EVALUATION OF EFFECT OF NOISE ON MODFET LNA DESIGNED USING DIFFERENT SUBSTRATES

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Abstract

In this paper, a performance comparison of MODFET Low Noise Amplifier design based on micro strip line technique is done. A RT Duroid substrate based design with specific dimensions of L = 9.4 mm and W = 2.1 mm is compared in performance with FR4 based design and performance is evaluated using parameters like noise figure and maximum gain. These comparisons are done by taking into account different combinations of performance parameters. Noise is inherent in this device and it is predominant particularly at higher frequencies, the reason for this behavior is it depends on the parameters like gate resistance, which is one of the important finding of this work. The low noise amplifier designed based on RT duriod has shown reasonable gain and low noise figure values, when compared with FR4 design. Layout of this design has been obtained and this work has been carried out using ADS software.

Keywords: Noise, Performance comparison, Noise Figure, Gate resistance, Maximum Gain.

I. INTRODUCTION

High electron mobility transistors are the emerging devices in the field of micro electronics and integrated circuits (VLSI) in the recent times. These devices offer numerous advantages over conventional devices, particularly at higher frequencies. Attempts were made to explore the characteristics of these devices by many researchers in the mid 90's and various models with different composition of substrate material were proposed. The evolution of this field had taken place gradually with focus shifting towards the applicative research of these devices. Eventually, there are many hindrances or challenges faced by researchers and one important aspect among them was the noise that is inherent in the device.

Semi Conductor device mechanics helped to certain extent in analyzing the reasons for these disturbances, but still the research is going on to list out the actual reasons and methods to overcome these difficulties pertained to device performance.(1,5). Equivalent circuit approach was also followed by many researchers to evaluate or to model these HEMT devices. (7). Device simulations were carried out with typical models of modulated doped field effect transistors. These devices are efficient as they offer higher speed, immune to radiation effects, consumes lesser power and even suitable for high frequency applications. (4). There are many substrates related to device fabrication and some of them are GaAs, AlGaN, Indium Phosphide and SiC. These devices play an important role in the development of microwave monolithic integrated circuits, radar and defense applications. (3, 4).

II. AlGaAs/GaAs MODFET

The structure of a basic AlGaAs/GaAs MODFET is illustrated in Figure 1. (2).

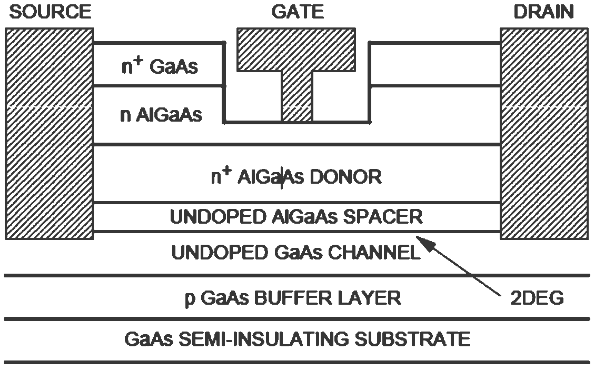

Fig. 1. AlGaAs/GaAs MODFET Structure (2)

Aluminium Gallium Arsenide is a semiconductor material with similar values of lattice constant as of Gallium Arsenide. It possesses a wider band gap, which is an added advantage at high power applications. This band gap value varying between 1.42 ev and 2.16ev. In hetero structure devices, this is used as a barrier material and the layer of AlGaAs is makes the electrons to be confined to GaAs region. One such device is infrared photo detector, works based on quantum mechanics. (9).

In general, Semiconductor sensitivity depends upon temperature, luminous intensity and impurity of atoms. Most of the semiconductor materials have electrical and optical characteristics that are not present in silicon. One among them is Gallium Arsenide, so it is often used for high speed and also for optoelectronics related applications. (5)

Conductivity at low temperatures is depending upon the bounded electrons in crystal, which are normally not available for conduction. Whereas, at higher temperatures thermal energy makes them to free from the covalent bonds, which generates electron hole pair. In a crystal, a large number of atoms are brought together and the interaction between these atoms causes discrete energy levels to reach out into energy bands. At lower temperatures, electrons in a semiconductor will occupy energy bands and the highest occupancy is in valence band. The next band is conduction band, which is separated from valence band by forbidden energy gap. For, silicon it is 1.12ev and for GaAs it is 1.42 ev. (9)

III. MODFET LNA DESIGN

A Low noise amplifier is used to amplify weak signals, which are received by antenna, for example in an RF front end radio receiver. The effect of noise in receiver architecture can be reduced by the gain of low noise amplifier. An efficient Low noise amplifier should possess lower noise figure, typically of less than 3 dB and reasonable gain values of around 20 dB. (6).Other parameters include bandwidth, stability and VSWR values.Low noise amplifier design can be carried out using different substrates.

