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Design and Simulation of Low Noise Amplifier at 10 GHz By GaN High Electron Mobility Transistor

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Abstract: *In this paper, design and simulation of a 10 GHz Low Noise Amplifier (LNA) for Wireless communication systems have been explored. The simulation result has been performed by using the Agilent Advanced Design System (ADS) software. Tuning and optimization tools of ADS software have been used to optimize results. The High Electron Mobility Transistor (HEMT) based on GaN is used for decreasing of Minimum Noise Figure (NFmin) of LNA. Also, for more decreasing NFmin of LNA radial stub elements are implemented in biasing network. We have designed a 10 GHz LNA based on three design manner basing on the lumped, the distributed and radial stub elements. The designed amplifier offers forward gain of 15.72 dB with the noise figure of 1.09 dB at 10 GHz. The input return loss (S11) is equal to -9.635 dB at 10GHz. The output return loss (S22) is equal to -10.009 dB at 10GHz. Also, the isolation (S12) of proposed structure is equal to -22 dB at 10 GHz. The simulation result have shown that the forward gain and noise figure of 10 GHz LNA are optimized noticeably with respect to the pervious works.*
Keywords: *forward gain, Low Noise Amplifier (LNA), noise figure, radial stub element, lumped element*

I. Introduction

Low Noise Amplifiers (LNA) are the building blocks of any wireless communication system. LNA is used to amplify very weak signals for example signal captured by an antenna [1]. The four most important factors in LNA design are: gain, noise figure, and non-linearity and impedance matching. Noise figure is very important factors which determines the performance of a LNA. Hence, we can decide which LNA is suitable for a particular application. Low noise figure results in better acceptance of signal [2]. With the low noise figure LNA must have high gain for the processing of signal into post circuit. According to requirement high gain LNA are designed for application by manufacturer. If the LNA doesn't have high gain then the signal will be affected in by noise in LNA circuit itself and maybe attenuated so high gain of LNA is the important parameter of LNA [2, 3]. Input matching circuit is used for making balance between gain and noise figure. Output matching circuit is used for improving gain, gain flatness, and input voltage standing wave ratio (VSWR) [1, 4].

The gain, Noise figure and stability circle of the circuits information have been achieved by the scattering parameter analysis. For low noise, the amplifier needs to have a high amplification in its first stage. Therefore, MESFETs and HEMTs are often used. For microwave high power and low noise application AlGaN/GaN HEMT attracted consideration because of their excellent microwave characteristics, low noise and high power microwave performance and high current drive capability [5].

LNA at 10 GHz has demonstrated a noise figure of 1.18 dB and forward gain of 13.14 dB [1]. HEMT technology and distributed and radial stab element is used for designing LNA in [1]. LNA with noise figure 1.38 dB and forward gain of 13.53 dB was reported [2]. LNA at 10 GHz has demonstrated a Noise figure of 3.5 dB and forward gain of 13 dB [6]. The RF-CMOS 65nm technology and cascode topology is implemented in its design. The LNA showed a noise figure of 2.29 dB and forward gain 9.11 dB at 10 GHz [7]. GaAs high frequency transistor and common source topology has been implemented for designing circuit in [7]. LNA with a noise figure of 2.72 dB and forward gain of 11.040 dB at 11 GHz were reported [8]. 180 nm RF-CMOS technology and two stage cascode topology is used for designing circuit in [8].

Three different structures are using for designing of LNA at 10 GHz. Lumped, distributed and radial stub elements are implemented for preparing these structures. LNA has demonstrated a noise figure of 1.097 dB and forward gain of 15.72 dB. The main task of this paper is explained completely in the following manner. The first part of this paper explains the performance of a 10 GHz LNA. In this section, the lumped and distributed elements are implemented for designing input and output matching networks. Also, radial stub elements are used for designing biasing networks. In the second part of this paper, the 10 GHz simulation results are explained. In the final part, the complete conclusion of this paper is explained.

