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Design of GaAs Based LNA at 26 GHz Band

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***Abstract*—Amplification is the most important functionality in modern Communication Radio receivers. The Low Noise Amplifier (LNA) is the chief design in the receiver architectures. In order to amplify the signal received from the antenna in a RF system, LNA is required. A low noise amplifier operated in 26 GHz band with maximum gain of 27.861 dB and minimum noise figure of 1.467 dB has been designed using GaAs p-HEMT technology. The design uses inductive source degeneration topology along with resistive shunt feedback amplifier to get appropriate trade-off between gain and noise figure. Advanced Design System (ADS) software has been used for observing the simulation results.**

***Index terms*— Low noise amplifier, mm-Wave, GaAs, p-HEMT, Advanced Design System.**

I. Introduction

The Low Noise Amplifier (LNA) is the main block and also the first level of RF receiver which is often used in wireless communication. It is often used for the amplification of weak signals received at receiver antenna. LNA consists meagre amount of internal noise, so it doesn't give much of its share to system noise [1]-[2]. As LNA is the main section of RF front end receiver, specifications like low noise figure (NF) and high gain should be taken into consideration while designing LNA to maintain overall receiver NF low. There are many applications of LNA in the field of communication such as in wireless communications, astronomy applications, radar and satellite communications, telecommunication etc. Gain, Noise Figure, input return loss and output return loss are the basic specifications of LNA. For the representation of these specifications S-Parameters of an amplifier are used. Along with these features some of other features to be considered while designing LNA are linearity, stability, bandwidth and power dissipation.

Until now, many LNAs are designed for various applications in 3G, 4G frequency spectrum but now, with the advances in wireless technology, LNAs designed in 4G frequency spectrum almost reached its limits and only very few further improvements can be made to LNA. Today, the desired data rates and expected communication quality are increasing exponentially. In the near future, LNAs designed in 4G frequency spectrum will not meet these requirements. To overcome this 5G mm-Wave spectrum is proposed. According to FCC, in 5G mm-Wave spectrum (24 GHz to 300 GHz), the frequency bands 26 GHz and 28 GHz can be made available for the service immediately [3] in India. So, we have chosen 26 GHz band (24.25-27.5) GHz among those available bands to design LNA to meet the requirements.

Engineers are developing different circuits and improving the existing topologies so that devices can operate in 5G frequency spectrum. After comparing the performance of LNA in 26 GHz band among different technologies like CMOS, SiGe, InP, GaAs p-HEMT, GaAs m-HEMT, GaN and etc., GaAs p-HEMT exhibits better performance [4]-[10], [29]. Recent improvements in GaAs high electron mobile density enables GaAs p-HEMT to operate devices with good performance in high frequencies. In high-frequency circuit, it is highly efficient, compared to silicon semiconductor because of its faster operation speed and low heat generation. Since these advantages are in the high-frequency region, GaAs-based devices are mostly preferred for high frequencies [11]-[23], especially in the design of LNA.

We studied and analyzed various topologies: Common source amplifier, common gate amplifier, Inductive Source Degenerated Amplifier [25]-[26] and Resistive Shunt Feedback Amplifier [27]-[28]. Among those topologies Resistive Shunt Feedback Amplifier and Inductive Source Degenerated Amplifier topologies shows appropriate tradeoff between gain and noise figure [24]-[28].

This paper comprises of IV parts in which section II briefs about the process of designing LNA, Section III displays the results of simulation and discussions. In the end, section IV gives conclusion.

II. Design of LNA

In this work LNA is designed to operate in 26 GHz band. The low noise amplifier has been designed and simulated using Advanced Design System (ADS) simulation software. ADS tool has many libraries. In this work, the active device used is from S – parameter library. The design uses S-parameter simulation controller to for obtain the device stability and other parameters. And to observe linearity harmonic balance simulation has been used.

In this work GaAs p-HEMT technology is used to achieve low noise figure. The main component of this amplifier is ATF-36077. It is an ultra-low-noise Pseudomorphic High Electron Mobility Transistor (p-HEMT). The main idea behind selecting ATF-36077 device in this work is due to its very low noise resistance as it decreases the sensitivity of noise performance due to variations in input impedance match by which the designing of Low Noise Amplifier will be much easier.

Inductors, capacitors and resistors are used in this design to provide input /output matching and biasing of the circuit.

The GaAs p-HEMT based LNA has been designed in this work using inductive source degeneration topology along with resistive shunt feedback topology to get appropriate trade-off between noise figure and gain.

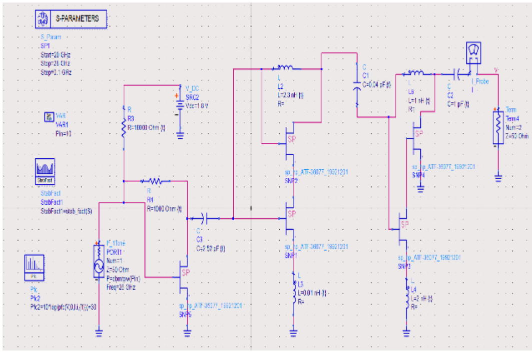

Fig. 1 Circuit design of LNA

Fig. 1 Represents the circuit design of the designed GaAs p-HEMT based LNA.

From the Fig. 1 LNA's initial stage at input is designed using resistive shunt feedback topology to make noise figure low and the other two stages of LNA are made up of inductive source degeneration topology to improve the overall gain of the amplifier. The supply voltage applied for this circuit is 1.8 V.