One such design in a novel approach of using specific parameter pertained to the choice of the substrate i.e RT duroid micro strip methodology is shown in the Fig.2 and here in this design RT duroid substrate with specific values of L=9.4 mm and W =2.1 mm is considered.

This MODFET or High Electron Mobility Transistor (HEMT) Low noise amplifier shown in Fig.2 is versatile and the line calculations depend on frequency of operation as well as characteristic impedance. In device simulations, it is customary that terminations should be done with 50 ohm, so the same rule is followed in this methodology along with proper impedance matching circuits. Scattering parameter analysis is used as these are more appropriate to analyze the performance of a design at higher frequencies as in this case 5.8 GHz. This design performance is evaluated by comparing with the low noise amplifier design based on FR4 substrate (8). The model parameters used in this design are H = 0.75 mm and T =0.15mm .These comparisons are very elaborate in terms of performance parameters like Gain and Noise Figure which are presented in the section IV of this paper.

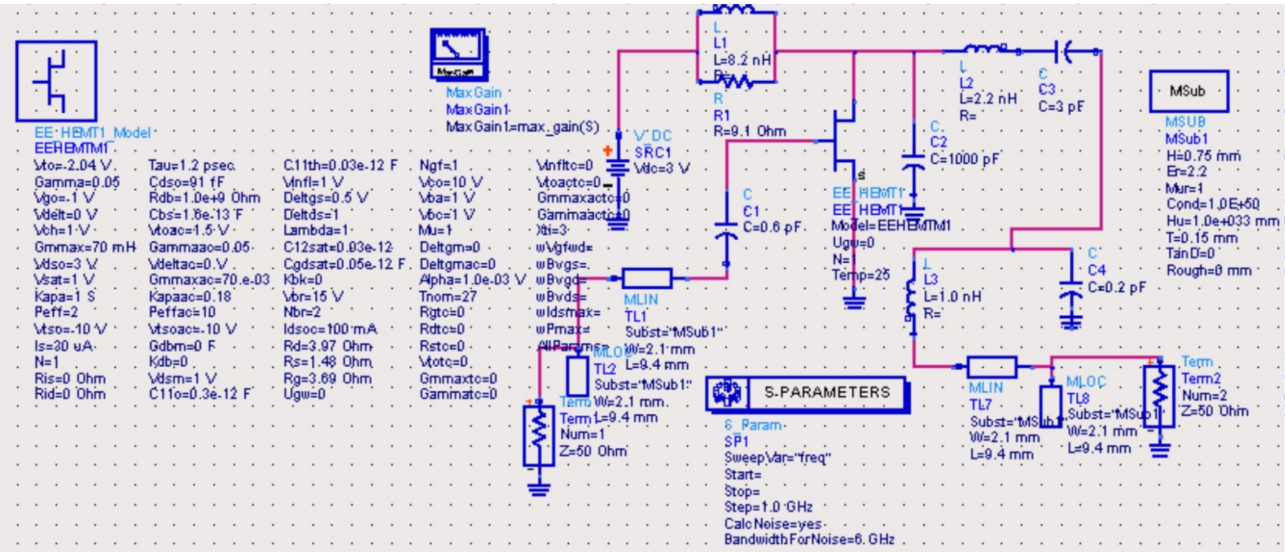

Fig. 2. MODFET LNA with L = 9.4 mm and W = 2.1 mm and a novel RT duroid based design

IV. RESULTS, COMPARISONS AND CONCLUSION

Results shown in Fig.3, Fig.4, Fig.5 and Fig.6 represent the variation of maximum gain and Noise figure values for different Rg values. Where as Fig.9 and Fig.10 represents comparisons of performance parameters like Gain and Noise Figure w.r.t to these Rg values.

