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The Experimental Comparison on the Various LNA Circuit Topologies for Wideband Applications

Kishor G Sawarkar[1], Kushal Tuckley[2]
[1]*(Research Scholar at MCT's RGIT, Mumbai University, Mumbai, India, kishor.sawarkar@mctrgit.ac.in)*
[2]*(Chairman R&D AGV System, Adjunct Professor at IITB Mumbai, India)*
Corresponding author: Kishor G Sawarkar

Abstract : *This paper critically explains comparison of the various low noise amplifier (LNA) circuit topologies using pHEMT technologies for wideband and ultra-band applications. In addition to the conventional techniques, all designs are evaluated with proper connecting microstrip lines. The proposed schemes are simulated simultaneously with measurements of noise figure, gain, return loss and stability are extensively compared with each other at various microwave frequencies. This paper includes the topologies like cascode, active load, balanced and cascaded structure. The performances of all circuit topologies are put into evidence numerically and the results are simulated in ads and AWR microwave office tool. At ultra-band frequencies, the best proposed scheme is found to be the cascaded topology. The new design cascaded topology LNA circuits combined with good matching network and best biasing circuit with the inherent pHEMT device technology, which provides performance benefits for next-generation for all ultra-wideband wireless applications.*

Keywords–*LNA, Microwave Engineering, HMIC,*

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I. INTRODUCTION

The unexpected and unprecedented growth in demand for increased communications capacity by telecommunications consumers has led to research in the designing of wireless components. The LNA is the most important component in the receiver chain [5][6]. The LNA design topology choosing is more challenging based on the applications. In this article gives suggestions with experimented results where it will be helpful for the designers to choose appropriate topology using hybrid microwave integrated circuit (HMIC). Beomkyu ko et.al [1], critically compares the various mono-lithic low noise amplifier (LNA) circuit topologies like cascode, common source inductive series feedback using bicmos or mesfet technologies for rf and microwave applications. David m. Upton et.al [2], design a topology using FET with doherty high efficiency amplifier technique to realize high linearity, efficiency and gain. Sara d'angelo [3], designed MMIC single pole double throw (SPDT) switch exploits a robust asymmetrical absorptive/reflective topology good is an insertion loss in the amplifier.

II. CONCEPTUAL ANALYSIS VARIOUS TOPOLOGY

In this section, LNAs are designed using five different types of topologies and discussed namely cascaded with LC components, cascaded with only capacitors, active load, balanced amplifier and other types merely similar to cascode. Each topology is discussed in brief as separate cases and conclusion is summarized in each subsection.

2.1 cascaded with LC components

In this case the attempt is done to design & simulation of low noise amplifier for 1 -2.8 GHz using AlN substrate (figure 1 and 2). The LNA is designed using two stage cascade topologies. It has been focused on intermediate matching network design of amplifier for low noise figure and selection of transistor pHEMT is based on noise figure as well as quiescent point required for 0 grid voltage so that amplifier will need only single dc supply i.e. vdd. Depends upon different topologies used for LNA design with wide band requirement, cascaded topology is chosen for good gain with low noise amplifier and optimized for greater bandwidth [7][8].

