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Noise Analysis of Novel Design of MODFET Low Noise Amplifier

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Abstract— In this paper, Noise analysis of a novel MODFET LNA was done that is designed using Micro strip based design methodology. A novel design has been proposed for MODFET LNA Load and stability has been obtained. A comparative analysis has been done for different values of drain voltages. Noise analysis has also been done and the design is carried out at a centre frequency of 2.4 GHz and the noise bandwidth considered is 6GHz. In this paper the work is carried out using ADS simulation software. Scattering parameter S11 and S22 are obtained. Noise figure and gain of Cascaded LNA is also obtained. Variation of noise figure and gain with respect to frequency has been obtained. From the results the effect of drain voltage on the design performance is explored. Layout of the proposed design has been obtained. Results obtained are in greater coherence with the theoretical observations.

Index Terms—MODFET, Noise, LNA, Micro Strip.

I. INTRODUCTION

Many Researchers are working in this field of Micro electronics from years together towards reaching to the ongoing demands of the industry. Modulation-doped field-effect transistors (MODFET's) in general are of great importance because of their unprecedented performance at high frequencies for digital and analog applications .[1],[3]. Gate capacitance and current gain, cut-off frequency are some of the most important parameters for small and large signal applications as well as for understanding of device operation at DC and high frequencies.The epitaxial structure of a basic MODFET is illustrated in Figure 1 [7].

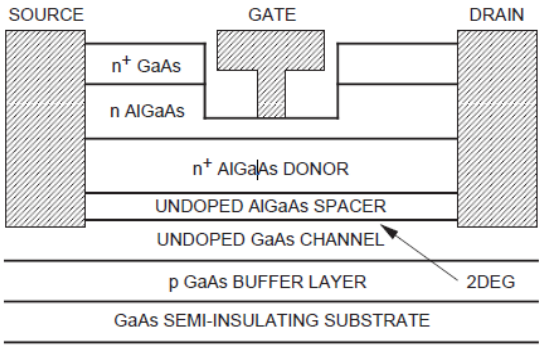

Fig.1. Structure of a basic AlGaAs/GaAs MODFET

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The electrons traveling in the vertical direction will be collected by 2DEG(Two Dimensional Electron Gas) layer and electrons that are generated due to incident light in the

Gallium Arsenide layer will contribute to increase in source to drain current. The concentration of two dimensional electron gas can be controlled by the applied gate voltage.

The buffer layer, also typically GaAs, is epitaxially grown on the substrate in order to isolate defects from the substrate and to create a smooth surface upon which to grow the active layers of the transistor. Many PMODFET structures contain a superlattice structure to further inhibit substrate conduction. A superlattice structure is a periodic arrangement of undoped epitaxial layers used to realize a thicker epitaxial layer of a given property. For example, alternating layers of Al*x*Ga1-*x*As and GaAs form a typical PMODFET superlattice. The AlxGa1-*x*As has a larger band gap than GaAs, making it superior to GaAs as a buffer. However, due to strain problems, the Al*x*Ga1-*x*As layer thickness is limited.

To resolve this problem, the Al*x*Ga1-*x*As is grown to just below its thickness limit and a thin layer of GaAs is grown on top. The GaAs relieves the strain and allows another layer of Al*x*Ga1-*x*As to be grown. This process is typically repeated 10 to 15 times, creating a layer that is “essentially” a thick buffer of Al*x*Ga1-*x*As. The most important point about the channel layer in the MODFET and PMODFET devices is the two dimensional electron gas (2DEG) that results from the band-gap difference between Al*x*Ga1-*x*As and GaAs [2].

Noise is an unwanted energy which in most of the times becomes hindrance to the performance of electronic systems. This is a random phenomenon even though in most of the cases the reasons are identified.

Noise is spontaneous and natural phenomena exhibited almost in every device and circuit. Any random variation of a physical quantity resulting in the unpredictability of its instantaneous measure in the time domain is termed as noise.

II. NOISE IN MODFET

To model noise in devices, the physical sources of the noise are to be first figured out. The two most common types of noises encountered in devices are thermal noise and shot noise. Thermal noise is present in resistive materials that are in thermal equilibrium with the surroundings. It is the noise found in all electrical conductors. Electrons in a conductor are in random thermal motion experiencing a large number of collisions with the host atoms. Macroscopically, the system of electrons and the host atoms are in a state of thermodynamic equilibrium. These electrons can be the sources of shot noise in junction devices like PN and metal semiconductor devices.

