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Design of Low Noise Amplifier for X band Application

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ABSTRACT

In this work various low noise amplifiers are designed for X band applications which ranges from 8 GHz to 12 GHz and the center frequency considered is 10.5 GHz. This frequency is used for Police Speed RADAR Application. For improving the stability of the amplifier inductive source degeneration methodology is used which not only improves the stability of the amplifier but also increases the signal strength i.e. improves the gain with minimum change in the noise figure. With the help of this technique a high power gain of 13.051 dB and optimum noise figure of 1.468 dB and minimum VSWR of 1.007 at the source side and 1.022 at the load side of the amplifier.

Keywords: LNA, ADS, Power Gain, Noise Figure, X band

I. INTRODUCTION

In the microwave spectrum of electromagnetic waves 8 GHz to 12 GHz frequency range is classified under X band by IEEE. There are various applications operating under this band like traffic light, detection system, Police Speed RADAR, Radio Navigation, Amateur Radio, etc. The main advantage of using X band frequencies for these sensitive applications is its high immunity towards atmospheric attenuation and being robust even in harshest weather conditions. Even in rain, sand storm and other much worse weather conditions there is high link available for the users.

Christina Lessi, Evangelia Karagianni designed an X band LNA for Marine Navigation RADAR and obtained a power gain of 15 dB and noise figure of 5 dB [1]. Tumay Kanar, Gabriel M. Rebeiz, designed cascaded low noise amplifiers using SiGe HBT for X band and K band applications obtaining a noise figure of 1.2 dB for X band and 2.2 dB for K band LNA with a power gain of 24.2 dB and 19 dB respectively [2]. Mohammad Fallahnejad, Yasaman Najmabadi, et al, designed different low noise amplifiers for 10 GHz applications using GaAs HEMT with lumped matching components obtaining a power gain of 15.049 dB and noise figure of 0.806 dB and to further improve the noise immunity RF chokes were used and could achieve less noise figure of 0.775 dB and gain of 14.77 dB [3]. Toahera Abdullah, Apratim Roy, et al, designed a wide band CMOS based LNA with gain flattening method obtaining a power gain of 11 dB, noise figure of 2.3 dB and VSWR of 3.5 at source side and 9.5 at load side of the amplifier [4]. Nan Li, Weiwei Feng, and Xiuping Li, designed a CMOS UWB LNA for 3–12-GHz using the load effect of common gate configuration which is applied with the dual resonance load network for noise figure flatness and wide-band matching which resulted in the power gain of 13.8 dB and noise figure of 3.5 dB [5]. Murat Davulcu, Can Caliskan, et al, designed high dynamic range SiGe BiCMOS LNA for X band applications obtaining a power gain of 15 dB and noise figure of 2.7 dB [6]. Jyh Chyurn Guo and Ching Shiang Lin designed an UWB CMOS LNA using resistive feedback under forward body bias condition and obtained the noise figure of 3.95 dB, gain of 10.55 dB [7]. Abdelkader Taibi, Mohamed Trabelsi, et al, designed low noise amplifiers with different techniques like connecting an inductor Li as a coupling device between the first and the second amplifier stage where they obtained a noise figure of 5 dB and power gain of 10 dB without Li and 15 dB with Li. Another technique is using a Microstrip band pass filter with the LNA in which power gain of 16 dB and 4.5 dB is achieved [8]. The main parameters of consideration for analysis of the efficient working of a low noise amplifier are power gain, noise figure, VSWR and scattering parameters.

II. DESIGN ASPECTS

Advanced Design System (ADS) simulation tool is used for designing the low noise amplifier. There are two different types of device libraries available in the ADS software namely S – parameter library and RF Transistor library. S – Parameter library works on fixed bias i.e. these parameters of the device are fixed for a particular bias point of the device. In this work, the S – parameter library device is used.