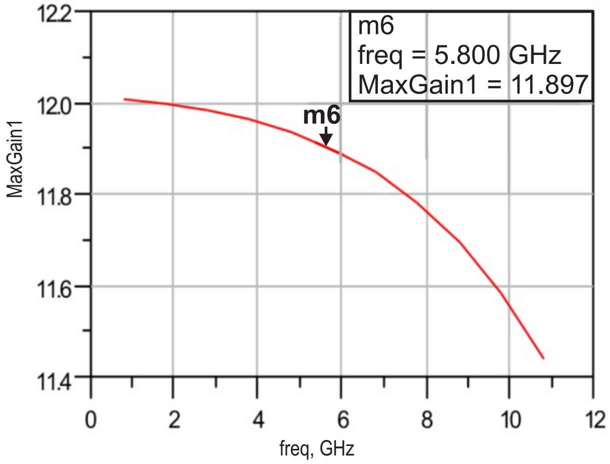

Fig. 3. Maximum gain when, Rg value is 3.69 ohm, Gm max = 70 mS, IS = 30UA, and VGS = – 3V

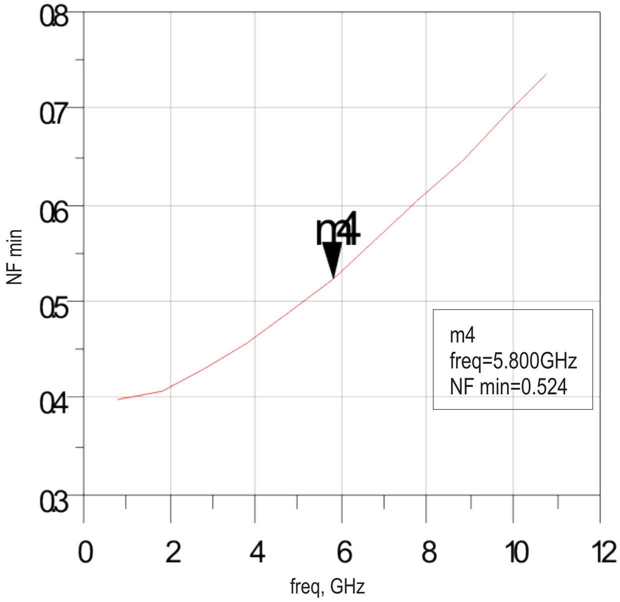

Fig. 4. Noise figure when, Rg value is 3.69 ohm, Gm max = 70 mS, IS= 30UA, and VGS = – 3 V

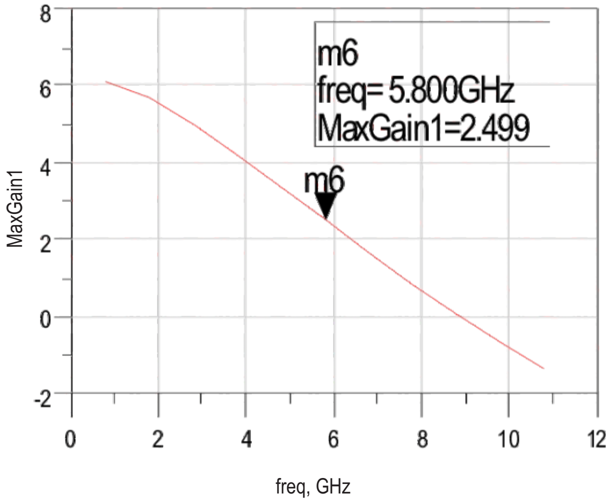

Fig. 5. Maximum gain when, Rg value is 3.69 Kohm, Gm max = 70 mS, IS = 30 UA, VGS = – 3V

