditionally stable.

I. INTRODUCTION

LNAs are found in radio communications systems, medical instruments and electronic equipment. They are employed in applications involving low amplitude signals such as many types of transducers and antennae. Although LNAs are primarily concerned with weak signals that are just above the noise floor, they must also consider the presence of larger signals that cause distortion. The demand of LNA increases due to the development of the modern technologies such as RADAR, Black-box of airplanes, GPS, Bluetooth, cell phones etc. It is quite obvious that certain applications, like deep space communications, radio astronomy or geodetic VLBI, need receivers with the ultimate sensitivity and noise performance. Today, most of the receivers in these applications use a cryogenic amplifier with GaAs high electron mobility transistor (HEMT) devices in the front-end. In paper [1] Silicon-germanium (SiGe) heterojunction bipolar transistor (HBT) technology has been utilized to provide band gap engineering to improve transistor performance while simultaneously maintaining strict compatibility with conventional low-cost Si CMOS manufacturing. The design at 10GHZ provided a 11.49dB gain, noise figure of 3.84dB,input return loss of 15.35dB and output return loss of -17dB. At 5.8GHZ, device produced a voltage gain of 16.07dB, noise figure 3.07 dB, input return loss of -18.1 dB and output return loss of -15.23dB. In paper [2] X-band is used for near space radar applications. It makes use of Si-Ge HBT technology to provide a gain of 9.5 GHZ, a noise figure of 2.78dB power dissipation of 2.5Mw. In paper [3] CMOS technology has been used. A method of noise match optimization with respect to base inductance in SiGe LNA design with large transistors is proposed. The paper works for two bands X, K bands at 8.5GHZ and 19.5 GHZ respectively. For X-band, the noise figure is 1.2 dB, power consumption is 32.8mW. For K-band its power consumption is 22.5mW. In paper [4] the active device chosen is HEMT (high electron mobility transistors). This is a cryogenic X-band used for deep space application. The device has an noise temperature of 4.8 and noise figure of 0.07 dB. Its power dissipation is 2mW per stage. In paper [5] X-band LNA is designed for police radios. This has a power gain of 13.051dB and noise figure of 1.468dB. The minimum VSWR is 1.007 at source side and at load side it is of 1.022. In this paper HEMT has been opted as active device, a single stage design has been proposed in order to reduce the noise figure. The centre frequency of X-Band 10GHZ has been utilized for the design and analysis of the design. Here proposed design is made for conditionally stable and unconditionally stable conditions.

II. PROPOSED DESIGN

A single stage with HEMT based amplifier design is proposed. The system makes use of common source topology in order to obtain a good gain and reduced noise figure. The design is also making use of inductive degeneration which will further increase gain and reduces noise figure. The advantage with single stage is that the noise figure is minimum. As we know that noise figure will increase with stages by the Frizz formula. Advantages of HEMTs are that they have high gain and high switching speeds, which are achieved because the main charge carriers in MODFETs are majority carriers and minority carriers, are not significantly involved. The HEMT have extremely low noise values because the current variation in these devices is low compared to other FETs. Advanced Design System is the world’s leading electronic design automation software for RF, microwave, and high speed digital applications. In a powerful and easy-to-use interface, ADS pioneers the most innovative and commercially successful technologies, such as X-parameters and 3D EM simulators, used by leading companies in the wireless communication &

![Figure 1. Proposed system](image-url)
Networking and aerospace & defense industries. The main perks using ADS (Advance Design System) are accuracy, reliability and simulation of lumped components. This paper presents a lumped component design.

III. DESIGN STEPS

De analysis

De biasing is done for the active component chosen to understand the bias characteristics of the active component. i.e HEMT

Figure 2.a. Biasing of active component

Figure 2.b. Bias curve

S-Parameter

The proposed schematic of system is converted into Amplifier symbol for simplicity of the spatial requirements using symbol generator tool of ADS. The symbol is terminated with 50 ohm in order to find impedance of the circuit.

Figure 3.a. Symbol generation

Figure 3.b. bTermination of amplifier for impedance calculation

After simulation by plotting the S(1,1) in smith chart, Frequency= 10.0GHz
S(1,1)=0.913/-125.829
Normalized Impedance =Z0(-0.05744-j0.51008)
=2.872-j25.504
Where Z0 =50ohm

1. Using Smith chart utility window the impedance of the circuit is matched to 50 Ohms. After matching the impedance using smith chart, the lumped components necessary are added to the main design.

Figure 4. After matching impedance for conditionally stable

2. The s-parameters are obtained by simulating the design.

3. The stability factor, noise figure and gain are other important factors plotted after simulating.

IV. SIMULATED RESULTS AND DISCUSSION

S-PARAMETERS

The s-parameters simulations of the design is obtained and depicted using ADS as below and the marker is placed at frequency of interest i.e 10GHZ

S-PARAMETERS FOR CONDITIONALLY STABLE DESIGN

Figure 5. Input side reflection coefficient

Figure 6. Reverse voltage gain

Figure 7. Forward voltage gain
S-PARAMETERS FOR UNCONDITIONALLY STABLE DESIGN

STABILITY
At 10 GHz the stability factor $K$ of the amplifier is 0.264. The stability factor at load is 0.496 and at source is 0.167 for stable design. While the stability factor is 2.380 and $\mu$ is 1.726. The figure below, gives the trace of $K$ and $\mu$ factor for stable and unconditionally stable designs.

NOISE FIGURE

\[
NF = 10 \log_{10} \frac{S_i/N_i}{S_0/N_0}
\]  

(1)[1]

Where

- $S_i$, $S_o$: input and output signal
- $N_i$, $N_o$: input and output noise signal

The minimum noise figure of the design is 0.539 dB at 10 GHz. For stable design it is 2.466 dB.
The common source topology gives a good power gain value with minimum noise figure of 0.593 dB for conditionally stable design. In conditionally stable design we obtained power gain of 12.121 dB (3 dB power gain). The input side reflection and output side reflection are kept minimal, which is good aspect of the design. The unconditionally stable design provides good input side and output side reflection coefficients. The stability factors both μ and k are greater than 1 for unconditionally stable design.

VI. FUTURE SCOPE

From the two designs we could infer that both conditionally stable and unconditional stable has good s-parameters. When it comes to gain there is reduced value in case of the unconditionally stable design. In case of stability over wide range of frequencies, the unconditionally stable amplifier is supreme. Adding cascaded stage will increase the gain of both amplifiers with increased noise figure. Inductive degeneration will increase the gain.

VII. REFERENCES


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