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Broadband CMOS LNA Design and Performance Evaluation

Mayank B. Thacker[*1], Shrikant S. Bhoyar[2], Praveen Kumar Rahangdale[3]

[*1]*Department of Electronics Engineering, RCOEM, Nagpur, India*
[2]*Department of Electronics Engineering, RCOEM, Nagpur, India*
[3]*Department of Electronics Engineering, RCOEM, Nagpur, India*

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***Abstract*—**This paper presents the design of a broadband Low Noise Amplifier (LNA). The work presented by the structure is capable of operating on a frequency band stretching from 0.8GHz to 2.5GHz i.e. covering most of the high speed data applications. Common source LNA design is offered in this paper. The design is implemented using 0.18µm CMOS process with a supply voltage of 1.3V. The Cascade LNA achieves 12.8 dB (min.) gain, 0.44 dB (min.) NF over operating frequency spectrumupholding high degree of stability factor. LNApresented in this paper consumes 19mW of power.

***Keywords*—**Broadband, LNA, Common Source, RF.

I. INTRODUCTION

In the past couple of decades, wireless communication systems have been evolving progressively, mounting in a greater dimension and this creates larger demand for devices that are smaller, lighter and inexpensive and of higher performance with reducing number of passive components in the circuit [1]. On the contrary, the need for high data rates and global flexibility has made the performance of the supported devices restricted by the support of the network and the mobile functionality itself. To address these limitations, research goals had been shifted towards achieving a broadband LNA which is able to accommodate many standards all in one system. Therefore, this paper presents the design of a broadband CMOS LNA.The broadband LNA proposed in this paper covers the applications related to mobile telephony giving a sufficient performance parameters for operation [2] [3].

II. LNA BASIC

A. LNA requirement

Being the first block of any receiver system LNA needs to have a proper broadband impedance matching network along with desired amount of gain and noise figure for the whole of frequency spectrum. LNA is also required to have an appreciable value of reverse isolation so as to have the signal not getting back-propagated into space.

B. Concept of LNA

LNA circuit comprises of two impedance matching networks sandwiching an amplifier core. The block schematic of LNA shown in Fig.1.

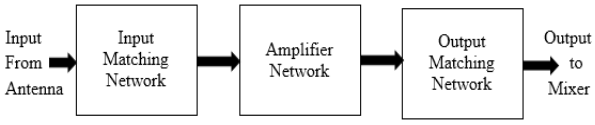

Fig.1. LNA block schematic

Corresponding Author:*Mayank B. Thacker*

C. Noise Figure Consideration

The Noise Factor of any cascaded system is given by the Frii's equation (1) as given:

$$F_{tot} = 1 + (F_1 - 1) + \frac{(F_2 - 1)}{G_1} + \cdots$$

Hence, from the equation it becomes very significant for the first stage to maintain a low value noise factor / figure.

LNA can be made using different configurations of Transistor amplifier. The work presented in this paper uses Common Source configuration which has a low value of noise factor as compared to other configurations (common-gate) [4]. The technique opted for Common Source configuration is Inductively Degenerated common source which provides simultaneous Noise and input matching(SNIM). Also the CS design provides better noise performance in low frequency side as compared to CG LNA [5] which depends on the ω_0/ω_T ratio

III. PROPOSED LNA

The circuit of proposed LNA is as shown in the figure below. The circuit uses Inductive degeneration along with a cascode stage. The inductive degeneration provides the negative feedback along with circuit stability. The cascode stage provides better reverse isolation along with proper biasing condition for the CS device. In the figure the MOSFET M1 and M2 act as LNA core. An extra capacitance connected between the gate and source terminals of M1 provide a condition for input match by increasing the value of C_{gs} thus catering to lower the value of input inductance. The input impedance matching is done by the inductors Ls and Lg along with the capacitors C_1 and C_2. Biasing is not shown in Fig.2. so as to avoid complexity. 0.18µmtechnology is utilized to simulate and test the results.