The low noise amplifiers are designed with the help of the S - parameters of the active device being used. These parameters are responsible for determining the stability of the device and hence the amplifier. The step by step procedure for designing a low noise amplifier is described in [9].

The active device used in this work is ATF – 36163 which is a surface mount pseudomorphic high electron mobility transistor (pHEMT) of Hewlett Packard. The range of operation of this device is between 1.5 – 18 GHz.

In a low noise amplifier, the vital parameters to be considered are, maximum gain provided by the active device which is termed as MAG (maximum available gain) and NFmin (minimum intrinsic noise) figure which in turn depends on the S parameters of the device.

Theoretically, the stability of the device is checked using Rollet K - |Δ| test which is described in [10].
Also, B is another parameter that is calculated for checking stability which should be positive for stable operation given by,

$$B = 1 + \left|S_{11}\right|^2 - \left|S_{22}\right|^2 - \left|\Delta\right|^2 \quad (1)$$

And Δ is given by,

$$\Delta = S_{11}\, S_{22} - S_{12}\, S_{21} \quad (2)$$

The condition for stability is that if $K > 1$, $|\Delta| < 1$ and B = +ve, then the device is unconditionally stable and if $K < 1$ then device is potentially unstable. This condition will tend the device to oscillate and the maximum available gain will be no more valid due to unstable condition.

Hence, the maximum gain produced by the device will now be said as MSG (maximum stable gain) which is mathematically expressed as,

$$MSG = \frac{|S_{21}|}{|S_{12}|} \quad (3)$$

If the device is unconditionally stable i.e. $K > 1$, then the gain obtained will be maximum available gain which is expressed as,

$$MAG = \frac{|S_{21}|}{|S_{12}|}\left(K \pm \sqrt{K^2 - 1}\right) \quad (4)$$

There is another parameter introduced to check the stability of the active device for stable operation given by,

$$\mu = \frac{1 - |S_{11}|^2}{|S_{22} - \Delta S_{11}{}^*| + |S_{12}S_{21}|} \tag{5}$$

For the device to operate in unconditionally stable region the value of μ should be greater than 1 (μ > 1) and if it's less than 1 then the device is potentially unstable. This condition will tend the device to oscillate which degrades the noise immunity and distort the signal.

Hence, to improve the stability of the active device there are various techniques available which are described in [11]. One such technique is to connect an inductor in series to the source terminal of the active device i.e. here pHEMT and this technique is said to be inductive source degeneration technique. This technique not only improves the stability of the amplifier but also improves the signal strength i.e. the power gain without much affecting the noise immunity [12]. Here, the circuit is designed both using the lumped elements and distributed components i.e. transmission line equivalent of the lumped components and in this work the fact that lumped components are not suitable to be used at high frequencies is understood due to the reason that is described in [13].

The substrate used for designing the Microstrip matching components is RT Duroid 5880 of Rogers Corporation which has following parameters shown in table 1.

TABLE I

RT Duroid 5880 parameters

Parameters	Values
ε_r	2.2
tanδ	0.0009
substrate height (h)	1.6 mm
metal thickness (t)	0.035 mm
conductivity (σ)	5.8 x e7

Voltage Standing wave ratio (VSWR) is another parameter which determines the amount of reflections that occurs in a microwave circuit due to improper impedance matching. It is represented in the form of reflection co-efficient which is mathematically described in [14].

The VSWR values ranges from 1 < VSWR < ∞ for the corresponding reflection co-efficient of 0 < Γ < 1 theoretically.

III. PROPOSED DESIGNS

The low noise amplifier is designed with source inductive degeneration for this application using lumped matching network components is shown in fig. 1.