II. 10 GHz in a design

Stability is a very important factor for designing microwave amplifiers. Stability can be defined by the S parameters of the device , the matching networks, the source and load terminations. For determining stability, calculate Rollet's Stability factor, (represented as variable K) using S-parameters at a given frequency. The adequate and essential situation for being unconditional stability are in the following manner [1]:

$$K = \frac{1-|S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}.S_{21}|} > 1 \quad (1)$$

$$|\Delta| = |S_{11}.S_{22} - S_{12}.S_{21}| < 1 \quad (2)$$

There are three parameters in ADS software for calculation stability factor of LNA such as Stab Meas, Stab fact, and mu. Where,

$$Stab\_fact = K \quad (3)$$

$$Stab\_meas = 1-|S_{11}|^2 - |S_{22}|^2 + |\Delta|^2 \quad (4)$$

$$MU = \frac{1-|S11|^2}{|S_{22} - conj(S_{11}).\Delta| + |S_{12}.S_{21}|} \quad (5)$$

For being unconditional stable: Stab_fact>1 and Stab_meas>1 or MU>1

The simulation result indicate in Fig. 1. According to the Fig. 1 stab fact and MU are smaller than 1, so the transistor is conditional stable in working frequency.

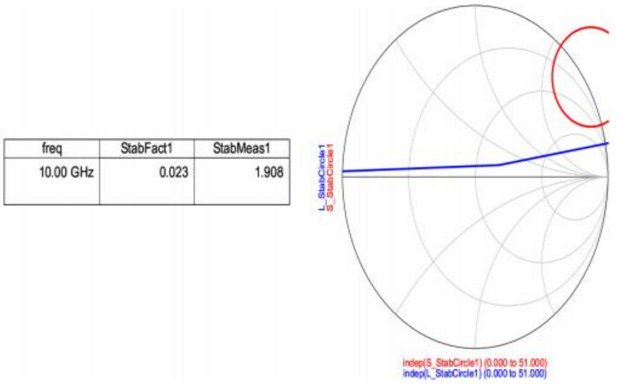

Fig. 1. Stability figure for active part of 10 GHz amplifier

The feedback resistor between drain and gate is used for improving stability of circuit. Optimization and tuning tools of ADS software have been used for calculating of feedback resistor. Fig. 2 indicate transistor with feedback resistor. The simulation result indicate in Fig. 3. According to the fig. 3 stab fact and MU are improved noticeably in working frequency.

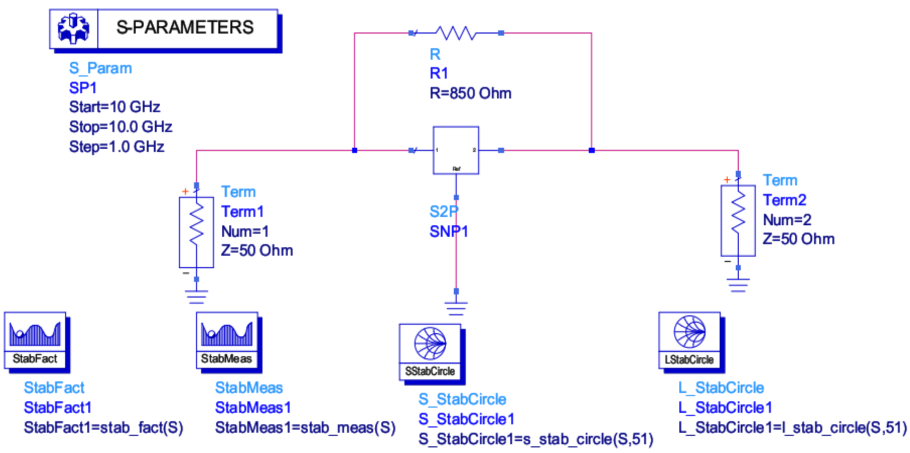

Fig. 2. Transistor with feedback resistor

freq	StabFact1	..abMeas1	NFmin	MaxGain1
10.00 GHz	1.024	1.329	0.867	18.102

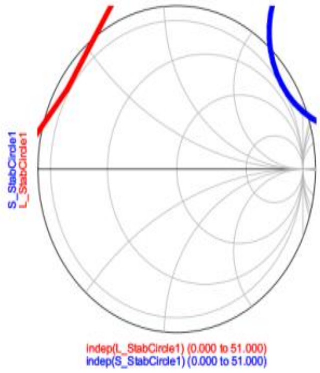

Fig. 3. Stability condition with feedback resistor

III. structures of lna with simulation results

The first LNA, design is based on lumped element for matching and bias networks as shown in Fig. 4.