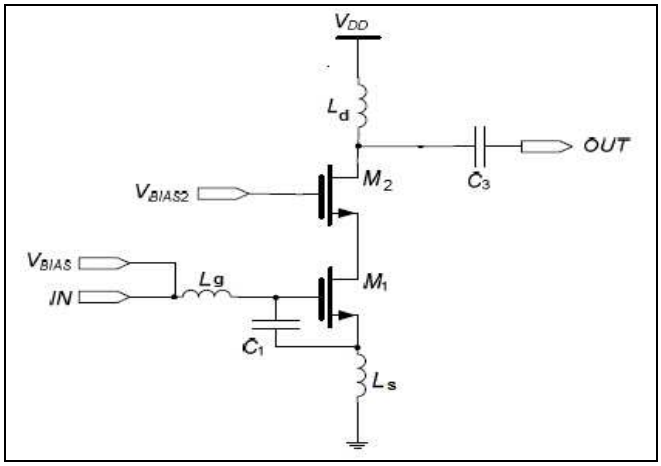

Fig.2. Proposed LNA schematic

The noise factor of this type of LNA [6] is given by the equation as:

$$F = 1 + \left(\frac{\omega_0}{\omega_T}\right)\frac{\gamma}{\alpha}\frac{1}{2Q}\,(1 - 2|c|x_d + (4Q^2 + 1){x_d}^2$$

Where, we have $x_d = \alpha\sqrt{\frac{\delta}{5\gamma}}$

Where γ, α and δ are process related parameters. ω_T is the transit frequency of MOS. Hence to have a broadband multi-standard match we cannot opt multi-section input matching networks. Considering the input side of the topology we have the equivalent circuit as shown below:

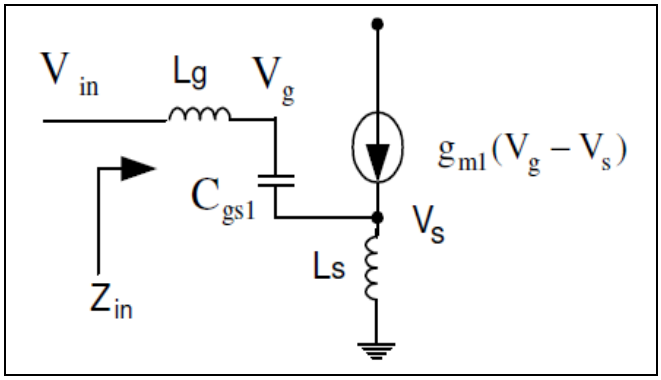

Fig3. Small signal model for input of LNA

The input impedance of LNA from above circuit can be given as:

$$Z_{in} = \frac{1}{j\omega C_{gs}} + j\omega\left(L_s + L_g\right) + \frac{g_m L_s}{C_{gs}}$$

The last term provides the resistive component and hence we get resistor without actually adding it, which acts as a negative feedback path and complements to circuit stability. Stability of the circuit is given by the Stern's stability factor and is given as:

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

IV. RESULTS AND GRAPHS

The results showing the S-parameters for LNA are as shown from Fig. 4 to 8:

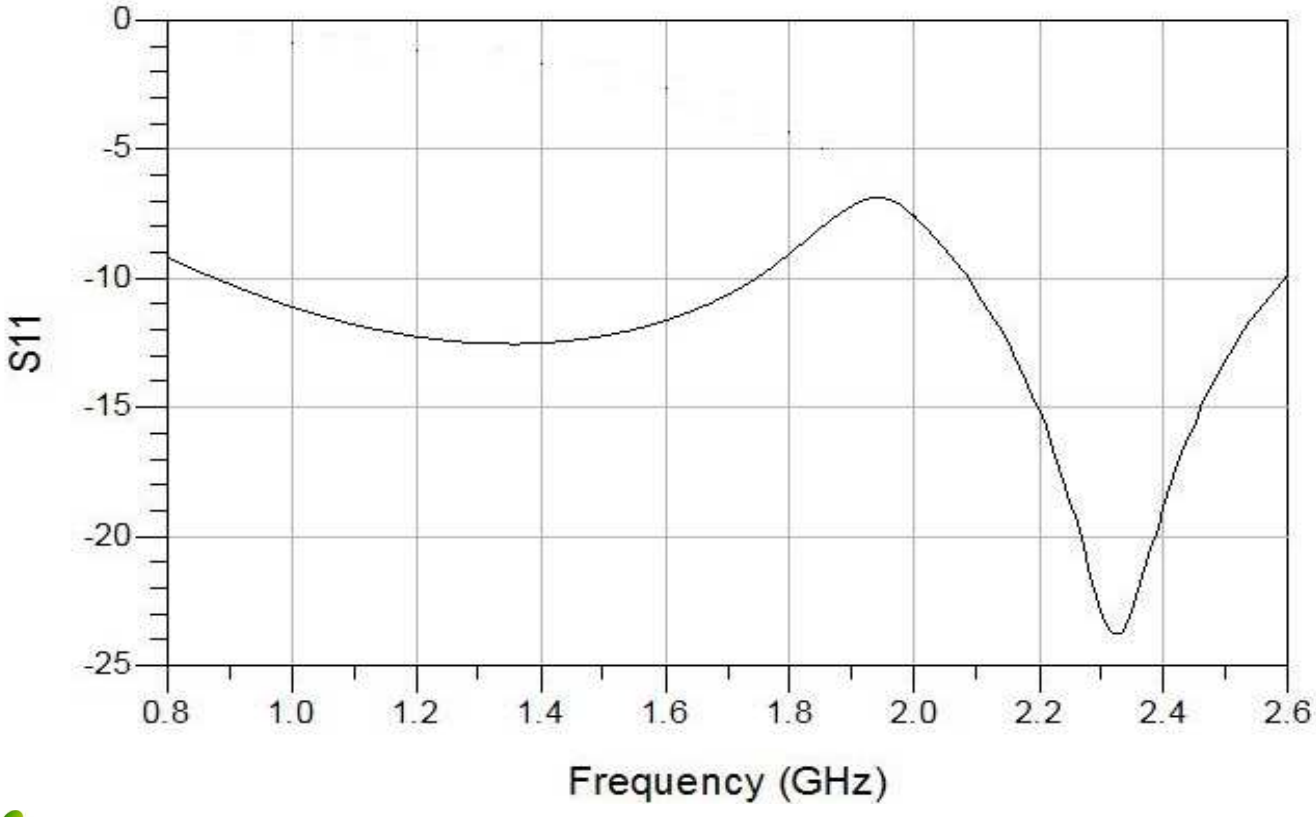

Fig.4. S11 of proposed LNA

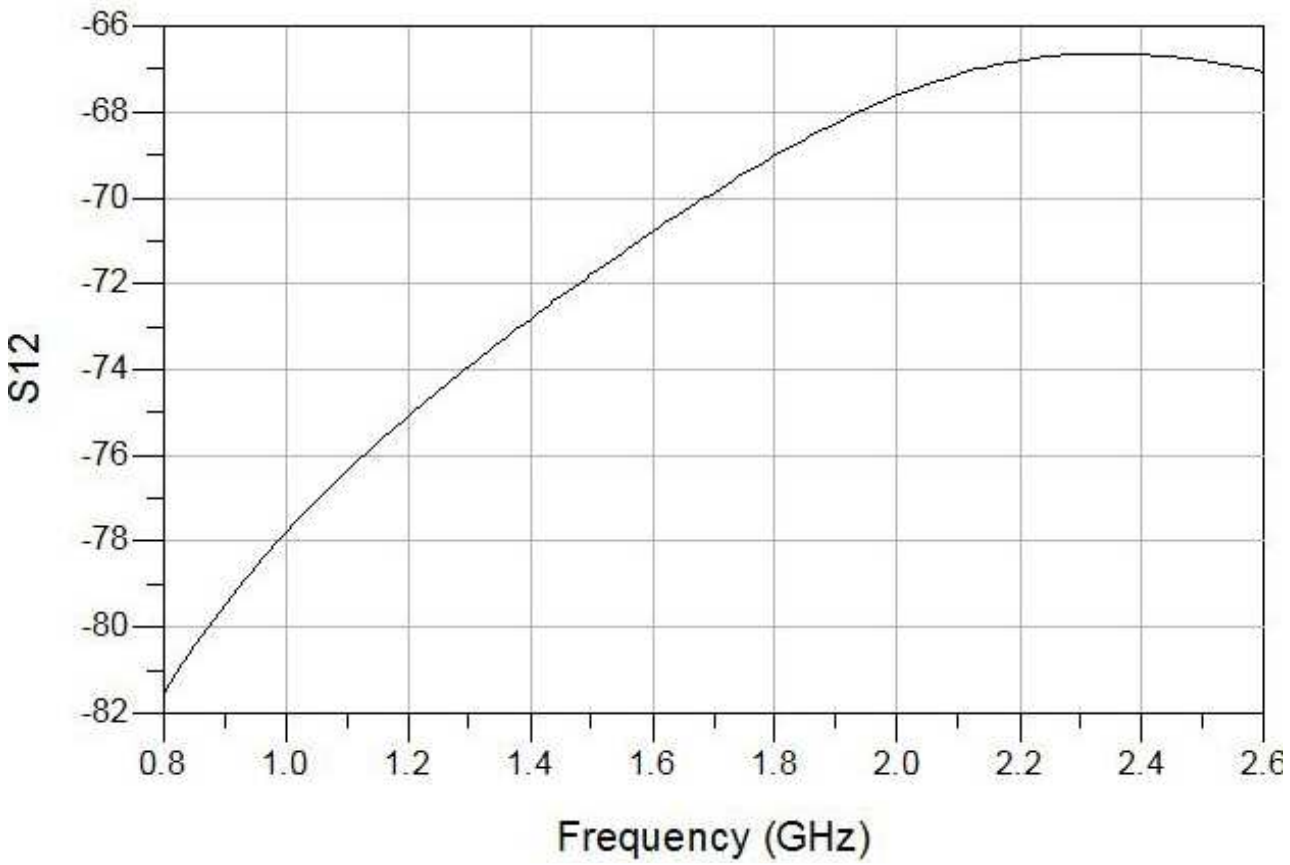

Fig.5. S12 of proposed LNA

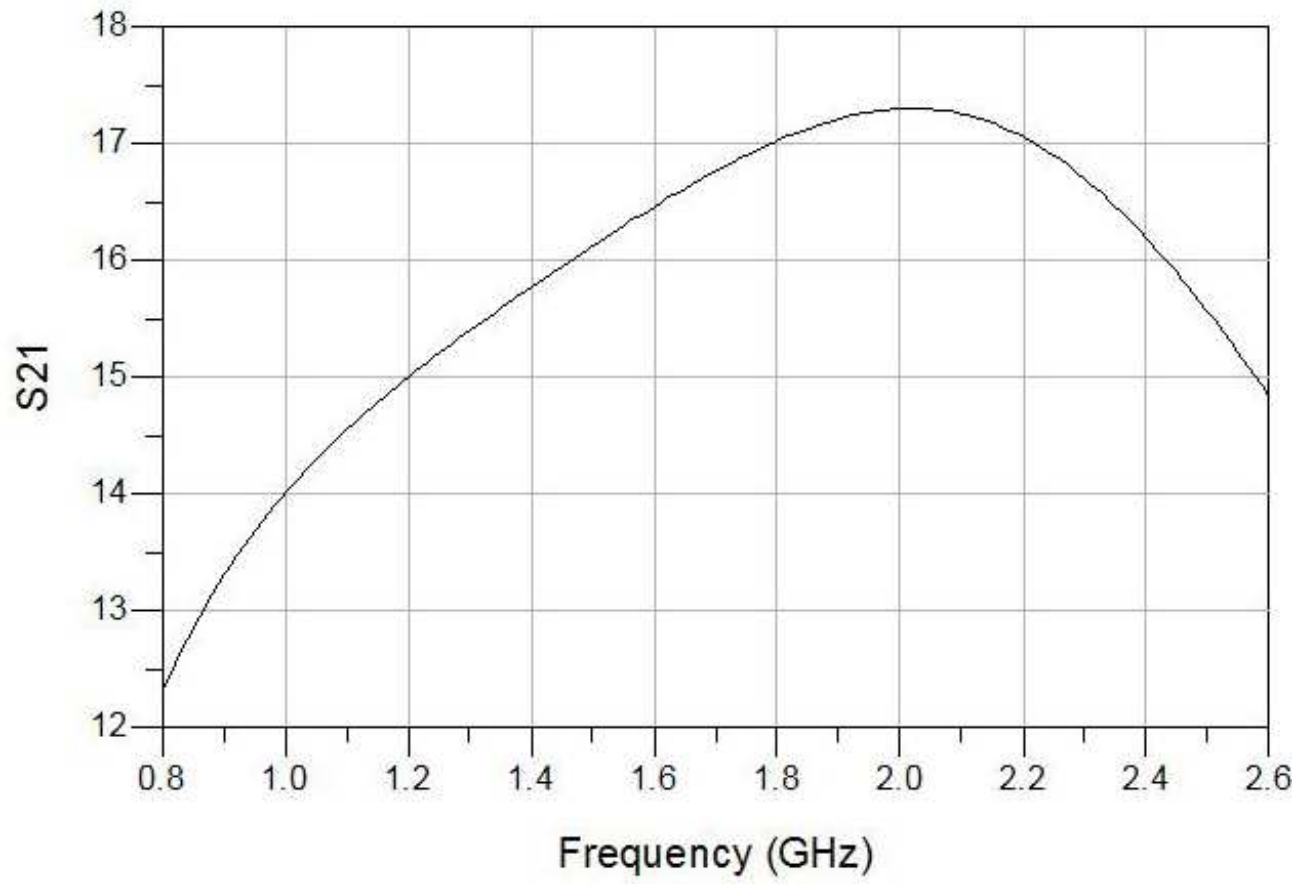

Fig.6. S21 of Proposed LNA

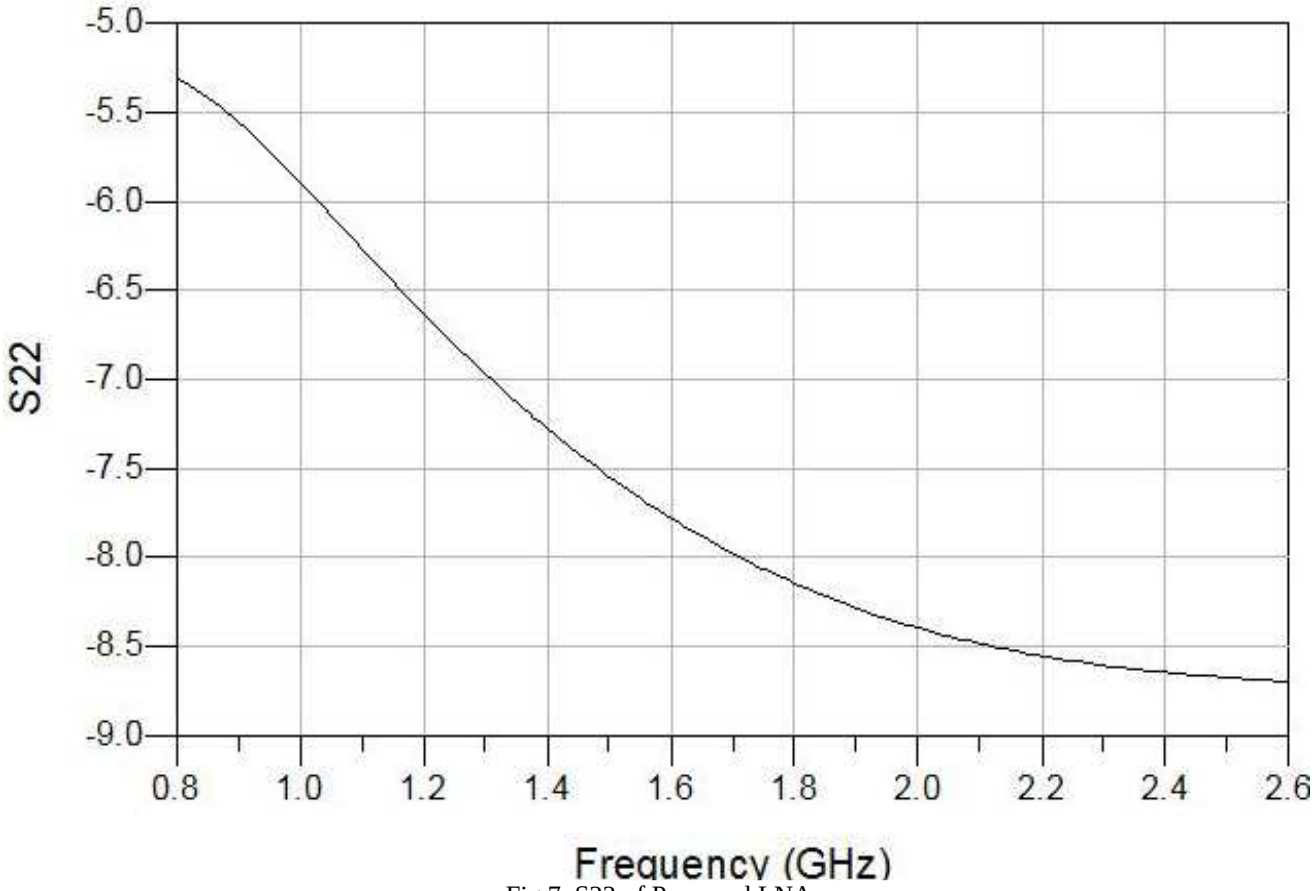

Fig.7. S22 of Proposed LNA

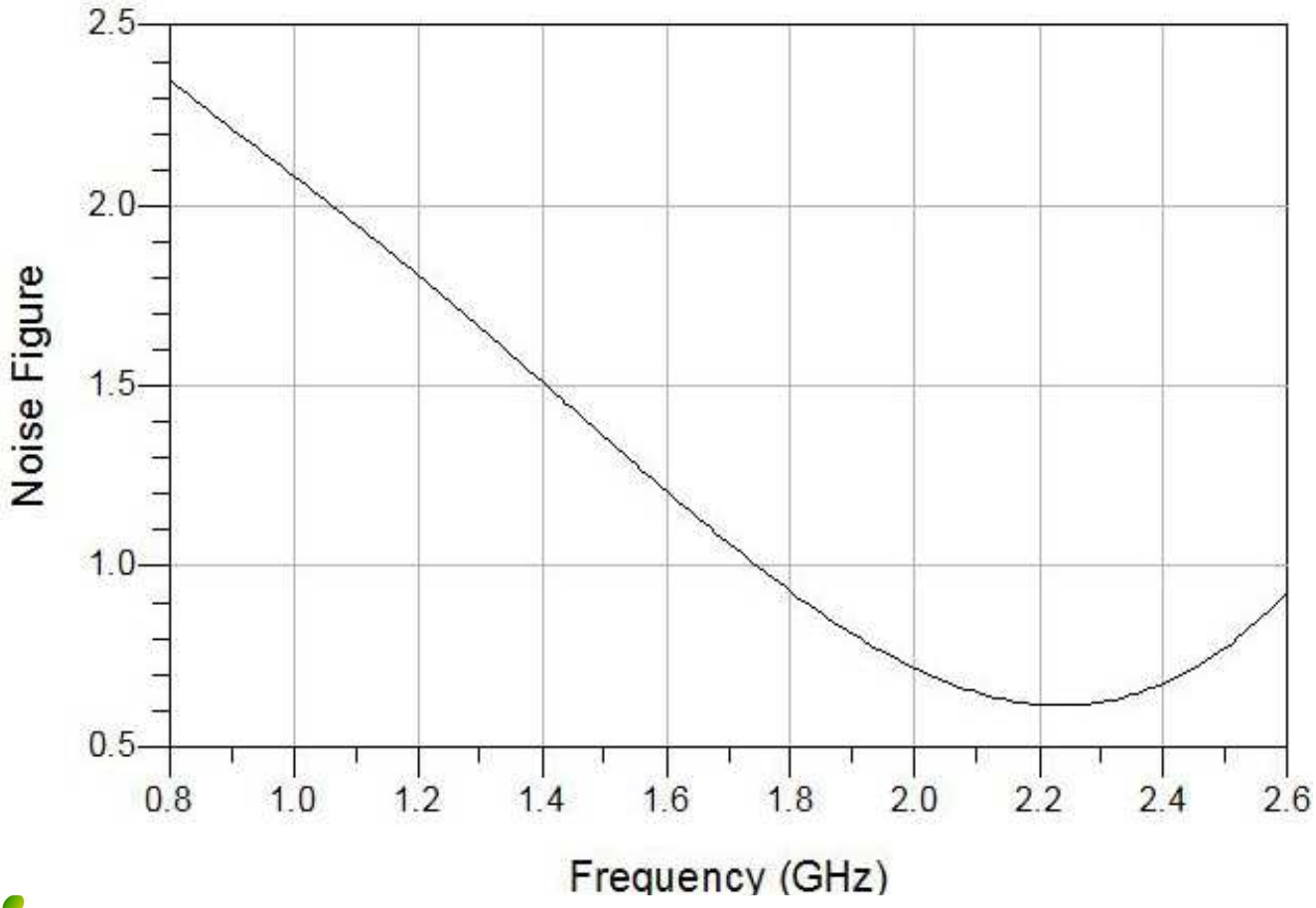

Fig.8. NF of Proposed LNA

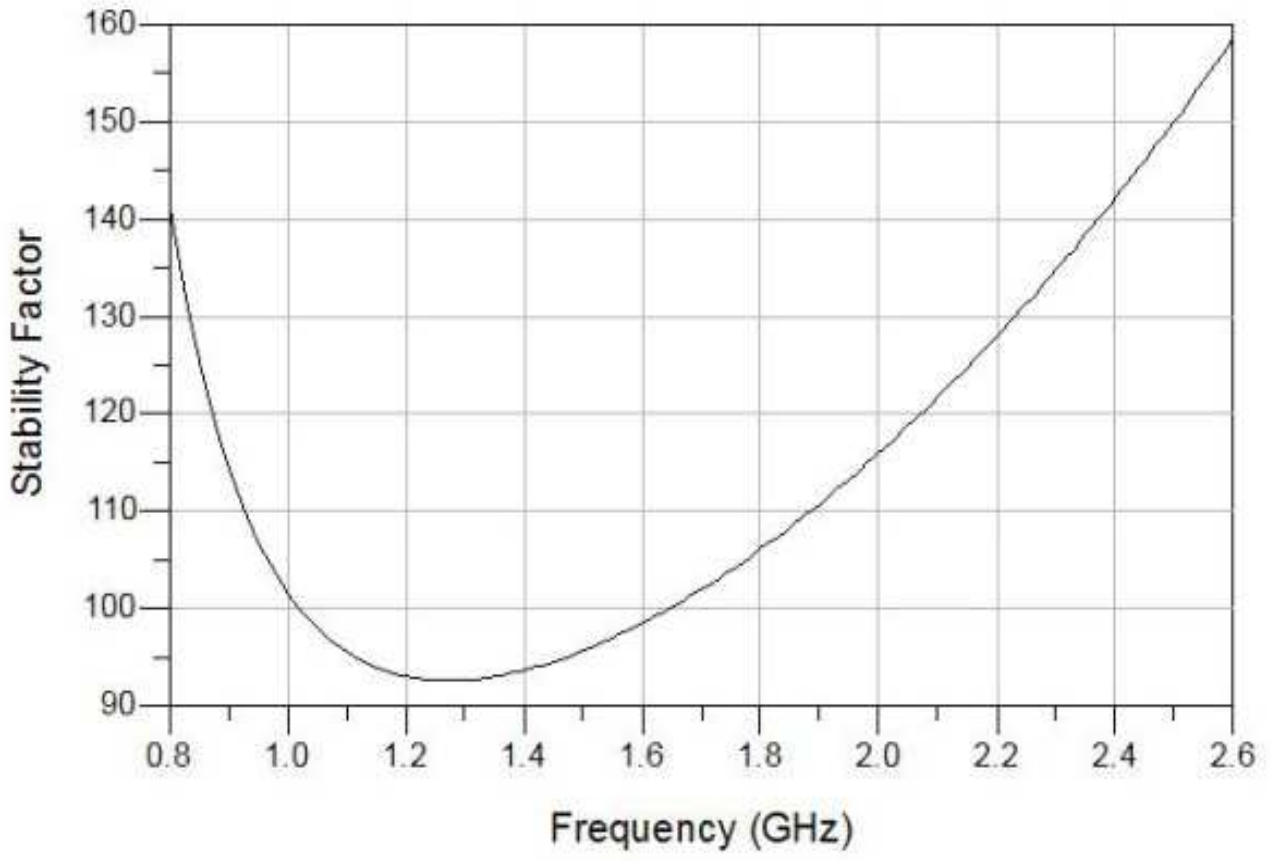