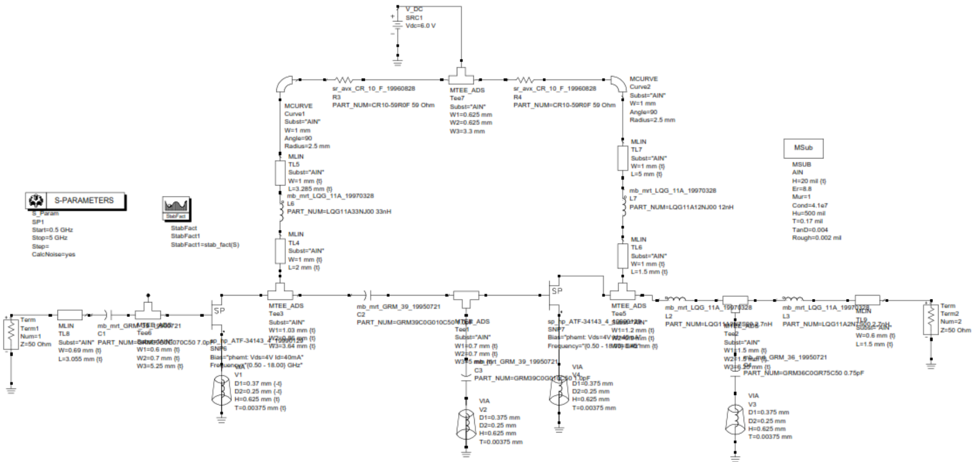

Figure 1. Shows Cascaded Amplifier Using ATF 34143 With LC Matching Network

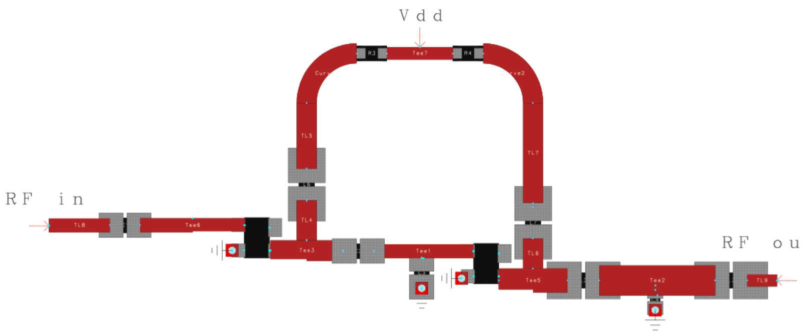

Figure 2. Layout Of LNA Case 1

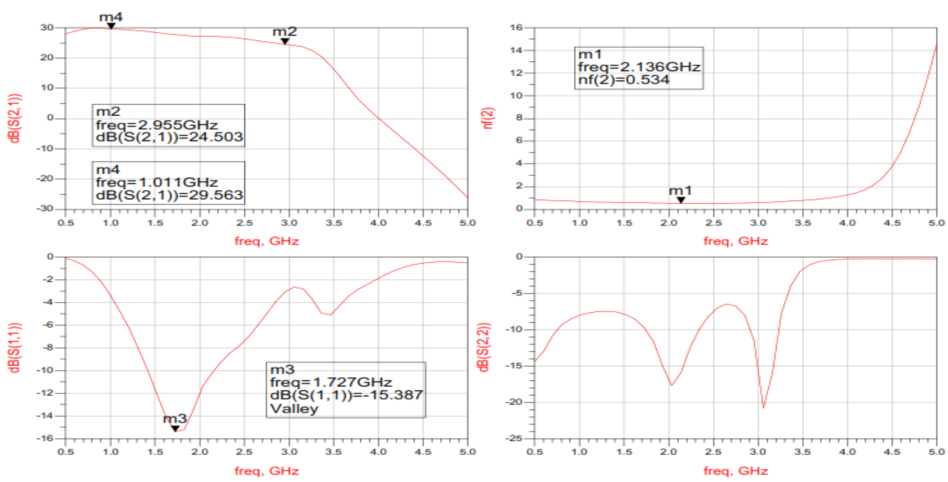

Figure 3. Collective Results Of Cascaded Topology With LC Components

Simulation results shows that noise figure obtained is 0.5 dB from 1 to 2.8 GHz and maximum noise figure is 0.64 at 1GHz. Input and output VSWR is less than 2 as s11 and s22 is less than -10 dB. VSWR is 2 to 3 in between 2.5-2.8 GHz. Reverse transmission coefficient is less than -40 and stability factor is more than 2 for desired frequency band and for worst case, 1.7 at 2.8 GHz dB as shown in figure 3.

2.1.1 Case Summary

In this case, LNA circuit with LC components followed by two stage cascading which operating between 0.5-3GHz provides very good NF of 0.5dB and variable gain 24-29dB with proper output return loss. limitation is input return loss achieved -10dB only at narrow band 1.5-2.5GHz.

2.2 Cascaded Series Capacitor and Source Inductance

In this case, bandwidth enhancement of low noise amplifier using inductive source and distributed components [4]. The LNA is designed for 1 to 2.8 GHz frequency band using pHEMT ATF34143, which is experimented with respect to some remedies and worked on few factors which enhanced bandwidth of LNA with respect to improvement in return loss as well as gain linearity [9][10].