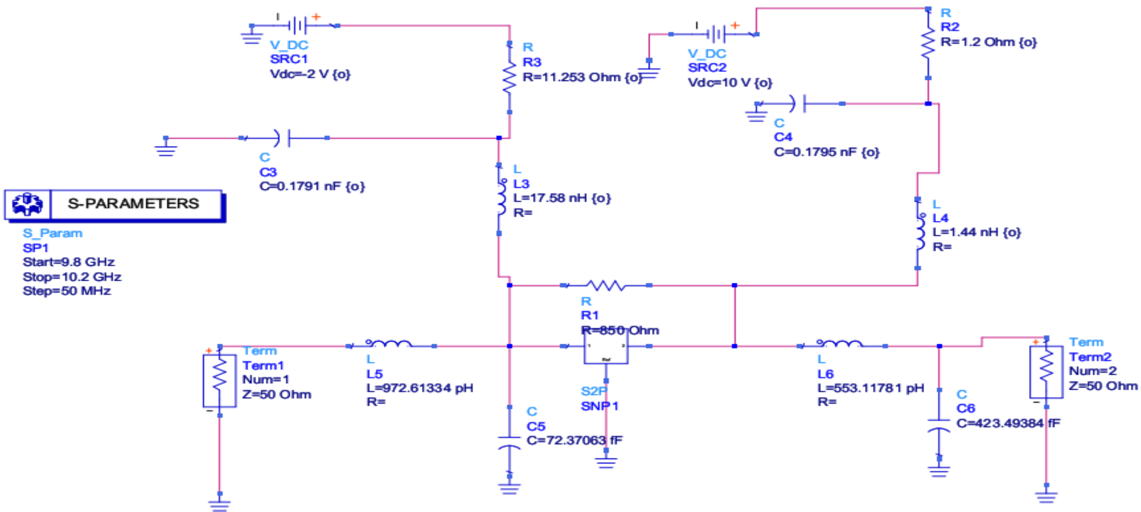

Fig. 4. LNA with lumped elements for matching and bias networks

The simulation results of LNA with lumped element for matching and bias networks indicate in Fig. 5.

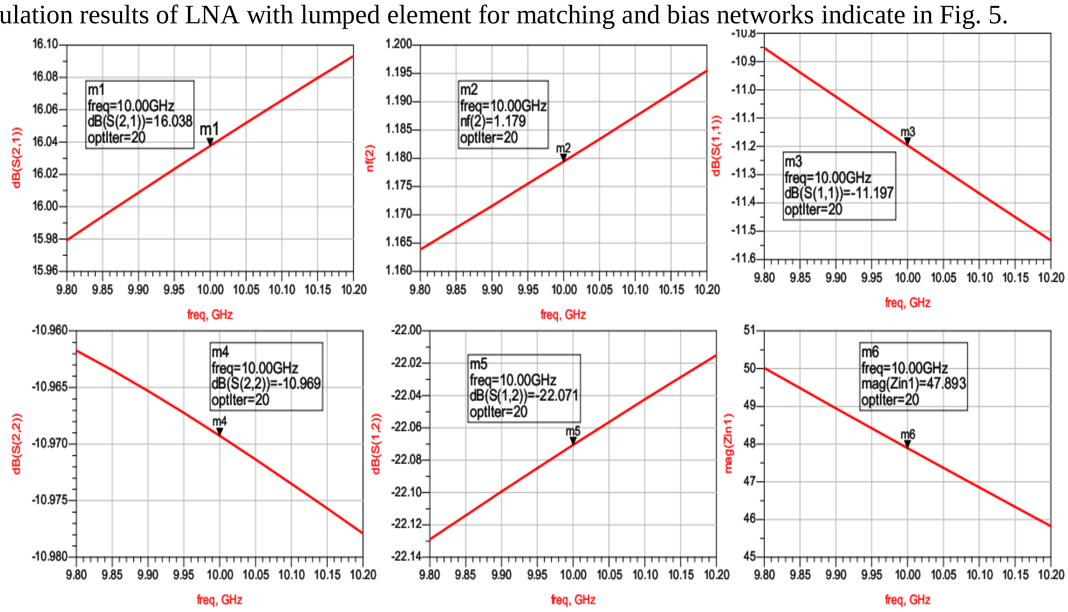

Fig. 5. Simulation results of LNA with lumped element for matching and bias networks

The second LNA, design employs distributed element for matching network and lumped element for Biasing network.