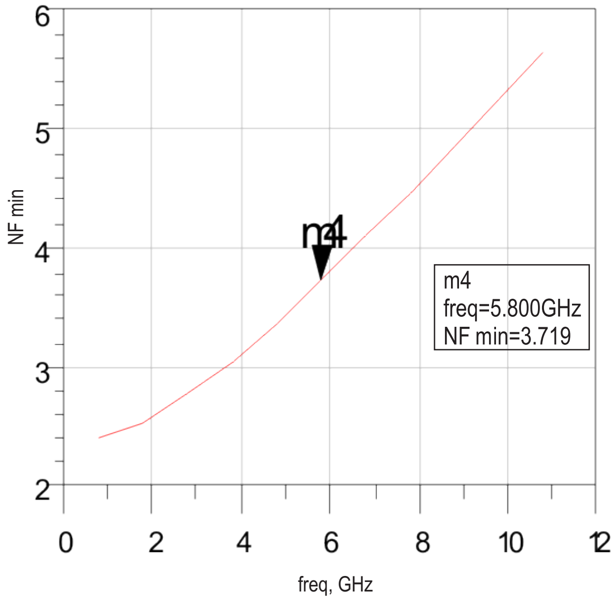

Fig. 6. Noise Figure when, Rg value is 3.69Kohm, Gm max = 70 mS, IS = 30 UA, VGS = – 3V

Fig. 8 and Fig.9 represents the performance evaluation of the design shown in Fig.2 by comparison w.r.t to the low noise amplifier design based on FR4 substrate Table 1. Present the various combinations of parameter values that are considered to evaluate the design in terms of Gain and Noise Figure. Fig. 11 depicts the Layout of the low noise amplifier shown in Fig.2. It can be observed from the layout the location of lines used in the design.

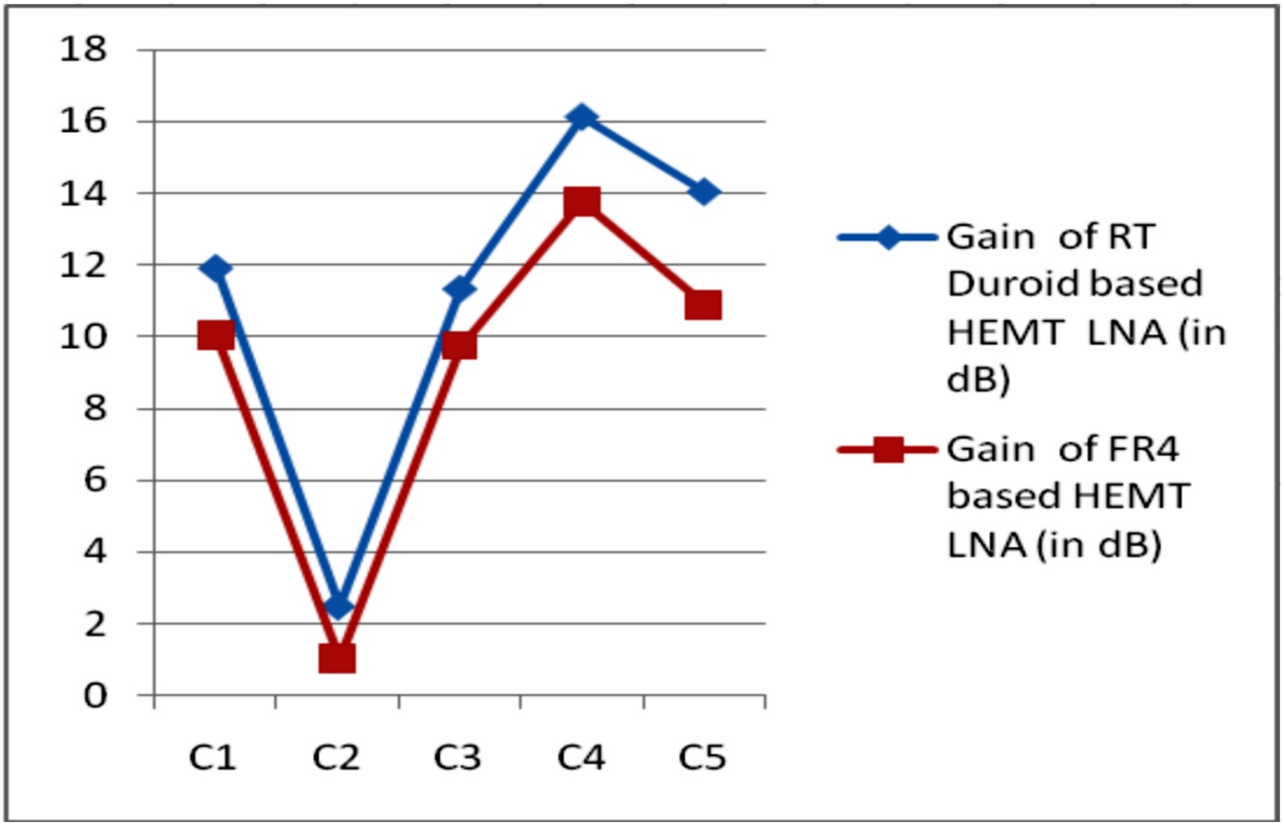

Fig. 7. Comparison of Gain of Novel RT duroid HEMT(MODFET) LNA design w.r.t to FR4 HEMT LNA