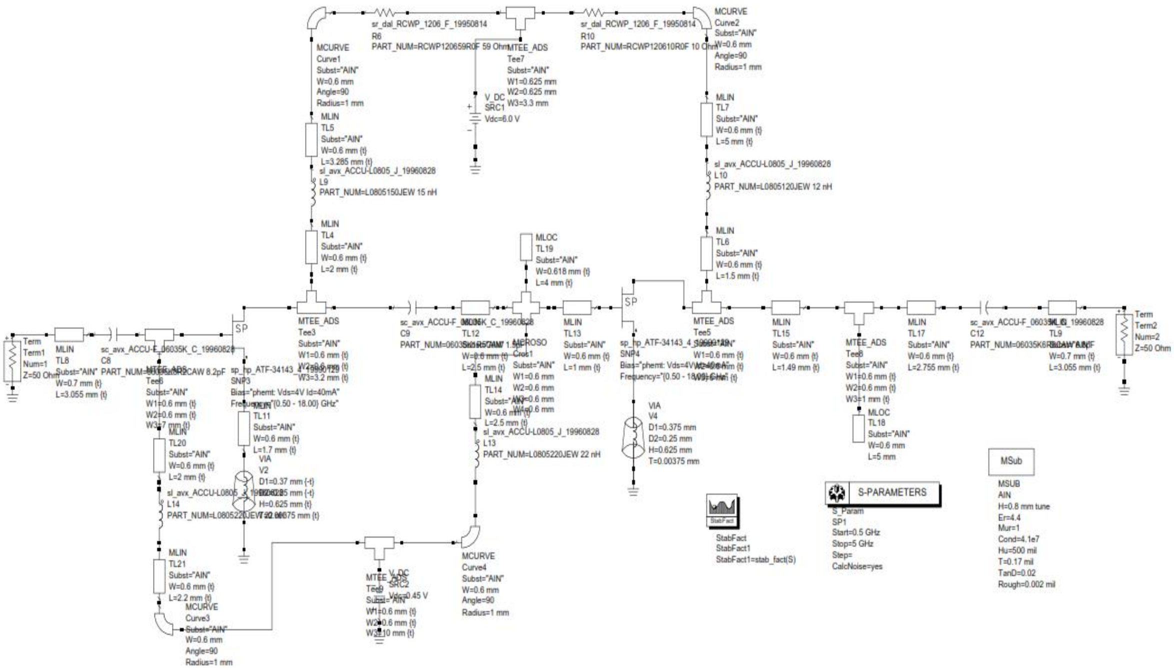

Figure 4. Circuit Schematic Of Cascaded Series Capacitor And Source Inductance

In continuation with case 1, circuit is prepared with only capacitors bandwidth is increased (0.5-3.5GHz) and gain flatness as got more variation (20-30dB) good noise figure up to 0.7dB. Input and output return loss characteristics are very good in the interested band shown in figure 5.