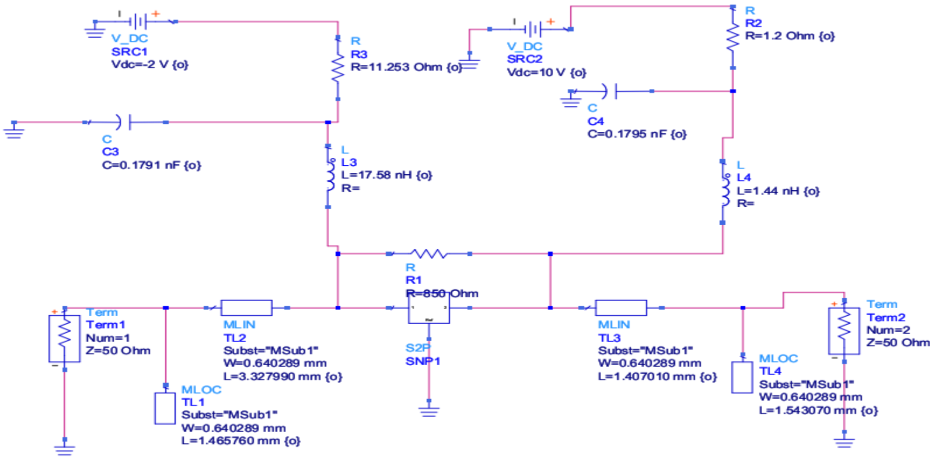

Fig. 6. LNA with distributed element for matching network and lumped element for biasing network

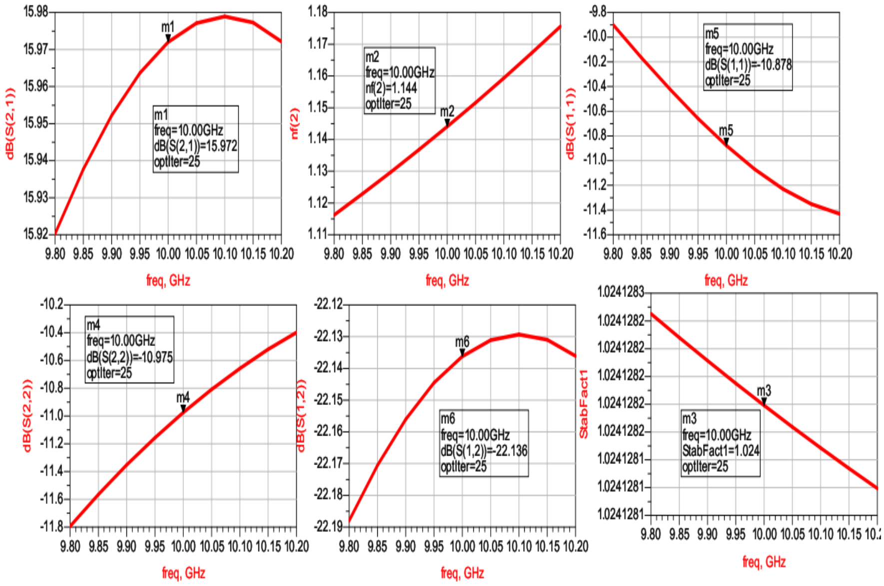

Fig. 7. Simulation result of LNA with distributed element for matching network and lumped element for biasing network

The third LNA, design is based on distributed element for matching network. The biasing network design based on radial stub, inductor and capacitor is shown in fig. 8. Also, biasing network performance is shown in fig. 9.

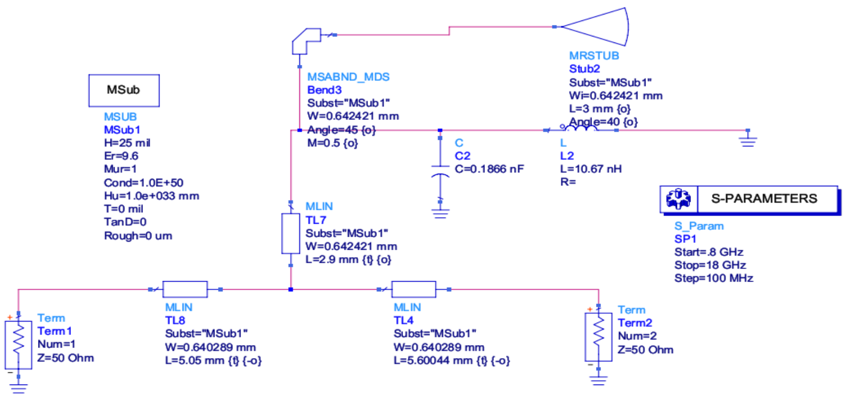

Fig. 8. Biasing network with radial stub elements

According to the Fig. 9 S11 is less than -50 dB and S21 confined to 0 dB, this result indicates that biasing network performance is satisfactory. The designed LNA is shown in Fig. 10. Distributed elements have been used for designing input and output matching networks.