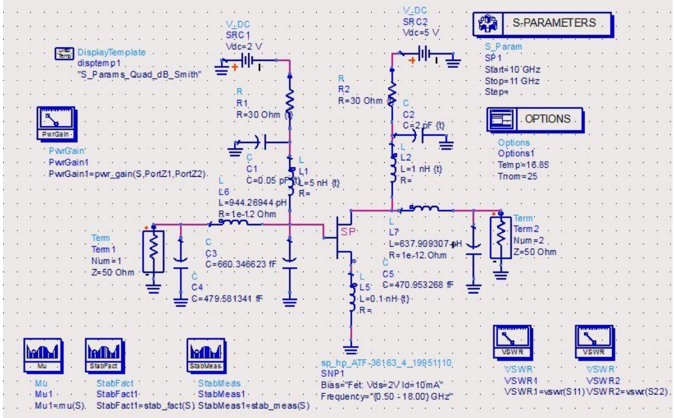

Figure 1. LNA Using Lumped Components

The Rollet's stability factor K, μ and |Δ| obtained for the complete designed amplifier including the matching network is shown above in fig. 2 which is obtained as 1.279, 1.083 and 0.446 respectively.

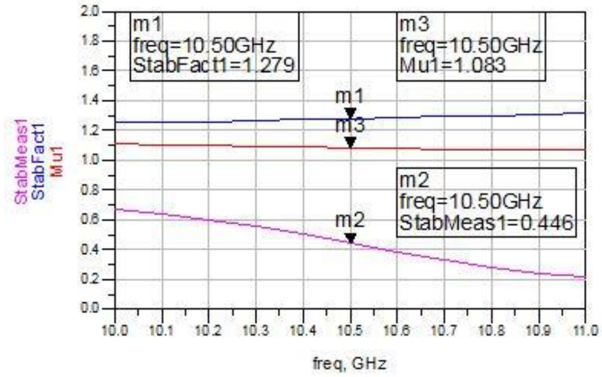

Figure 2. Stability check

Therefore, the above obtained values of K > 1, |Δ| < 1 and μ > 1 proves that the device is unconditionally stable.

The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 3 which are 1.009 and 6.049 at input and output side respectively. Though the source side VSWR is less, the load side VSWR is very high which signifies that the amount of reflections is very high and hence maximum input power cannot be transferred to the output side of the amplifier.

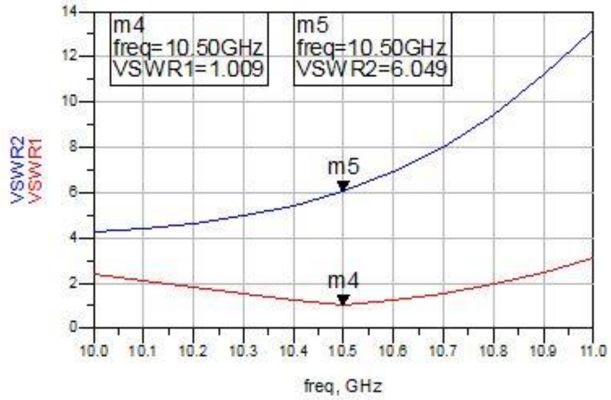

Figure 3. VSWR

The second LNA designed is using distributed Microstrip components for the input and output matching network which is shown in fig.4.