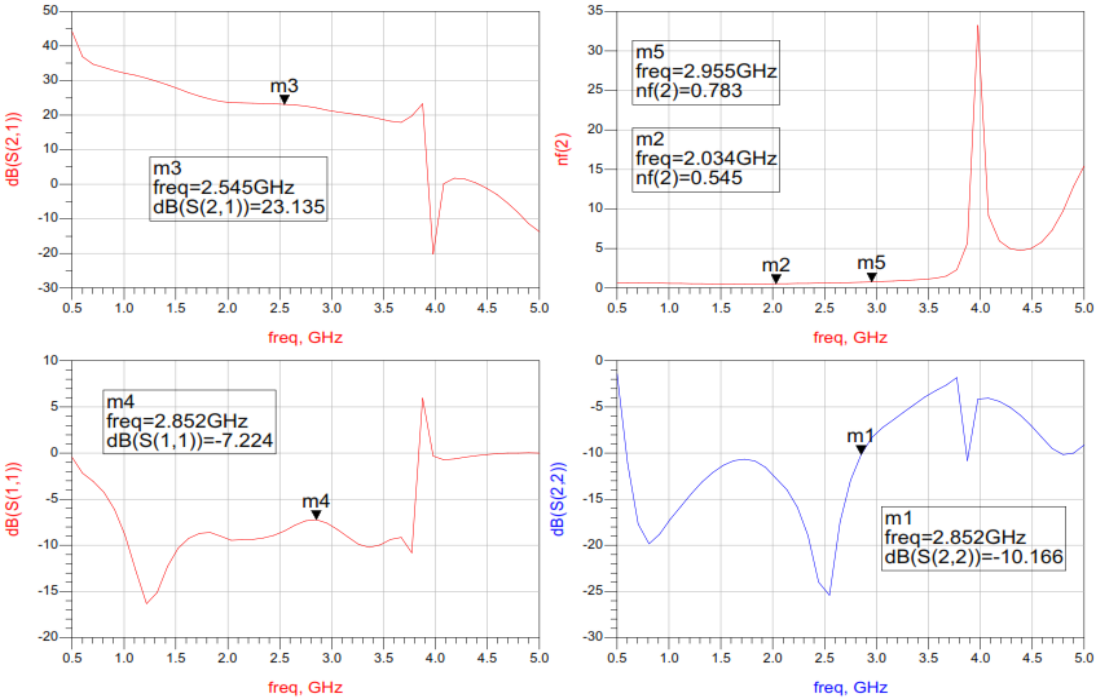

Figure 5. Collective Results Of The Case Cascaded Series Capacitor And Source Inductance

2.3 Active Load

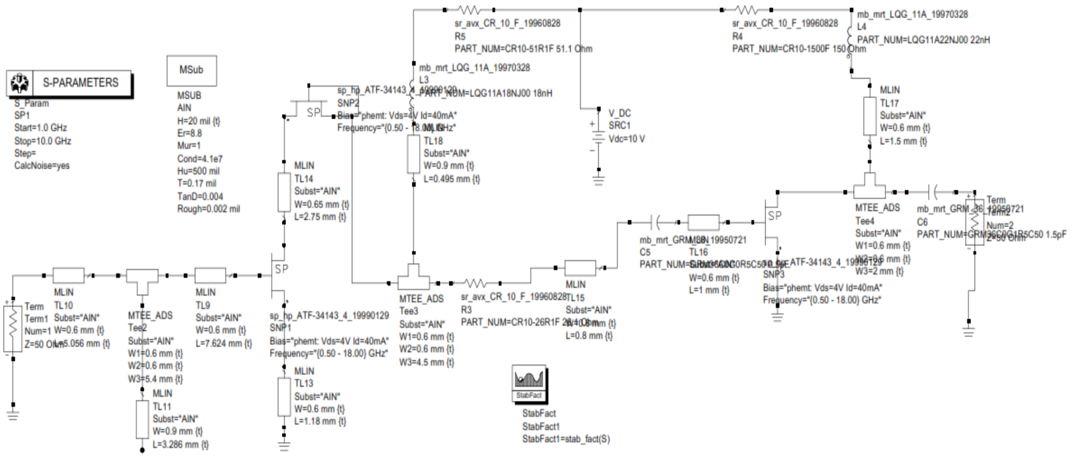

Figure 6. Schematic of the LNA using active load topology

In this topology, first stage is designed with active load technique to improve the gain and its linearity followed by single stage amplifier in cascading structure. The simulated results are good up to 7GHz but improvement in the gain is not observed (Figure 7).

