The Eurasia Proceedings of Science, Technology,
Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2022

Volume 21, Pages 196-201

IConTES 2022: International Conference on Technology, Engineering and Science

Design of Dual-Stage Ku- Band Low Noise Amplifier for Satellite Downlink Application

Naman Chetan RAJDEV
Pes University

Lasya V
Pes University

Rashmi SEETHUR
Pes University

Abstract: This paper presents the design methodology of a Low-Noise Amplifier (LNA) with a dual-stage structure. It is implemented using ultra-low-noise Pseudomorphic High Electron Mobility Transistor (PHEMT) (ATF-36077). The LNA is biased at a Vds of 3.3V with an Id of 0.029A for which 0.095W of power is consumed. A common source mode design is employed and a matching circuit is implemented using microstrip lines. The circuit adopts a single-ended dual-stage solution connected by a coupling capacitor. The amplifier provides an average forward gain (S21) of 19.944dB. It has an input and output return loss of -11.167dB and -13.099dB respectively. The Noise Figure variation at the operational frequency is 1.507dB. Ku-Band satellite applications have experienced a sharp rise in the past few years in the communication domain and a low noise amplifier is an essential element in satellite front-end applications. The designed LNA is suggested for applications in satellite downlink communications as it has an operational frequency of 11.5 GHz.

Keywords: KU-band, Low noise amplifier, Satellite dowlink application, Gallium arsenide

Introduction

With the evolution of mankind, the terrain of exploration has expanded beyond the earth into space as well. Over recent years, immense advancements in technology have resulted in a large number of satellites being launched into space. These satellites however have to be in contact with the earth. Downlink satellite communication is essential for the transmission of information from these satellites to the earth.

LNA finds applications in satellite communication systems where it is used in ground station's receiving antennas. A communication satellite is used for the purpose of receiving and retransmitting signals from the earth. Signals received from the satellites are weak as a consequence of the limited power of the satellites and their distance from the earth. LNAs are used to amplify these weak RF signals at the receiver with minimal distortion. The employment of LNA here helps to overcome feed line losses between the antenna and receiver.

A low noise amplifier (LNA) is an amplifier specifically used to amplify very low-power signals without loss of information. A typical amplifier would amplify both the signal and the noise in the input while introducing some additional noise as well. LNAs are designed to prevent degradation of the signal-to-noise ratio thus resulting in reduced additional noise. This is achieved by adopting appropriate circuit topologies and using low-noise components. Typically, an LNA configuration includes an input-matching network, a transistor amplifier, and an output-matching network as shown in Figure 1.

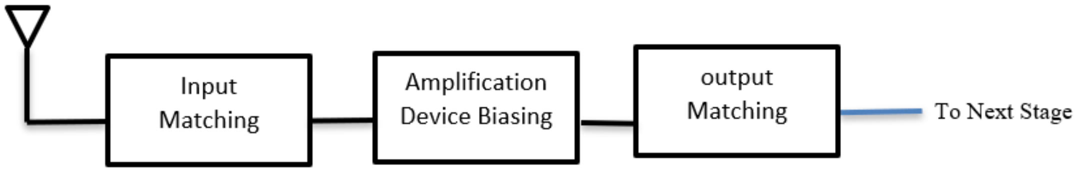

Figure 1. LNA configuration

The performance of the LNA is evaluated based on several crucial parameters. These parameters include input and output impedance matching, noise Figure (NF), gain, etc. These parameters will also influence power consumption and signal bandwidth.

This paper presents the design of a Ku-band low-noise amplifier (LNA), with an operational frequency of 11.5GHz, with its application in the Ku-Band satellite communication channel. The LNA is implemented using pHEMT (pseudomorphic high-electron-mobility transistor) technology. The transistor chosen is ATF-36077 which is acknowledged for its ultra-low noise capabilities. A 2-stage amplifier structure is chosen for this purpose(Bishoyi,2015). Keysight's ADVANCED DIGITAL SYSTEM (ADS) is used to simulate the LNA and parameters such as gain(S21), input return loss(S21), output return loss(S22), and noise Figure(nf2) are calculated. According to the results, the LNA has noise Figure(nf2) of 1.507dB and a forward gain of 19.944dB. Microstrip lines are used to implement the low noise amplifier (LNA) as they help in providing a low return loss(Venkatesh Murthy, 2020). Resistors and inductors are used in the design to provide stability. A dual-stage design is adopted to improve the forward gain.