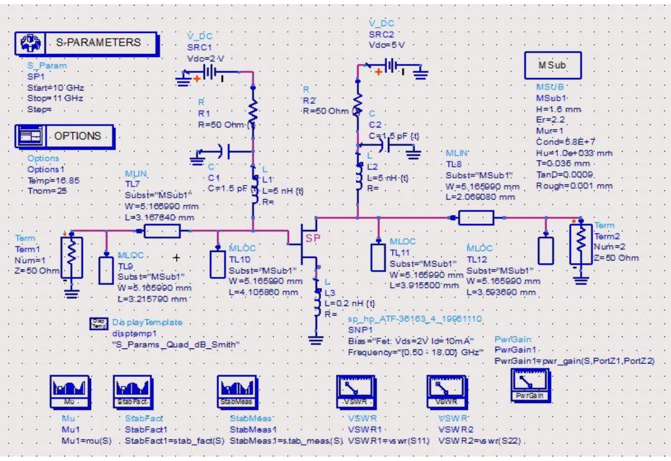

Figure 4. LNA Using Microstrip Components

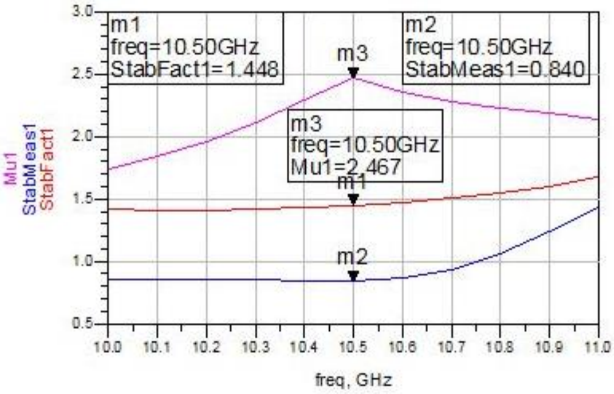

Figure 5. Stability check

The Rollet's stability factor K, μ and |Δ| obtained for the complete designed amplifier including the matching network is shown above in fig. 5 which is obtained as 1.448, 2.467 and 0.840 respectively.

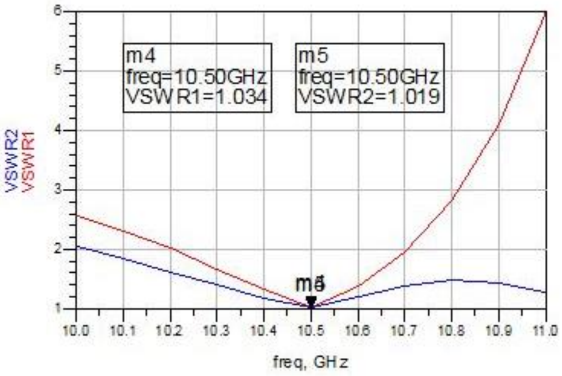

Figure 6. VSWR

The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 6 which are 1.034 and 1.019 at input and output side respectively. These minimum values of VSWR signifies that the amount of reflections is very less and hence maximum input power can be transferred to the output side of the amplifier.

The third low noise amplifier is designed using RF chokes connected both at the gate and drain terminal of the active device because of the fact described in [15]. The designed LNA is shown in fig. 7.

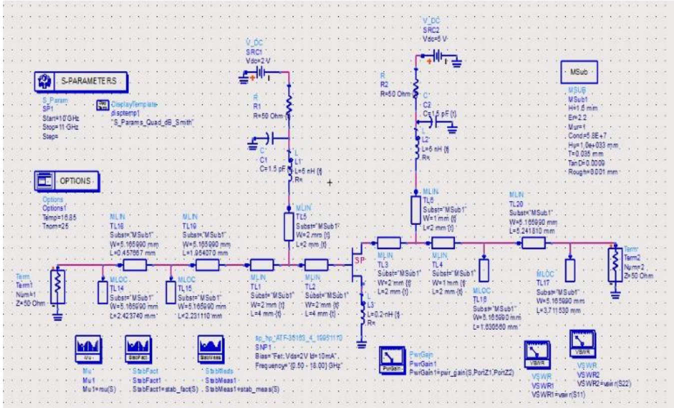

Figure 7. LNA using RF choke

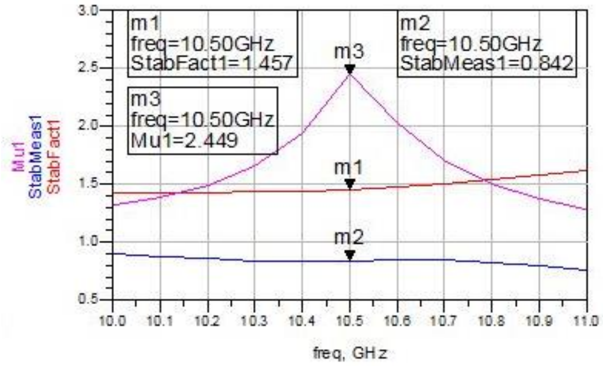

Figure 8. Stability check

The Rollet's stability factor K, μ and |Δ| obtained for the complete designed amplifier including the matching network is shown above in fig. 8 which is obtained as 1.457, 2.449 and 0.842 respectively.