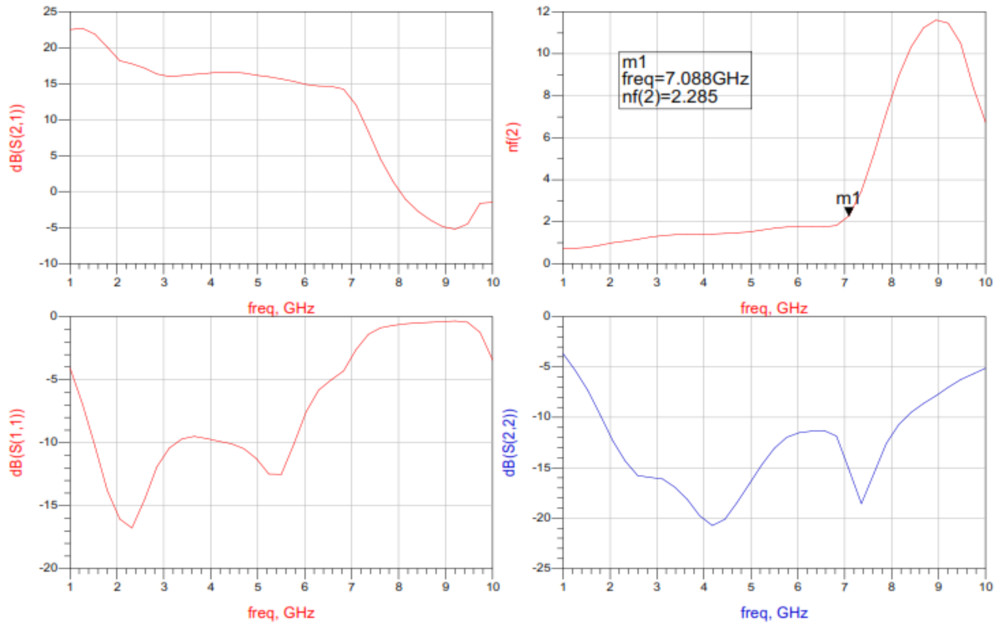

Figure 7. Collective Results Of The Active Load Topology LNA

2.3.1 Summary

In this topology, first stage is designed with active load technique to improve the gain and its linearity followed by single stage amplifier in cascading structure. The simulated results are good up to 7GHz but improvement in the gain is not observed.