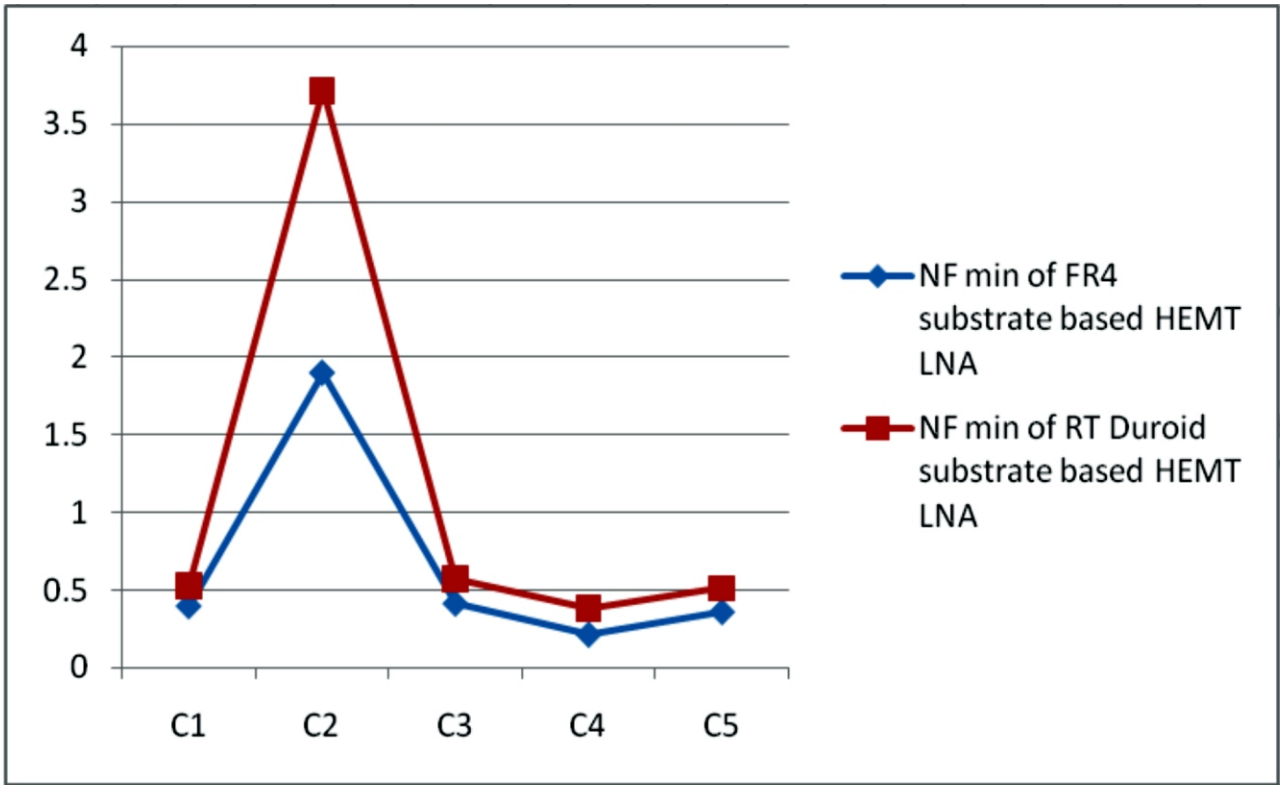

Fig. 8. Comparison of Noise Figure of Novel RT duroid HEMT(MODFET) LNA design w.r.t to FR4 HEMT LNA