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Shot noise is a resultant of probabilistic nature of the carriers that are penetrating through the barrier. This results in the fluctuation of electric current randomly around a level. The fluctuations reflect the random and discrete nature of the carriers.

Shorter channel lengths of MODFET's also contribute to higher noise current. Noise currents are inversely proportional to channel resistance which in turn to gate length. At very high drain currents and voltages, noise begins to increase more rapidly. Parasitic contribution and channel noise is greater for MODFET structure. Origins of noise include; Noise in channel region, which is a result of high field diffusion noise and parasitic elements consisting of gate metal resistance, source resistance and drain resistance. [5], [8].

III. PROPOSED DESIGN OF ALGAAS/GAAS LNA

A low noise amplifier (LNA), which provides modest RF gain at a low noise Figure in RF front end applications. LNA is a key component in the receiving section of the communication system. The main objective of LNA is to receive the input signal, which is in general very weak and to amplify besides maintaining minimized noise levels. The performance metrics of this RF front end subsystem are Gain and Noise Figure.

MODFET LNA is designed using microstrip line methodology [4], [6] and the substrate chosen is FR4, where the dielectric constant value is 4.6. Noise bandwidth is 6 GHz and H =1.6mm, where as W =3.00mm and L = 6.79 mm. The operating voltage is 3v dc. Stability of the design is calculated using, $\Delta = (S11 * S22) - (S12 * S21)$ and $\Delta < 1$ AND $K > 1$ has been obtained for this design. The centre frequency of the design is taken as 2.4 GHz in accordance with the demands of the communication applications like Software Defined Radio. EE_HEMT Model is considered. Eleven micro strip lines were used in the design along with the passive components like resistors. Resistors are contributors of the noise. Sweep frequency is considered to be 1 GHz to 10GHz with a step value of 1GHz. The design is as shown in Fig. 2. The design is novel because of the fact that the combination of the parametric values considered here for the gate resistance, trans conductance, gate source voltage and Is are yielding towards the better values of the noise figure. This design is terminated with 50 ohm resistance. Scattering parameter simulation is done to measure the minimum noise figure.

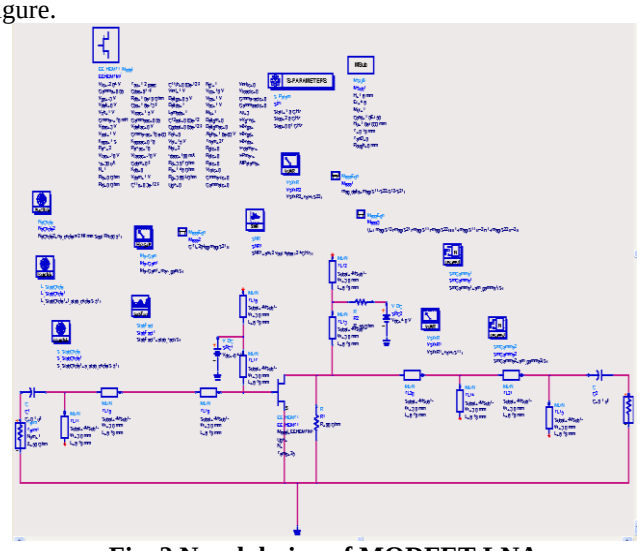

Fig. 2.Novel design of MODFET LNA

Cascaded LNA has been developed using proposed model. The basic design of cascaded LNA is as shown in the Fig.3.

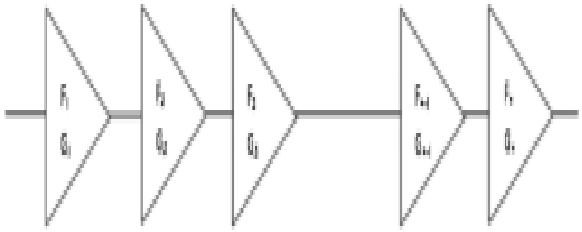

Fig.3. A Basic Cascaded LNA System

The Cascaded LNA was designed with advanced Design System (ADS 2008) , with 3 Volts (VDS) and 10mA of bias current was supply. The overall performance of the low noise amplifier is determined by calculating the transducer gain GT, noise figure F and the input and output standing wave ratios. Stability of the design is calcualted using mag_delta calculation and noise figure is also computed and its variation with respect to the frequency has been analyzed. For better performance in gain of the amplifier which can be achieved by increasing the number of stages to improve the gain and noise figure of the design. Higher gain would expand the coverage or communication distance.

