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The Development of Cascode Low Noise Amplifier with Double Feedback Technique Architecture for Wireless Communication

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ABSTRACT

The paper aims to develop a new cascode low noise amplifier (LNA) by using double feedback technique architecture for wireless communication especially for long term evolution (LTE). The objective of this article is to display the improved performance of gain by minimizing noise figures with innovative techniques for the realization of Long Term Evolution (LTE). The innovation technique with implementation double feedback technique architecture outlines the possibility to improve the performance in various parameters such as bandwidth, stability, gain, noise figure, power consumption and complexity. The realization using cascode LNA is verified by using FHX76LP Super Low Noise HEMT that operate at 5.8 GHz in compliant with LTE standard. The Advance Design System (ADS) software is used to obtain characteristics for collecting data in a smith chart and s-parameter generated by simulation. The cascode LNA with the double feedback technique achieves an average gain of 20.887 dB with a noise figure of 0.341 dB. The input return loss and output return loss are – 14.354 dB and – 11.879 dB respectively. The outcome of this work will contribute to providing a better wireless signal receiver especially for the LTE standard and it potentially addressing wireless communication issues in rural areas.

1. Introduction

In wireless communication systems, the low noise amplifier is a very important component for increasing Radio Frequency (RF) signal, especially for long-distance. The main task of a low noise amplifier is to increase the RF signal and at the same time reduce Noise Figures (NF) especially in rural areas. This is a solution for transceivers that can be implemented carefully by paying attention to different architectures, circuit designs and accessible technologies. The wireless network devices including Long Term Evolution (LTE), Wireless Local Area Network (WLAN), and Worldwide Interoperability for Microwave Access (WIMAX) are also different.

Thus, the demand for Low Noise Amplifiers (LNA) is relentless which continues to drive innovation for high-rate data communication systems in today's world. Today's technology requires high-speed

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transmission efficiency with less energy consumption and LNA is one of the exceptional products that can meet all parameters. LNA is a core component in a communication reception system that provides satisfactory performance for RF receivers who see in terms of sensitivity, selectivity or propensity for receiver reception error [1]. An LNA has five features that directly influence the design and directly affect the receiver sensitivity namely linearity, bandwidth, noise, gain estimation and dynamic operating range. To monitor these parameters, adequate knowledge of the active device, impedance matching and installation methods and amplifier amplifiers is required and optimal output with reduction can be achieved. An LNA used in communication systems amplifies very weak signals captured by antennas that play an important position to recover data in communication systems with minimum noise figures play an important role in architecture [2].

According to Azzouni *et al.,* [3], LTE serves to provide upstream and downstream bandwidth, reduce network access time for end-users, bandwidth flexibility and integrate with current networks contributing to the rapid development in communication systems. Because the unlicensed 5.8 GHz frequency manages to provide a broad spectrum frequency that makes it possible to cover higher data rates which is an alternative way without having to ask permission to use and low cost to meet the communication prospects to penetrate the channel. The advantage of LTE is that it can experience an incredible distance between 100 mm - 10 mm to communicate with users compared to Wi-Fi which is a distance between 10 m - 100 m in addition to having more network capacity because it is open for everyone to continue to demand available services. According to Shayla Ibraheem *et al.,* [4], based on the International Telecommunication Union (ITU) forecast the demand for mobile data traffic in 2020 increase to four times more than in 2015 resulting in rapid mass-market adaptation to access high-speed data in line with either an increase in bandwidth (BW) or signal-to-noise ratio (SNR) or both.

Figure 1 shows the basic overview of the low noise amplifier architecture. In general, there are several techniques used to design low noise amplifier circuits. Previously, cascaded LNA designs with various techniques such as current reuse techniques, inductive source degeneration, feedback techniques and using feedback body bias (FBB) to evaluate LNA's ability to reduce noise while maintaining gain and overcoming stability problems important to improve achievement.