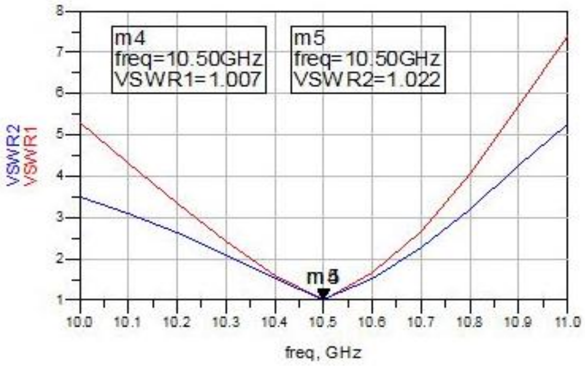

Figure 9. VSWR

The VSWR obtained for the source (VSWR1) and load (VSWR2) matching is shown in fig. 9 which are 1.007 and 1.022 at input and output side respectively. These minimum values of VSWR signifies that the amount of reflections is very less and hence maximum input power can be transferred to the output side of the amplifier.

IV. SIMULATED RESULTS AND DISCUSSION

The power gain and noise figure obtained for the source degenerative LNA using lumped components are 8.327 dB and 1.902 dB as shown in fig. 10 and 11 respectively.

Figure 10. Power Gain

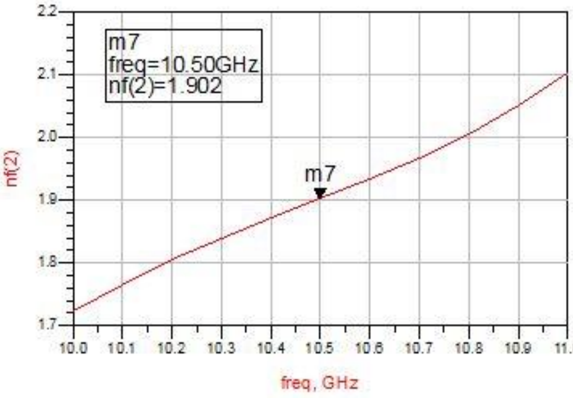

Figure 11. Noise Figure

These values of gain and noise figure shows that the lumped components are not suitable for highter frequency applications due to its low noise immunity.

The S - parameters obtained for lumped component LNA is shown in fig. 12. The values obtained are S_{11} as -46.647 dB, S_{12} as -22.029 dB, S_{21} as 8.327 dB, and S_{22} as -2.899 dB.

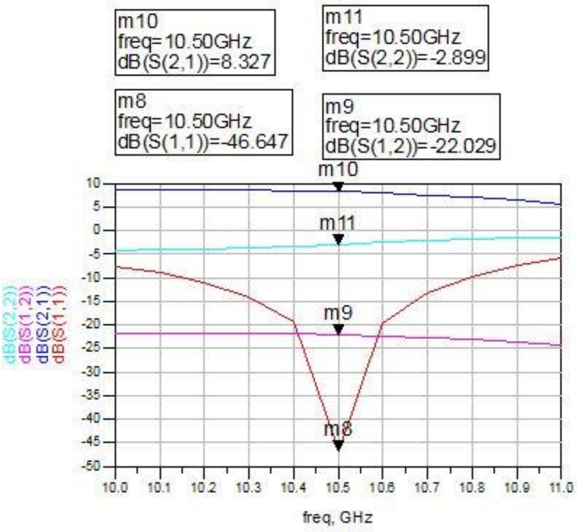

Figure 12. S parameters

The power gain and noise figure obtained for the source degenerative LNA using Microstrip components are 13.014 dB and 1.484 dB as shown in fig. 13 and 14 respectively.