Method

Design Implementation

The 95mW Ku-band low noise amplifier (LNA) has been designed using ATF-36077 pHEMT transistor from Hewlett Packard's. On analysis of the basic parameters for the transistor from the vendor's datasheet, it is observed that the operating frequency is from 2GHz-18GHz. Therefore, an operating frequency of 11.5GHz is chosen thus comfortably placing it in Ku-Band and satisfying the satellite downlink applications. The selected device offers a low noise figure of 0.5 dB at 12GHz. The operating voltages for gate and drain bias are fixed at 0V and 3.3V respectively resulting in an operating current Id of 0.029A.

Then the basic biasing circuit is constructed and simulated. The simulation results are shown in Figure 2. Parameters like gain, noise figure, stability, input reflection coefficient, and output reflection coefficient are plotted. It can be observed from Figure 2 that the device is unstable because its mu factor is less than 1. The transistors are conditionally stabilized using a resistor of suitable value on the output side. Input and output impedances are matched using transmission lines aiding in better noise figure. The stage one low noise amplifier is given in Figure 3. Its outputs are presented in Figure 4. Although the parameters obtained are satisfactory, the forward gain is too low for any practical application, hence we opt for a dual-stage structure. In order to ensure stability, source degeneration is used in the dual-stage LNA with 1.6nH inductors at the source. The biasing circuit is extended to a dual-stage using a capacitor of 0.5pF to increase forward gain while maintaining conditional stability. The stability is further ensured with the usage of a 47 Ohm resistor at the output. The gate and drain bias consist of a 2.2 Ohm resistor and 1.8nH inductor respectively. A 3-stage T circuit consisting of transmission lines is used at the input to act as a DC block and serves for input impedance matching. The output of the device is a T circuit consisting of transmission lines that acts as the DC Block and serves for output impedance matching. The stage two low noise amplifier is given in Figure 5.

Results and Discussion

The input impedance for the dual-stage is 62.733-j23.095ohm at 11.5GHz. Similarly, the output impedance is 7.319-j4.721ohm at 11.5GHz. The input and output impedances are matched using transmission lines. The source impedance of 62.733-j23.095ohm is matched to 50 ohms and the resulting transmission lines are converted to microstrip lines. Similarly, 50 ohms is matched to output impedance 7.319-j4.721ohm. The input and output impedances obtained after matching are shown in Figure 6. We then proceed to convert the transmission lines to microstrip lines and replace all the ideal components such as resistors, capacitors, and inductors to vendor-provided components. The input and output impedance matchings are given in Figure 7 and

Figure 8 respectively. The outputs for the dual-stage LNA after the previously mentioned conversions are given in Figure 9. We now come to the last stage of the design process which is making a layout. A layout is generated for microstrip lines and an adequate gap is left in between them to accommodate the other components such as a transistor and resistors. This layout of the microstrip lines is run for EM simulation and it is replaced into the actual schematic for which we run the co-simulation. This schematic for co-simulation is given in Figure 10. Results for the co-simulation are given in Figure 11.