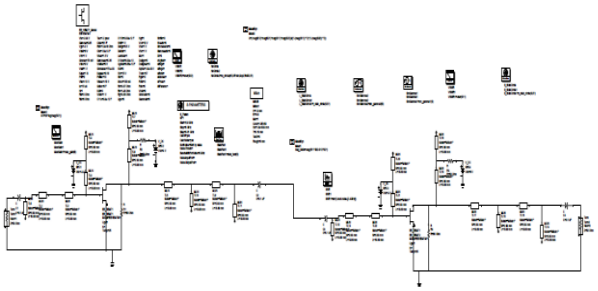

Fig.4. Design of cascaded LNA (no. of stages two)

IV. RESULTS

S- Parameter simulation yields results in terms of scattering parameters s11, s22 . Fig.5 and Fig.6 represents these parameters variation with respect to frequency.

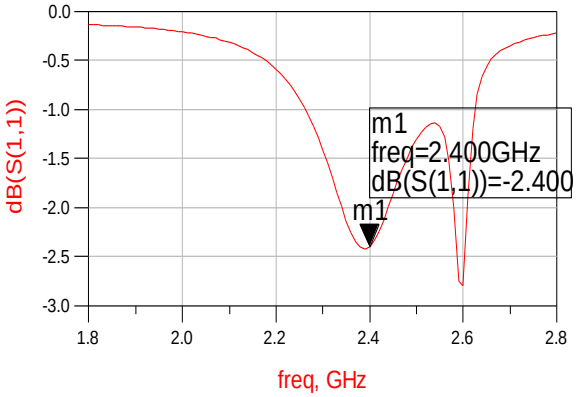

Fig.5 S11 variation with frequency

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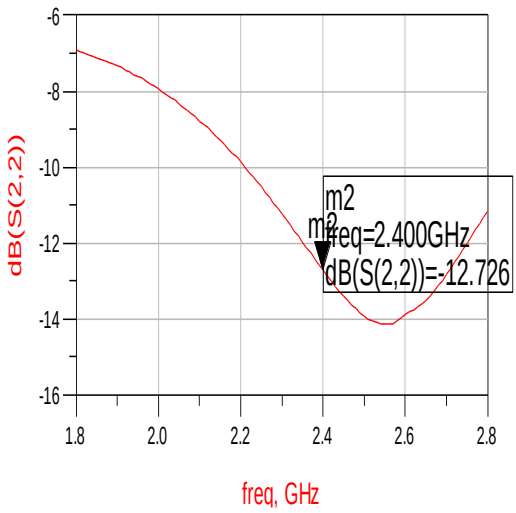

Fig. 6 S22 variation with frequency

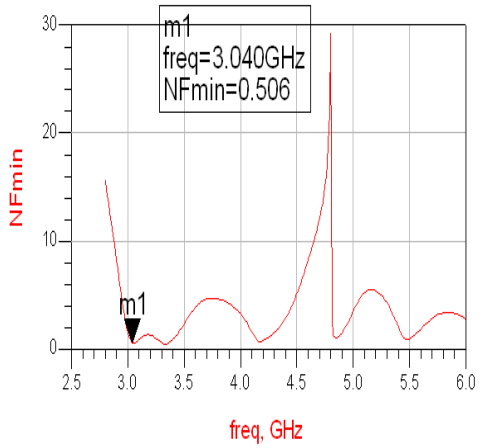

Fig.7. NF min variation with respect to frequency of cascaded LNA using proposed model

Noise figure variation with frequency of a cascaded Low Noise Amplifier design using proposed novel design of MODFET LNA is represented using Fig.7 and its gain variation with respect to frequency is evident from Fig.8

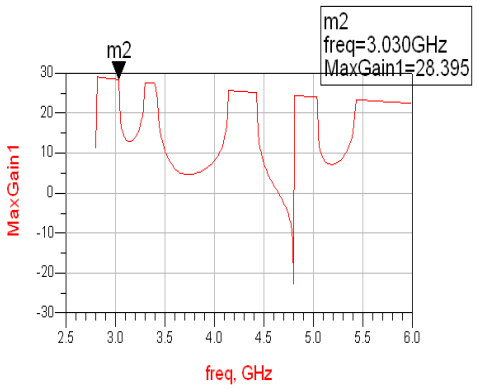

Fig.8. Gain variation with respect to frequency of cascaded LNA using proposed model

Fig.9 represents the load stability condition of the proposed novel MODFET LNA. Stability analysis has been carried out at 2.4 GHz. Table I is the comparative statement of the noise figure values for different drain voltages of different models of MODFET LNA and the proposed model of LNA.