2.4 Balanced Amplifier

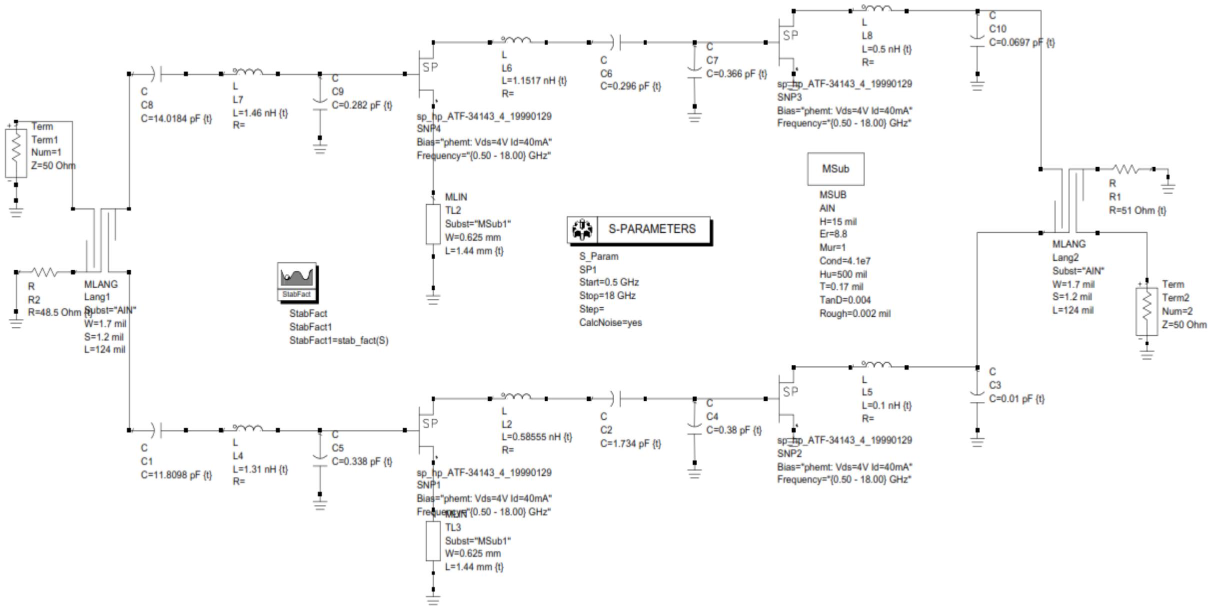

Figure 8. Schematic Of LNA Design Using Balanced Amplifier Technique

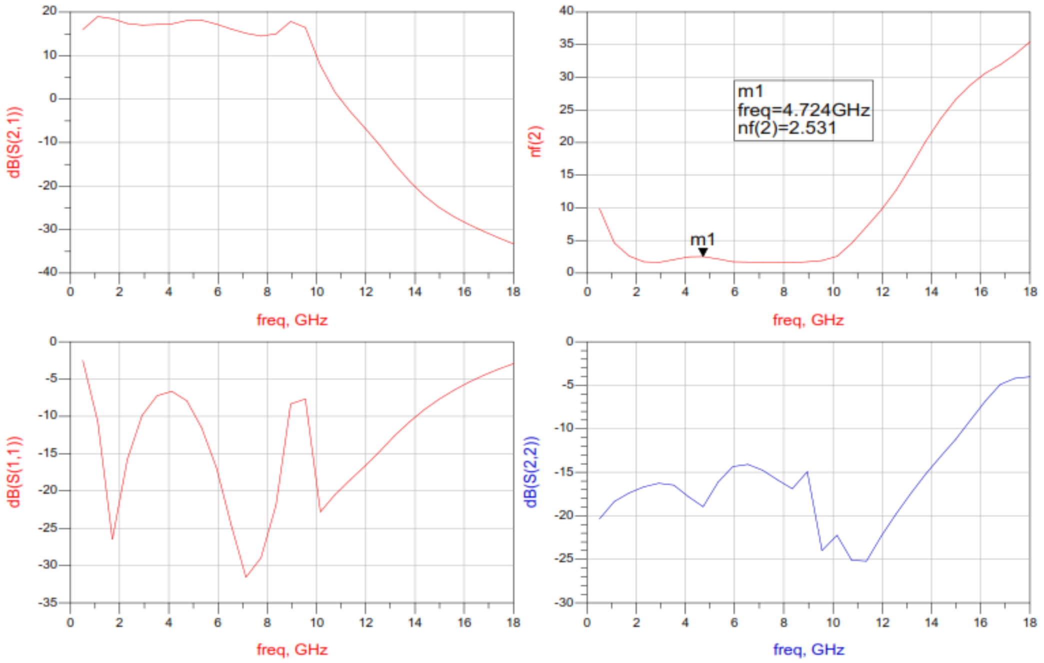

Figure 9. Collective Result Of LNA Design Using Balanced Amplifier Technique

A balanced amplifier has two amplifying devices that are run in quadrature. That is, they are operating 90 degrees apart in transmission phase. A quadrature coupler or splitter on the input phase-shifts the two signals 90 degrees at the amplifier inputs, then a second quadrature coupler on the output "un-phase-shifts" the signals at the amplifier outputs so they combine in phase. In this case the amplifying device is two stage cascaded amplifier with corresponding LC matching circuits. The observation on the simulated results are having better performance over the bandwidth 2-10GHz. Limitation in the circuit is microstrip divider (mlang 1) at the input side and microstrip combiner (mlang 2) at the output side are used which as very less width of less than 2mils it is challenging for the fabrication point of view [11][12]. The minimum expected with of the microstrip lines is 8 mils, in case increase of the width of the mlang results in poor noise figure (figure 9).

2.5 Other type

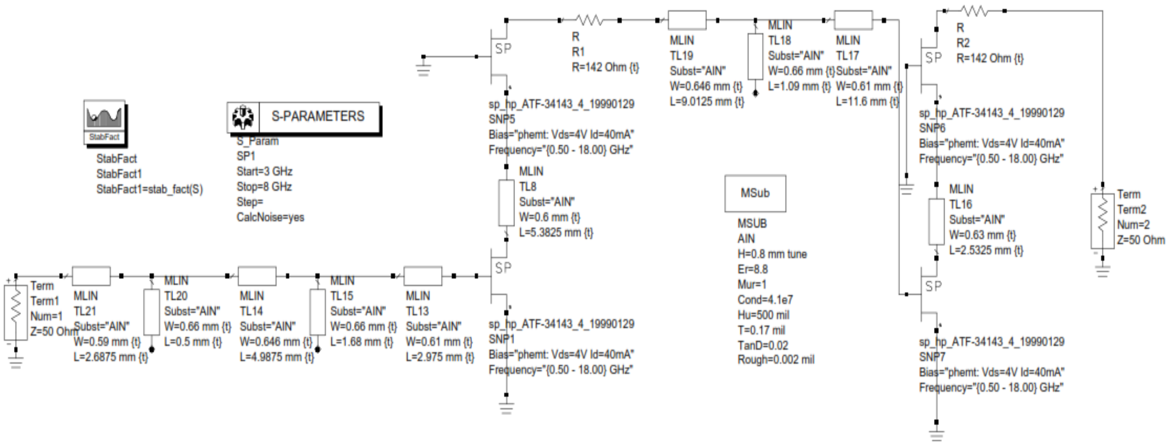

Figure 10. Schematic Of Unique Topology Similar To Combination Of Cascode And Cascade