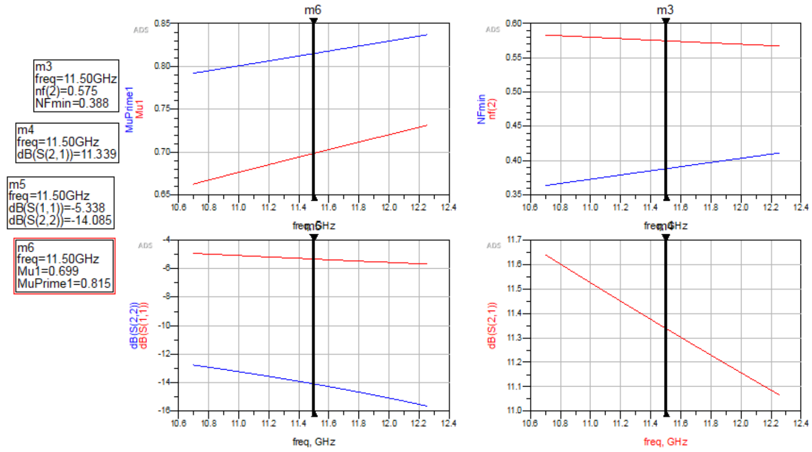

Figure 2. Outputs of biasing circuit

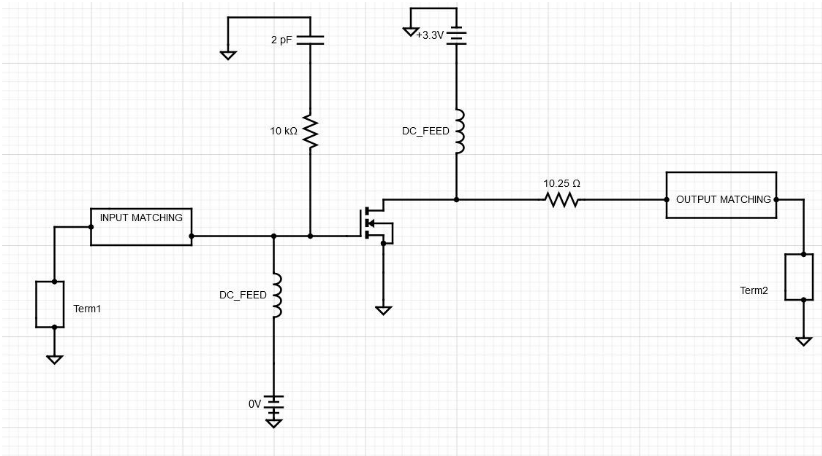

Figure 3. Single-stage LNA schematic

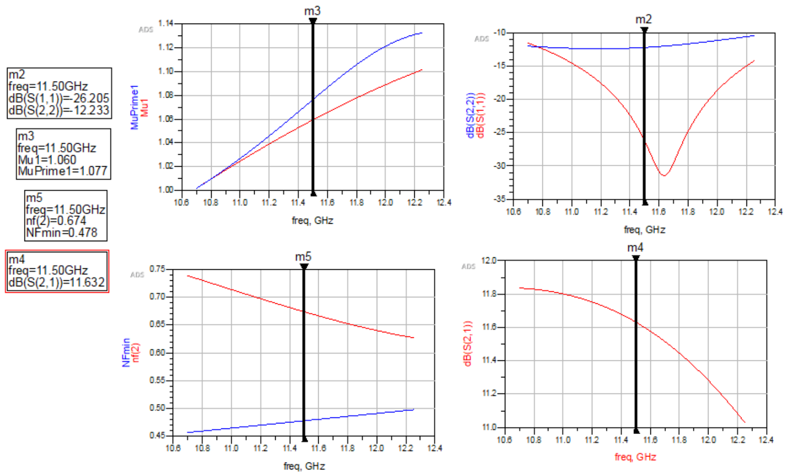

Figure 4. Outputs of single-stage LNA

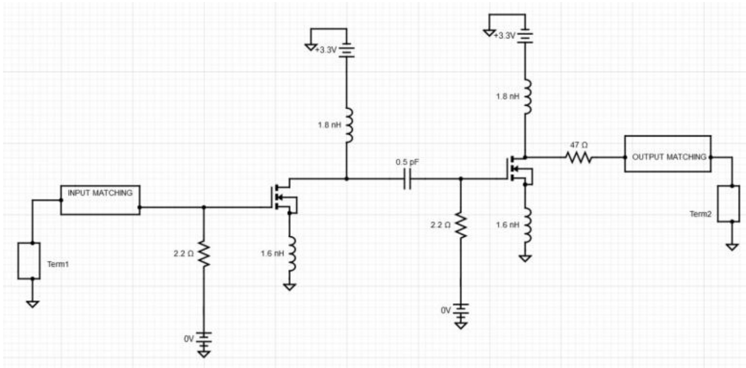

Figure 5. Dual-stage LNA schematic

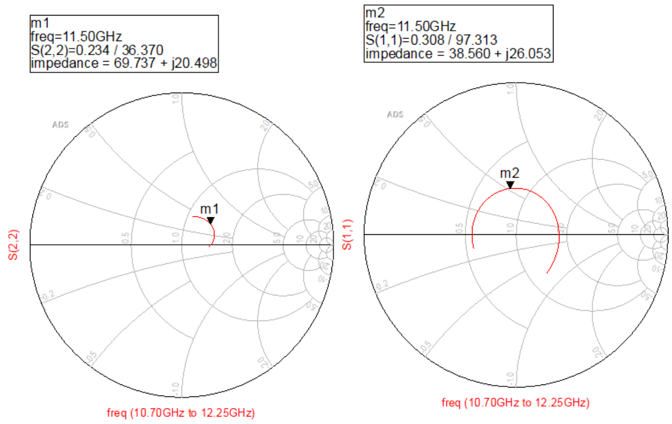

Figure 6. Input and output impedances after matching

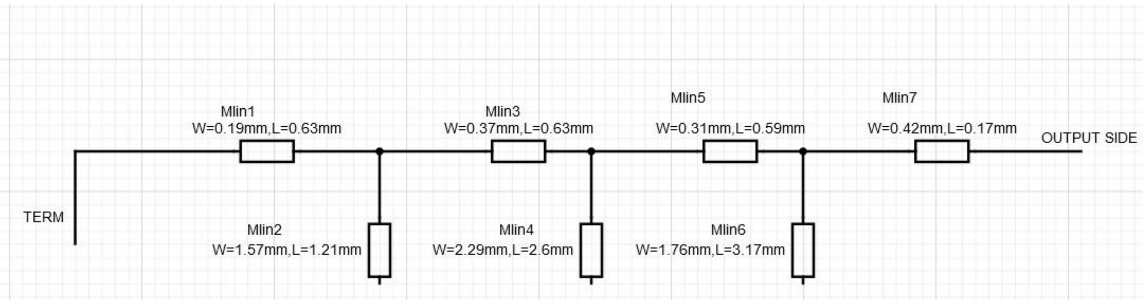

Figure 7. Input impedance matching

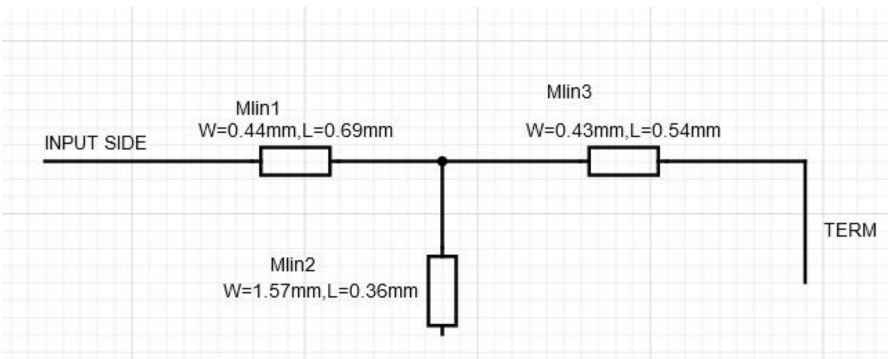

Figure 8. Output impedance matching

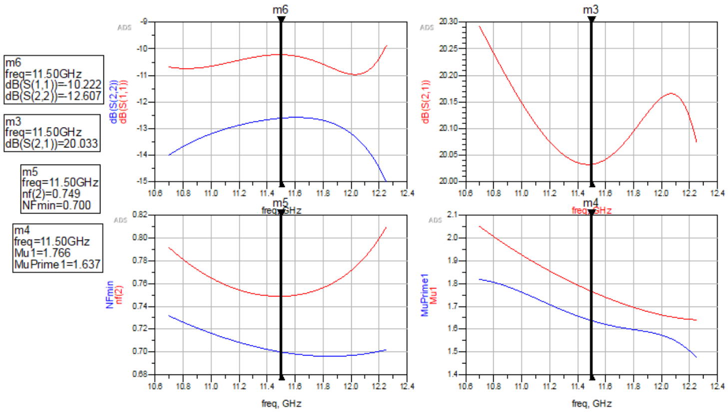

Figure 9. Outputs of dual-stage LNA with vendor components and microstrip lines

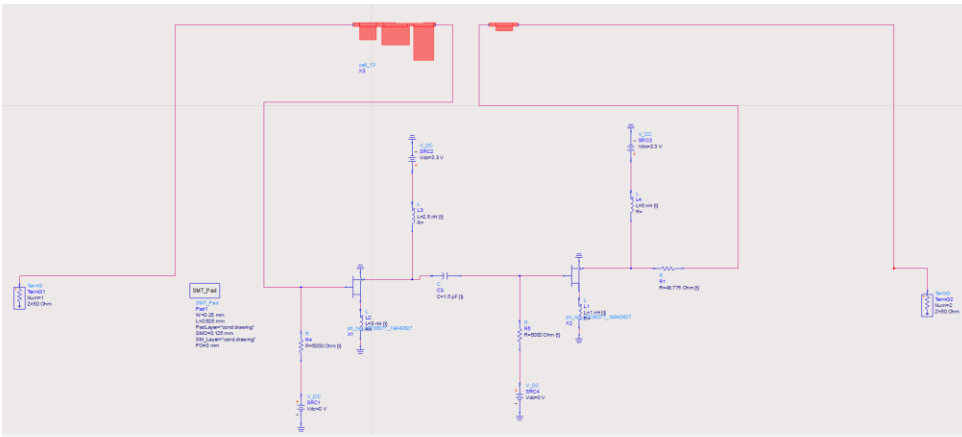

Figure 10. Co-simulation schematic

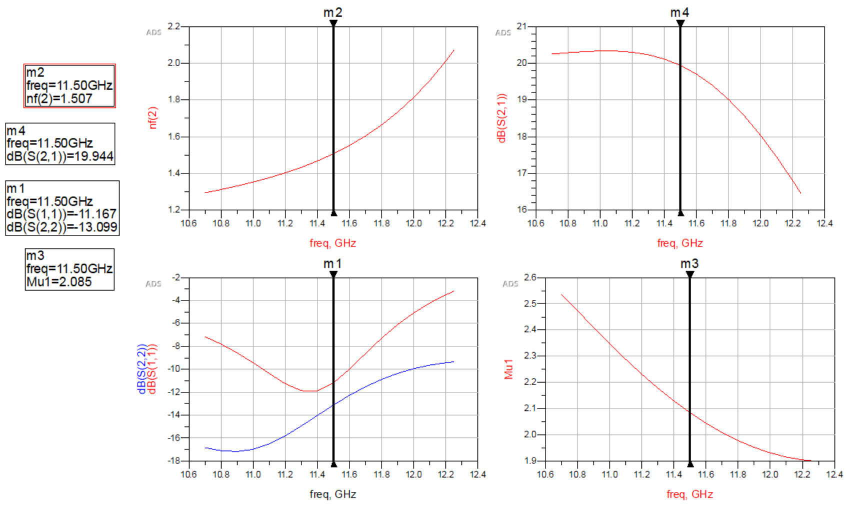

Figure 11. Outputs of co-simulation

Conclusion

Single and dual-stage low-noise amplifiers have been implemented. Also, the results of the co-simulation have been plotted. The designed LNA operates at 11.5 GHz and provides a high gain with a low noise figure which is ideal for downlink satellite communication applications. All the crucial