III. Simulation Results and Discussions

The designed low noise amplifier circuit as shown in Fig.1 has simulated and analysed with the help of ADS tool. First, we need to check the whether the circuit is unconditionally stable or not. For the circuit to be unconditionally stable K >1 and |Δ|<1.

Where,

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

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

S_{11} = input return loss

S_{22} = output return loss

S_{12} = reverse gain

S_{21} = forward gain

The simulation result for stability factor of designed LNA is shown in Fig. 2. The result indicates that the LNA is stable as the stability factor is greater than 1.

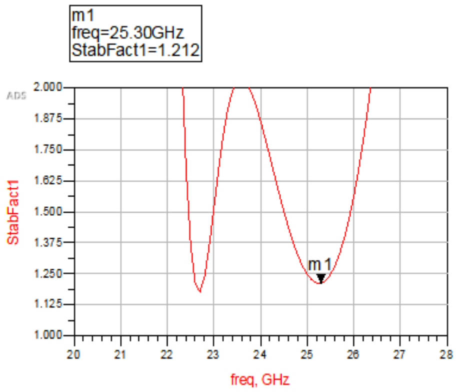

Fig. 2 Stability factor of LNA

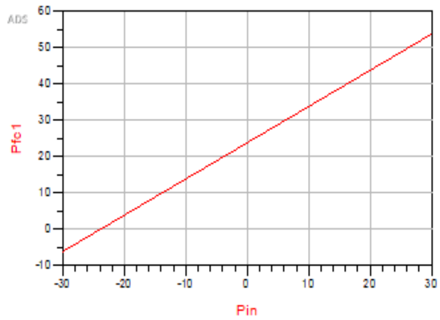

Fig. 3 Linearity of LNA

Fig. 3 Simulation output of linear characteristics of the proposed LNA. Results indicate that the system which was designed is linear in the entire region of operation.

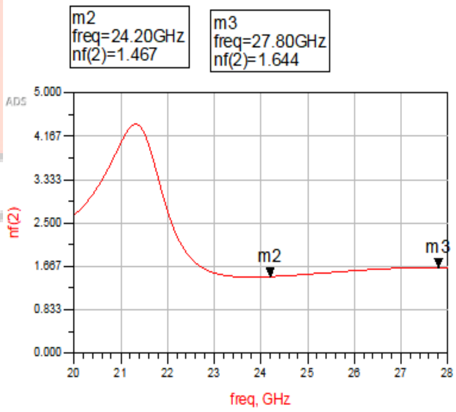

Fig. 4 Noise figure of LNA

Fig. 4 Shows simulation output of Noise figure of our Final LNA design. Results indicate that the NF is optimized at 26 GHz band (24.25 GHz-27.5 GHz) which is the new frequency band of use for future 5G communication systems in India. The NF of our proposed LNA design is around 1.5 dB (1.467 dB-1.64 dB).

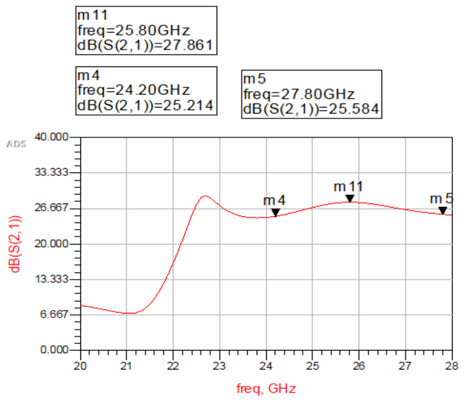

Fig. 5 Gain of LNA

Fig. 5 Shows simulation output of S_{21} for the designed LNA. The gain is optimized with the minimum of 25 dB and maximum gain of 27.861 dB in 26 GHz band.

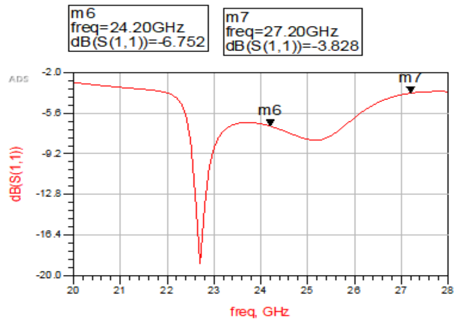

Fig. 6 $S_{11}$of LNA

Fig. 6 shows simulation output of S_{11} for designed LNA circuit. Results indicate that the S_{11} is negative in 26 GHz band.

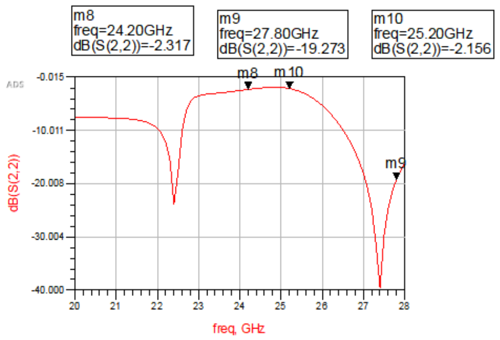

Fig. 7 S_{22} of LNA

Fig. 7 shows simulation output of S_{22} for designed LNA circuit. Results indicate that the S_{22} is negative in 26 GHz band.

IV. Conclusions

In this paper, the design of GaAs p-HEMT based LNA operated in 26 GHz band has been presented. It is observed that designed circuit is unconditionally stable. The power supply applied to the circuit is 1.8 V. The simulation results show that maximum gain of 27.861dB in the required 26 GHz band is obtained at 25.80 GHz and the minimum noise figure of 1.467 dB is obtained.

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