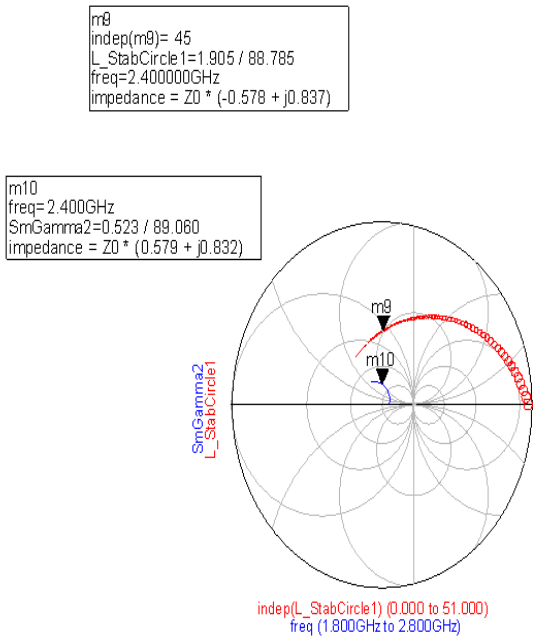

Fig. 9.Stability at the Load of proposed LNA

Table 1: Comparative analysis of proposed model with other models

Hemt equal microstrip

NF min	vdd
2.689	2
1.889	3
1.472	4
1.221	5
1.063	6

HEMT unequal microstrip

NF min	vdd
13.207	2
12.9	3
12.75	4
12.726	5
12.695	6

proposed model

NF min	vdd
4.311	2
4.524	3
0.256	4
0.267	5
0.279	6

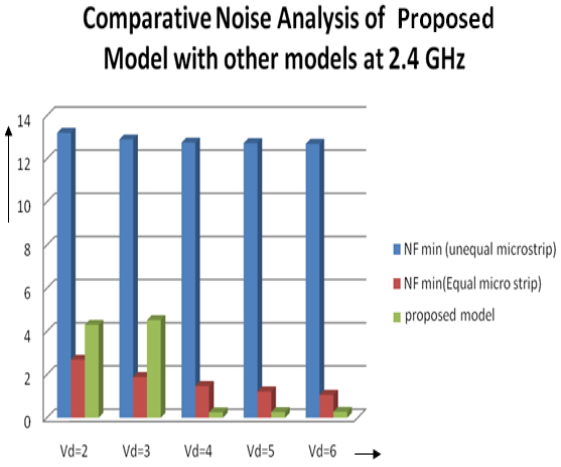

Fig. 10. Comparative analysis of NFmin at different values of Vd

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Fig. 10 represents the comparative anlaysis of performance of different LNA's with respect to drain voltage and in terms of noise figure. Fig.11 represents the layout of the proposed model of MODFET LNA design.

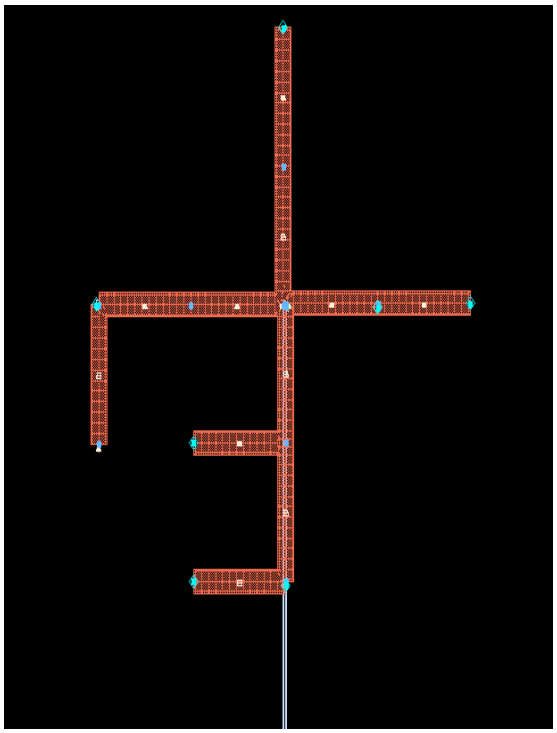

Fig.11 Layout of the proposed model

V. CONCLUSION

The design is stable and the noise figure values indicates that the proposed model has better values when compared with the equal and unequal micro strip based models. S-Parameter simulation results explored the behavior of the novel design with respect to the frequency. As the drain source voltage increases the noise figure values reduces in all the models. Noise figure of 0.56 and gain of 28.395 dB obtained for cascaded MODFET LNA that has been designed using proposed model.

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