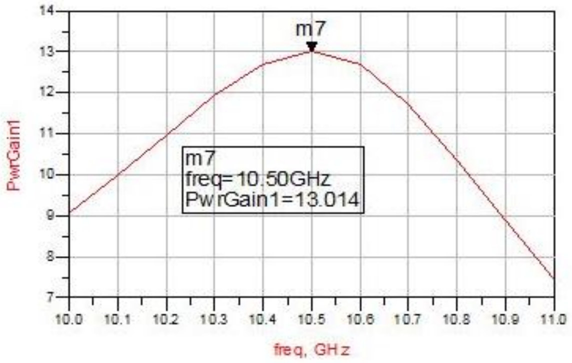

Figure 13. Power Gain

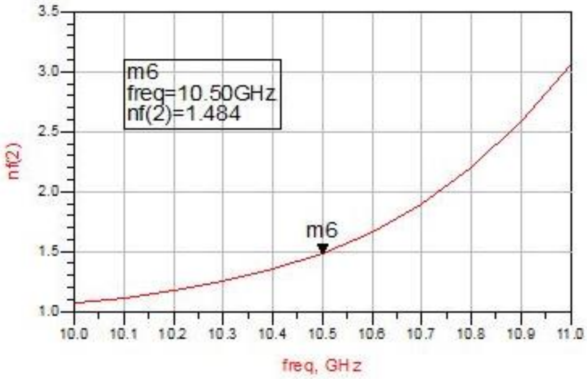

Figure 14. Noise Figure

The S - parameters obtained for Microstrip component LNA is shown in fig. 15. The values obtained are S_{11} as -35.613 dB, S_{12} as -20.995 dB, S_{21} as 13.014 dB, and S_{22} as -40.430 dB.

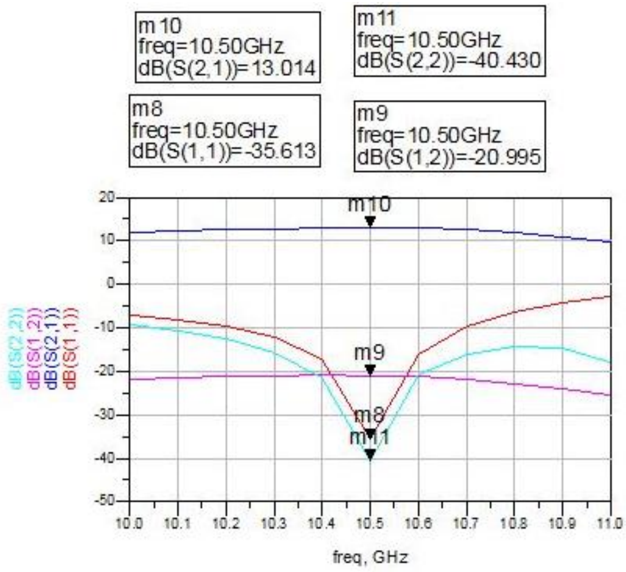

Figure 15. S parameters

The power gain and noise figure obtained for the source degenerative LNA using RF chokes are 13.051 dB and 1.468 dB as shown in fig. 16 and 17 respectively.