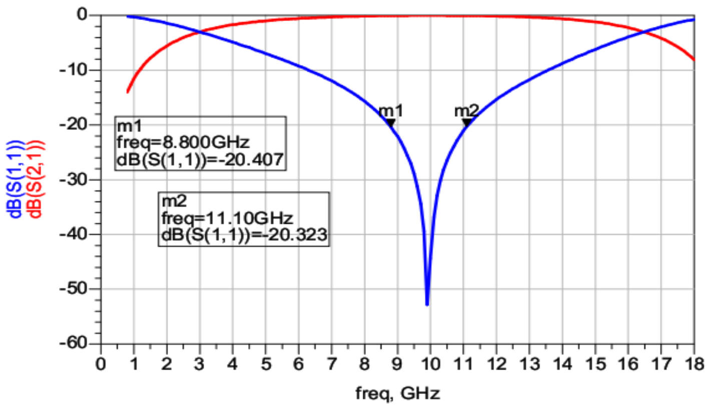

Fig. 9. Biasing network performance

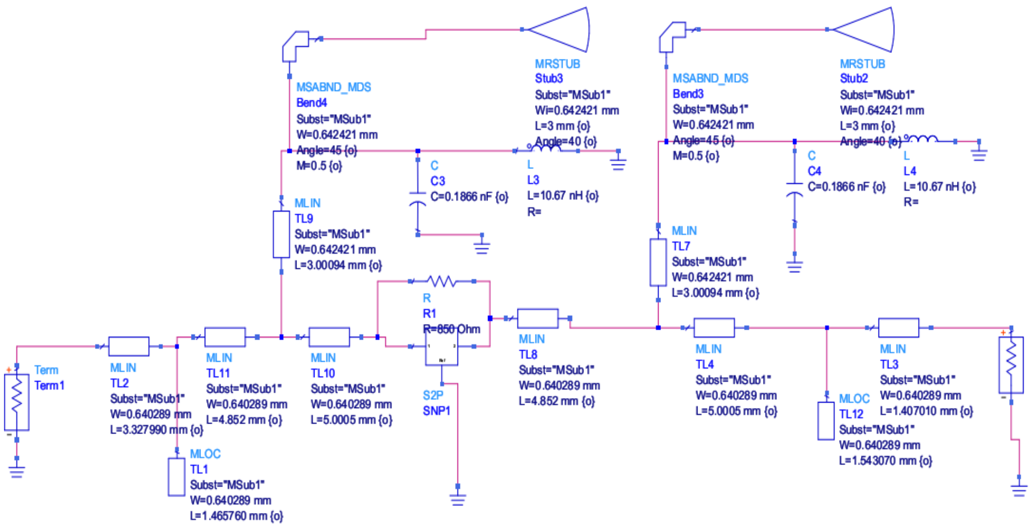

Fig. 10. Designed LNA

The simulation result of designed LNA is shown in Fig. 11.

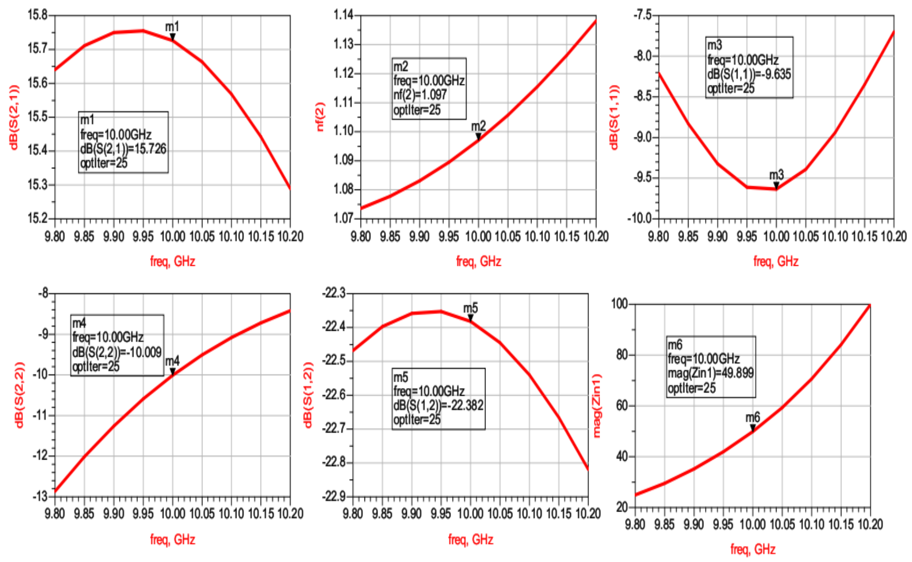

Fig. 11. Simulation result of designed LNA

IV. summary of simulation results

Table I presents the summary of simulation results of a 10 GHz LNAs. The obtained results show that the forward gain and noise figure of these designs is almost 15.7 dB and 1.097 dB respectively in 10 GHz. Input impedance of these structures are nearly 50 ohm. Since the characteristic impedance is equal to 50 ohm, this result indicates that design of input matching network has been accurate.