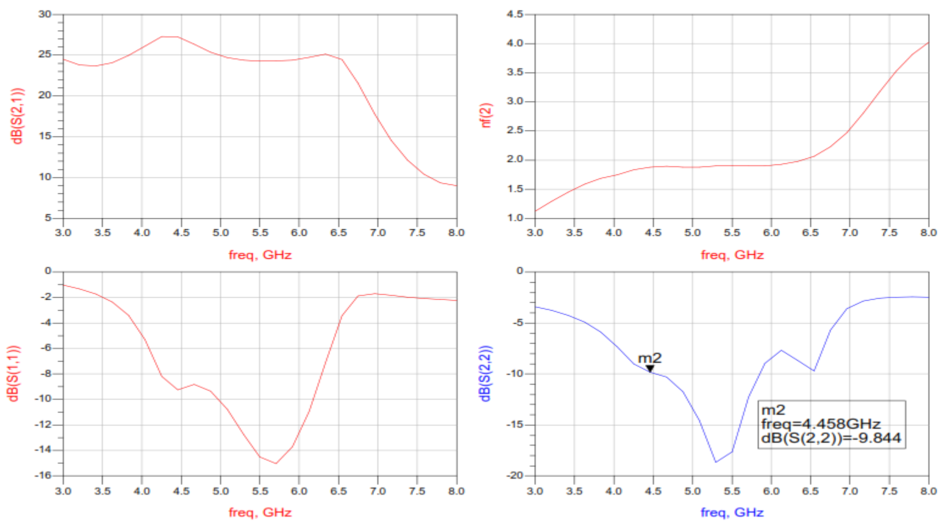

Figure 11. Collective results of unique topology similar to combination of cascode and cascade

The unique LNA topology have been experimented with simulation to improve gain and bandwidth keeping NF with moderate value. In this case, keeping reference of cascode and cascade topology as shown the figure 10. In this case two cascode kind of amplifier are cascaded for the improvement in the gain. Microstrip line structure is referred by the article on filter [7]. Furthermore, this circuit biasing circuit is not added and consider as ideal bias condition 4v, 40ma using ATF34143 transistor for simulation. It has been observed that gain is linear and having good flatness +/- 2dB over the band of frequency up to 7GHz and NF less than 2dB till 6GHz. Return losses are better in between the band 4-6GHz.

2.5.1 Case Summary

In this case, two cascode kind of amplifiers are cascaded for the improvement in the gain. Furthermore, this circuit biasing circuit is not added and consider as ideal bias condition 4v, 40mA using ATF34143 transistor for simulation. It has been observed that gain is linear and having good flatness +/- 2dB over the band of frequency up to 7GHz and NF less than 2dB till 6GHz. Return losses are better in between the band 4-6GHz.

III. Conclusion

This article is prepared based on the various topologies that can be used for the LNA design namely cascaded with LC components, cascaded with only capacitors, active load, balanced amplifier and other types merely similar to cascode. All topologies are designed and simulated in the ads software and their measurements are tabulated in the table 1. Short summaries are provided under each case to conclude about every topology.

Table 1. Comparison of the topologies with LNA parameters

Topology	Frequency (GHz)	Gain (DB)	Noise Figure (DB)	Return Loss (DB)
Cascade With LC	0.5-3	24-29	<2.2	S11<-4, S22<-7
Cascade With C	1-3.8	20-30	<2.1	S11<-7, S22<-10
Active Load	1-7	15-20	<2	S11<-5, S22<-10
Balanced Amplifier	1-10	Average 18	<5	S11<-10, S22<-15
Unique Topology	3-6.5	Average 25	<2	S11<-4, S22<-5

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