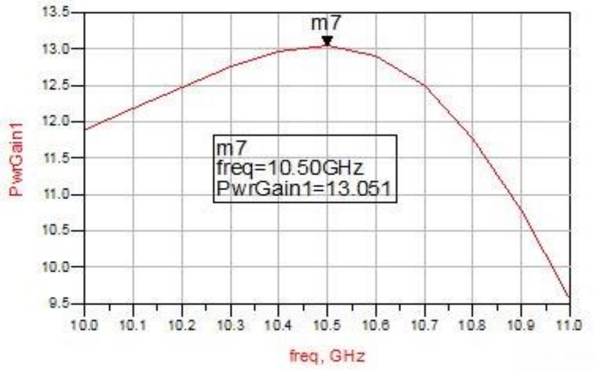

Figure 16. Power Gain

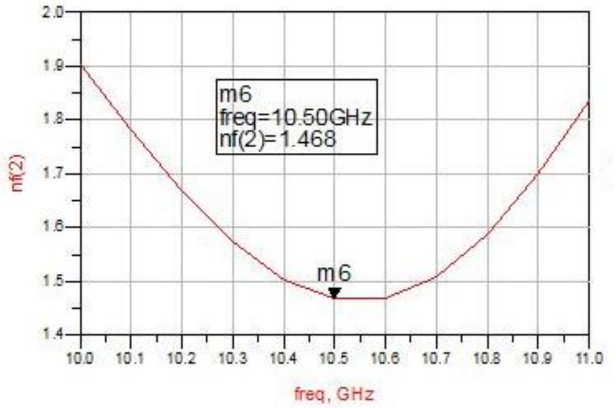

Figure 17. Noise Figure

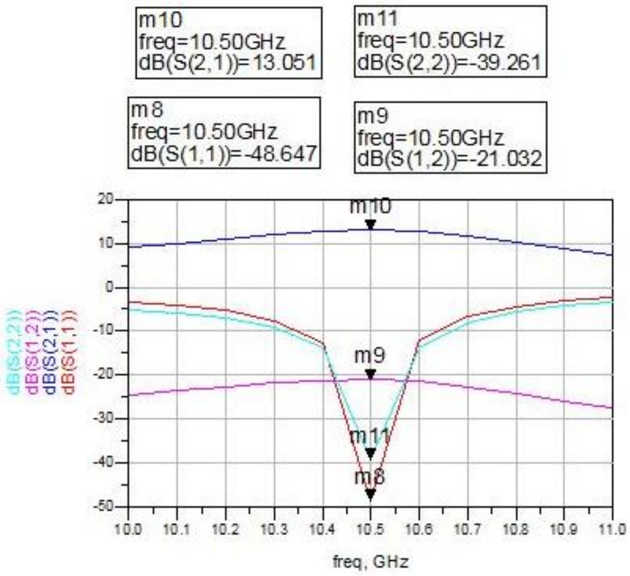

Figure 18. S parameters

The S - parameters obtained for RF choke LNA is shown in fig. 18. The values obtained are S_{11} as -48.647 dB, S_{12} as -21.032 dB, S_{21} as 13.051 dB, and S_{22} as -39.261 dB.

TABLE II

Comparison results of various LNA's

Parameters	**Lumped Component LNA**	**Microstrip Component LNA**	**RF Choke LNA**
K	1.279	1.448	1.457
|Δ|	0.446	0.840	0.842
μ	1.083	2.467	2.449
S_{11} (dB)	-46.647	-35.613	-48.647
S_{21}/G* (dB)	8.327	13.014	13.051
S_{12} (dB)	-22.029	-20.995	-21.032
S_{22} (dB)	-2.899	-40.430	-39.261
NF# (dB)	1.902	1.484	1.468
VSWR	1.009 (I) 6.049 (O)	1.034 (I) 1.019 (O)	1.007 (I) 1.022 (O)

G* - power gain, NF# - noise figure

IV.CONCLUSION

In this work various low noise amplifiers are designed and the results are obtained in ADS software. Different components like lumped components, distributed components, and RF choke are used for getting better noise immunity, gain and minimum VSWR while source degenerative technique is used for improving the stability of the amplifier and considering the overall comparison results from section 4 we can conclude that the RF choke designed low noise amplifier is providing better performance by providing a power gain of 13.051 dB, 1.468 dB noise figure, source side VSWR of 1.007 and load side VSWR of 1.022 which shows that minimum reflections will occur both at the input and output side of the amplifier resulting in maximum power transfer from source to load. The bandwidth constraint in these designs can be solved by implementing multistage cascading and cascoding techniques in LNA design.