Table I. Comparison between the designs of 10 GHz LNAs

LNA types	Gain [dB]	Noise Figure [dB]	Input return loss [dB]	Output return loss [dB]
Fig. 4	16.038	1.179	-11.19	-10.96
Fig. 6	15.97	1.14	-10.87	-10.97
Fig. 10	15.72	1.097	-9.63	-10.009

Table II indicates a comparison between the simulated results with other works. According to table II, Noise figure in [1], [2] and [6] is equal to 1.18 dB, 1.38 dB and 3.5 dB respectively. But noise figure in our study is equal to 1.097 dB. This result indicates noise figure is reduced in compare with prior literature [1, 2, and 6]. Forward gain (S21) is higher than [1, 2, and 6]. Also, input and output reflection coefficient (S11, S22) of these structures are improved noticeably. To our knowledge, these are the best noise figure performance of GaN-HEMT- LNAs ever reported at 10 GHZ.

Table II. Comparison with to other reported designs

Reference	F0 [GHz]	Gain [dB]	Noise Figure	Input return loss [dB]	Output return loss [dB]
This work	10	15.72	1.097	-9.63	-10.009
[1]	10	13.14	1.18	-18	-8.78
[2]	10	13.53	1.38	-17.98	-10.016
[6]	10	13	3.5	-16	-27

V. Conclusion

In this paper, LNAs at 10 GHz for communication system have been designed and simulated. We used three different structures for design of LNA at 10GHz. It is observed that the forward gain and noise figure of these designs is almost 15.72 dB and 1.097 dB respectively in 10 GHz. This results indicate noise figure and forward gain of this structures are improved noticeably with respect to the previous works. The simulation result have good assent with desired demand.

References

[1] Mohammad Fallahnejad, Alireza Kashaniniya, Design of Low Noise Amplifiers at 10 GHZ and 15 GHZ for Wireless Communication Systems characters, *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 9, Issue 5 Ver. IV,* 2014, 47-53.

[2] Mohammad Fallahnejad, Alireza Kashaniniya, Design of a Low Noise Amplifier for 10 GHz Wireless Communication systems, *6th Iranian conference on electrical and electronic engineering ICEEE),* 2014

[3] Yu. Na Su and G. Li, Design of a Low Noise Amplifier of RF Communication Receiver for Mine, *Electrical & Electronics Engineering (EEESYM), , 2012 IEEE Symposium on,* 2012, 125-127

[4] C. Kumar and N. Gupta, Design of Front End Low Noise Amplifier for Wireless Devices, *Engineering and Systems (SCES), 2012 Students Conference on* , 2012, 1-4

[5] Mohammad Fallahnejad, Alireza Kashaniniya, Mehdi Vadizadeh, Design and Simulation Noise Characteristics of AlGaN/GaN HEMT on SIC Substrate for Low Noise Applications, *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 10, Issue 3 Ver. II,* 2015, 31-37

[6] Hakchul Jung, Hee-Sauk Jhon, Ickhyun Song, Minsuk Koo, Hyungcheol Shin, Design optimization of a 10 GHz Low Noise Amplifier with gate drain capacitance consideration in 65 nm CMOS Technology, *Solid-State and Integrated-Circuit Technology,* 2008, 1480-1483

[7] M. Challal, A. Azrar, H. Bentarzi, R. Ecioui, M. Dehmas and D. Vanhoen Acker Janvier, On Low Noise Amplifier Design for Wireless Communication Systems, *Information and Communication Technologies: From Theory to Applications (ICTTA), 3rd International Conference on,* 2008, 1-5

[8] B. Afshar and Ali M. Niknejad, X/Ku Band CMOS LNA Design Techniques, *IEEE Custom Integrated Circuits Conference (CICC),* 2006, 389-392

[9] Avago Technologies, Low Noise High Freq PHEMT, ATF-36077 Data Sheet, April 29, 2008.

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