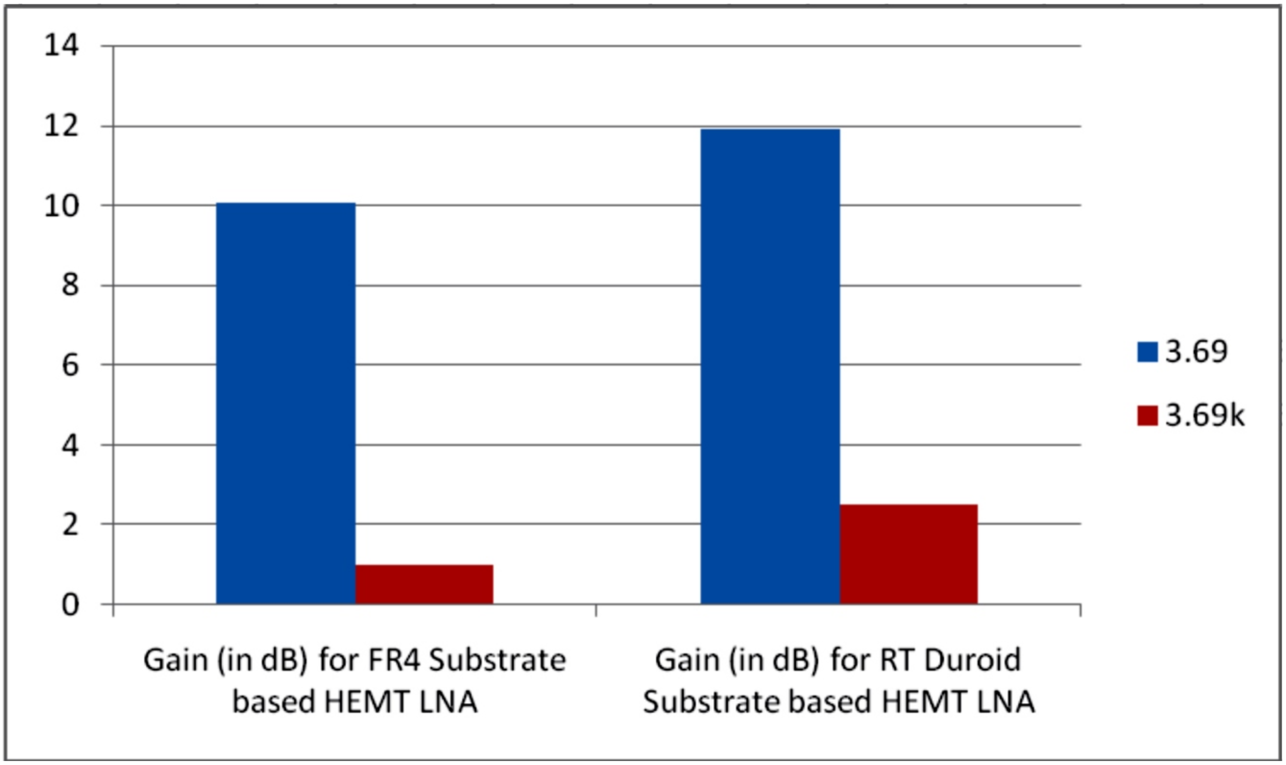

Fig. 9. Comparison of Gain of Novel RT duroid HEMT(MODFET) LNA design w.r.t to FR4 HEMT LNA when the gate resistance is of 3.69 and 3.69k ohms.