LNA properties are attained with minimal trade-offs. A comparative analysis of the above-designed LNA is done with the other existing Ku-Band LNAs and the results are tabulated in Table 1.

Table 1. Comparative analysis of Ku band LNA results

Ref	Frequency (in GHz)	Noise figure (in dB)	Gain (in dB)	Number of stages
(Rudolph,2009)	8-10	<2.8	>18	2
(Suijker Rodenburg, 2009)	14	1.9-2.4	>19.8	3
(Resca,2013)	12.8-14.8	<1.8	>20	3
This work	11.5	1.507	19.944	2

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 16-19, 2022.

References

Bishoyi, P.K., & Karthikeyan, S.S. (2015). Design of a two stage Ku band low noise amplifier for satellite applications. *2015 International Conference on Communications and Signal Processing (ICCSP)*,0270-0273.

Murthy, B. V., Singh, N. K., Jha, R., Kumar, N., & Kumar, R. (2020, June). Ultra Low Noise Figure, Low Power Consumption Ku-Band LNA with High Gain for Space Application. In *2020 5th International Conference on Communication and Electronics Systems (ICCES)* (pp. 80-83). IEEE.

Resca, D., Scappaviva, F C., Florian, S., Rochette, J.L., Muraro, V., DiGiacomo Brunel, C., & Chang, D. B. (2013). A robust Ku-band low noise amplifier using an industrial 0.25-µm AlGaN/GaN on SiC process. *Eurpean Microwave Integrated Circuit Conference*,496-499.

Rudolph, M., Dewitz, M., Liero, A., Khalil, I., Chaturvedi, N., Wipf, C., Bertenburg, R.M., Miller, J., Würfl, J., Heinrich, W., & Trankle, G. (2009). High robust x-band LNA with extremely short recovery time. *IEEE MTT-S International Microwave Symposium Digest*, 781-784.

Suijker, E. M., Rodenburg, M., Hoogland, J. A., Van Heijningen, M., Seelmann-Eggebert, M., Quay, R., ... & van Vliet, F. E. (2009, October). Robust AlGaN/GaN low noise amplifier MMICs for C-, Ku-and Ka-band space applications. In *2009 Annual IEEE Compound Semiconductor Integrated Circuit Symposium* (pp. 1-4). IEEE.

Author Information

Naman Chetan Rajdev
PES University
Bengaluru, India.
Contact e-mail: *namanrjdv@gmail.com*

Lasya V
PES University
Bengaluru, India

Rashmi Seethur
PES University
Bengaluru, India.

To cite this article:

Rajdev, N. C.. & V.L., & Seethur, R.. (2022). Design of dual-stage Ku- band low noise amplifier for satellite downlink application. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 21*, 196-201.