Fig.9.Stability of Proposed LNA

The components used along with their values are as given in the table below:

Sr. No.	*Item*	*Value*
1.	*M1 / M2*	*70µ / 0.18µ*
2.	*Ls*	*0.5nH*
3.	*Lg*	*6nH*
4.	*C1*	*0.1 pF*
5.	*Ld*	*12 nH*
6.	*C3*	*2 pF*

V. DISCUSSION AND CONCLUSION

After investigating the design process and actual simulation we can conclude that, inductively degenerated common source LNA is sufficiently proficient to furnish the needs of high speed data applications. It provides superior noise figure in most of the frequency of operation along with relatively excellent gain factor by consuming only 19 mW power with 1.3 V supply. From the Fig.9, we can easily state that the LNA is highly stable, whereas figure 5 shows us that there is inconsiderable reverse gain. The LNA is capable of matching at both the ends for the frequency of attentiveness which is very clear from figure 4 and 7.This LNA can be further improvised to accommodate more standards or improvement in noise figure or by investigating and improving system linearity.

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AUTHORS PROFILE

Mayank B. Thacker received his Masters Degree in VLSI Design from RCOEM, Nagpur, India in 2013. His major subjects include Analog/RF and Mixed Signal Design. He did his Bachelors in Electronics Engineering from RTMNU, Nagpur, India in 2009. He also did his dilpoma in Engineering in Electronics and Communication from MSBTE, Maharashtra, India.

Shrikant S. Bhoyar received his BE degree in Electronics and Tele-Communication Engineering from DYPIET, Pune, India in 2011. His main research intrests include Analog/RF circuits and ASIC/FPGAimplementations Digital Circuits.

Praveen Kumar Rahangdale received his BE degree in Electronics and communication Engineering from RGPV, Bhopal, India in 2010. His main research intrests include Analog/RF circuits and ASIC/FPCA implementations of Digital Circuits.