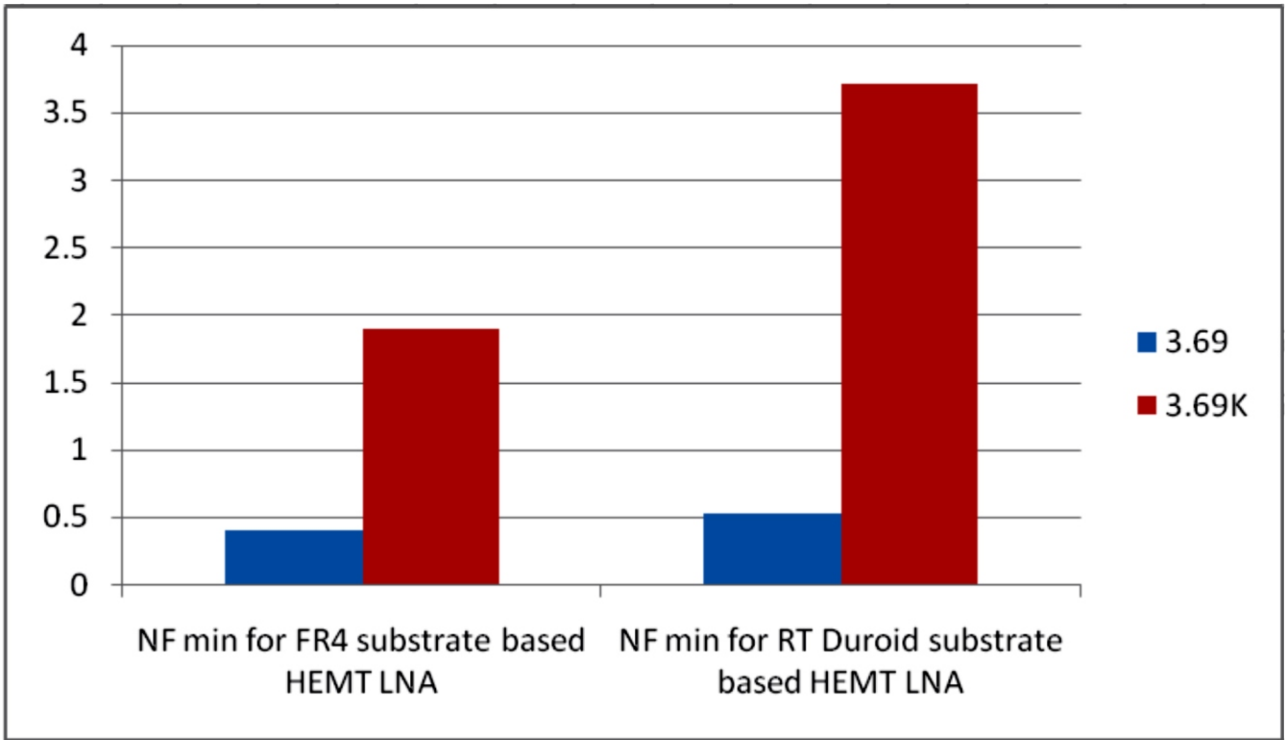

Fig. 10. Comparison of Noise Figure of Novel RT duroid HEMT (MODFET) LNA design w.r.t to FR4 HEMT LNA when the gate resistance is of 3.69 and 3.69k ohms.

Table 1. Gain and Noise Figure Variation w.r.t to different parameters combinations

Combination	Parameters				Gain (in dB)	NF min
	Rg (ohm)	gm (mS)	Vgs (V)	Is (uA),		
C1	3.69	70	– 3	30	11.897	0.524
C2	3.69k	70	– 3	30	2.499	3.719
C3	3.69	100	– 3	30	11.321	0.572
C4	3.69	70	– 3	15	16.108	0.379
C5	3.69	70	– 1	30	14.026	0.512

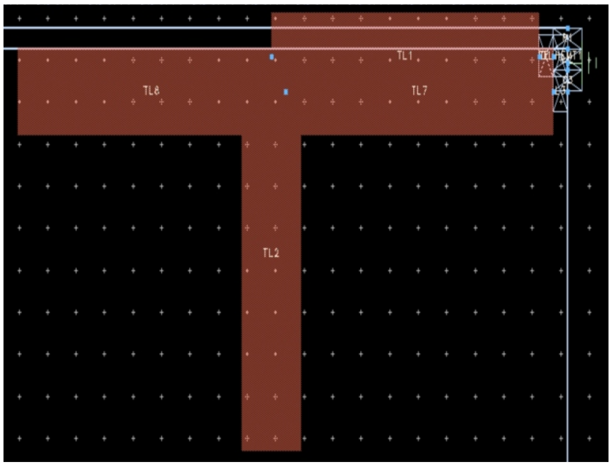

Fig. 11. Layout of the MODFET LNA

Results obtained and comparative analysis has shown that the low noise amplifier designed based on RT duroid has shown reasonable gain and low noise figure values, when compared with FR4 design. It can also be concluded that variation of Rg value also alters the performance of the Low noise amplifier. This noise figure whose value should be less than 3 dB for a good design is satisfied in all the combinations and whereas in the combination C2, where the resistance value is higher noise figure is a higher value. Therefore, it can be concluded that higher values of greater resistance hampers the performance of the device and this is due to the shot noise influence at the higher frequencies.

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