V. REFERENCES

[1] Christina Lessi, Evangelia Karagianni, “An X-Band Low Noise Amplifier Design for Marine Navigation Radars,” *International Journal of Communications, Network and System Sciences*, vol. 7, March 2014.

[2] Tumay Kanar, Gabriel M. Rebeiz, “X- and K-Band SiGe HBT LNAs with 1.2- and 2.2-dB Mean Noise Figures,” *IEEE Transactions on Microwave Theory and Techniques,* vol. 62, no. 10, October 2014.

[3] Mohammad Fallahnejad, Yasaman Najmabadi, et al, “Design and Simulation of Low Noise Amplifier at 10 GHz By Using GaAs High Electron Mobility Transistor,” *IOSR Journal of Electrical and Electronics Engineering,* vol. 10, Issue 5, Sep – Oct. 2015.

[4] Toahera Abdullah, Apratim Roy, et al, “A Wideband 6.9-17.7 GHz CMOS Low-Noise Amplifier with a Gain Flattening Technique,” *16th International Conference on Computer and Information Technology*, March 2014.

[5] Nan Li, Weiwei Feng, and Xiuping Li, “A CMOS 3–12-GHz Ultra wideband Low Noise Amplifier by Dual-Resonance Network,” *IEEE Microwave and Wireless Components Letters*, vol. 27, no. 4, April 2017.

[6] Murat Davulcu, Can Caliskan, et al, “X-Band High Dynamic Range Flat Gain SiGe BiCMOS Low Noise Amplifier,” *Proceedings of the 10th European Microwave Integrated Circuits Conference,* September 2015.

[7] Jyh-Chyurn Guo, Ching-Shiang Lin, “Low Power UWB CMOS LNA Using Resistive Feedback and Current-Reused Techniques Under Forward Body Bias,” *Proceedings of the 47th European Microwave Conference,* October 2017.

[8] Abdelkader Taibi, Mohamed Trabelsi, et al, “Efficient UWB low noise amplifier with high out of band interference cancellation,” *IET Microwaves, Antennas & Propagation Journal*, vol. 11, Issue. 1, 2017. Doi: 10.1049/iet-map.2016.0187

[9] Makesh Iyer, T Shanmuganantham, “Design of LNA for C band Applications,” *IEEE International Conference on Circuits and Systems,* March 2018.

[10] Makesh Iyer, T Shanmuganantham, “Design of LNA for Satellite Uplink,” *Elsevier’s SSRN Journal of Information Systems & eBusiness Network,* March 2018.

[11] Makesh Iyer, T. Shanmuganantham, “Optimum LNA for WAVE Application,” Proceedings of *International Conference on Micro-Electronics, Electromagnetics and Telecommunications*, February 2018.

[12] M.H. Misran, M.A. Meor Said, et al, “Design of Low Noise Amplifier for WiMAX Application,” *IOSR Journal of Electrical and Electronics Engineering*, vol. 6, Issue 1, June 2013.

[13] Makesh Iyer, T Shanmuganantham, “LNA Design for Airport Surveillance RADAR Receiver System,” *IEEE International Conference on Recent Advances in Engineering and Technology,* December 2017.

[14] Makesh Iyer, T Shanmuganantham, “LNA design for WLAN Applications,” *IEEE International Conference on Circuits and Systems,* March 2018.

[15] Makesh Iyer, T. Shanmuganantham, “Design of LNA for RADAR Altimeters,” *Proceedings of International Antenna Test and Measurement Society Conference (ATMS),* March 2018.