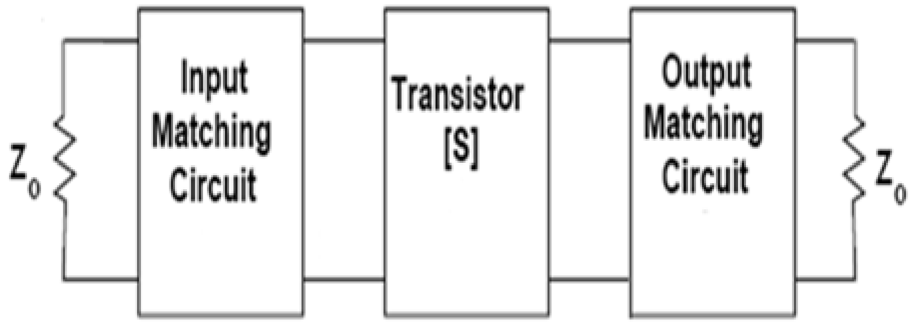

Fig. 1. The basic of low noise amplifier architecture

2. Low Noise Amplifier Review

The cascode topology is a common method used to design the LNA as it is the most versatile with input and output by having better isolation which improve the stability of the circuit. Cascode topology offers better stability, stabilize noise figure, higher signal gain, good reverse isolation and unbiased of input and output matching t cascode with various techniques such as current-reused technique by Khosravi *et al.,* [9], employed to reduce power consumption and provide a flat gain over a wide bandwidth in the 2.4 GHz and 5.2 GHz frequency bands that suitable for applications in multi-band WLAN receivers. The inductive source degeneration used to achieve simultaneous noise contribution and input matching such that the antenna has optimal power transfer which commonly matched with off-chip components [10]. Meanwhile, utilizing the CG feedback body biasing (FBB) technique at the input transistor leads to a further decrease in the supply of power (Vdd) due to a decrease in the threshold voltage resulting from a decrease in the use of power consumption for 3.1 – 10.6 GHz frequency wideband matching [11]. According to Wu & Yang [12], the feedback technique proposed utilized improvement in the bandwidth and employed compensation on gain and become a major factor to surpass the crucial problem of stability and gain flatness besides capable of solving problem low breakdown voltage and achieve high power performance.

Desirable performance levels, high linearity and efficiency are the key feature considerations. For cascode LNA in this paper used double feedback technique for LTE adopting T-matching for input and output impedance running for 5.8 GHz frequency band while improving the gain, minimizing noise figure, better reverse isolation, and improved linearity as the objective of this paper.

3. Circuit Design

The proposed LNA is to be designed such that to comply with the LTE specifications whereby the LNA needs to provide a high gain of greater than 20 dB with a noise figure of lower than 3 dB and operating at low power at 5.8 GHz. The input and output reflection coefficient should ideally be lesser than -10 dB in order to have good input and output matching including circuit stability. The architecture of this design is presented and utilize the targeted S-parameter specification as shown in Table 1.

Table 1
Design specification of targeted S-parameter for cascode with double feedback LNA

Design Parameter	Design Specification
Input reflection coefficient S_{11} (dB)	-10
Return loss S_{12} (dB)	-10
Forward Gain S_{21} (dB)	-20
Output reflection coefficient S_{22} (dB)	-10
Noise Figure (dB)	< -3
Stability (K)	>1

The Pseudomorphic High Electron Mobility Transistor (PHEMT) FHX76LP is used to design cascode with double feedback LNA where the S-parameter obtained from data-sheet for 5.8 GHz and the simulation are conducted by using Advance Design System (ADS) technologies to meet the designation result illustrated in Table 2.

Table 2
S-parameter acquired from data-sheet FHX76LP provided

S-parameter	S_{11}	S_{12}	S_{21}	S_{22}
Magnitude	0.192	0.075	11.075	0.225
Angle	93.830°	21.513°	76.337°	157.977°

The cascode LNA is selected to put into action for the LTE application. This topology was chosen to yield appealing gain with minimum noise figure besides have good input and output isolation that can boost the stability. The T-matching network has been adopted at the input and output port for excellent maximum power transfer when impedance between two circuits match at load and source which can improve the performance. To acquire better certainty Smith Chart tools in ADS is being used to design a T-matching network. Double feedback techniques have been purpose in RF circuit design which tolerate instability distortion and maintain the flatness of gain with low noise interruption. In this case, cascode amplifier can control the gain limitation from negative feedback and positive feedback in double-loop transformation feedback but affecting minor noise figures to enhance other parameters. Considering the 50 ohms at the input and output in simulation can reduce the reverse isolation with positive feedback placing in between output and source cascode LNA and negative feedback in between source to reduce the issuing of noise figure. On the side, the inductor peaking was added placed in series to conjoin with the output passive network to improve the nonlinearity of LNA. The optimum reflection coefficient obtained for 5.8 GHz were 20.209 – j 36.711 and as 171.121 + j 24.457 for purpose design LNA. Figure 2 shows the complete schematic diagram of cascode LNA with negative feedback.

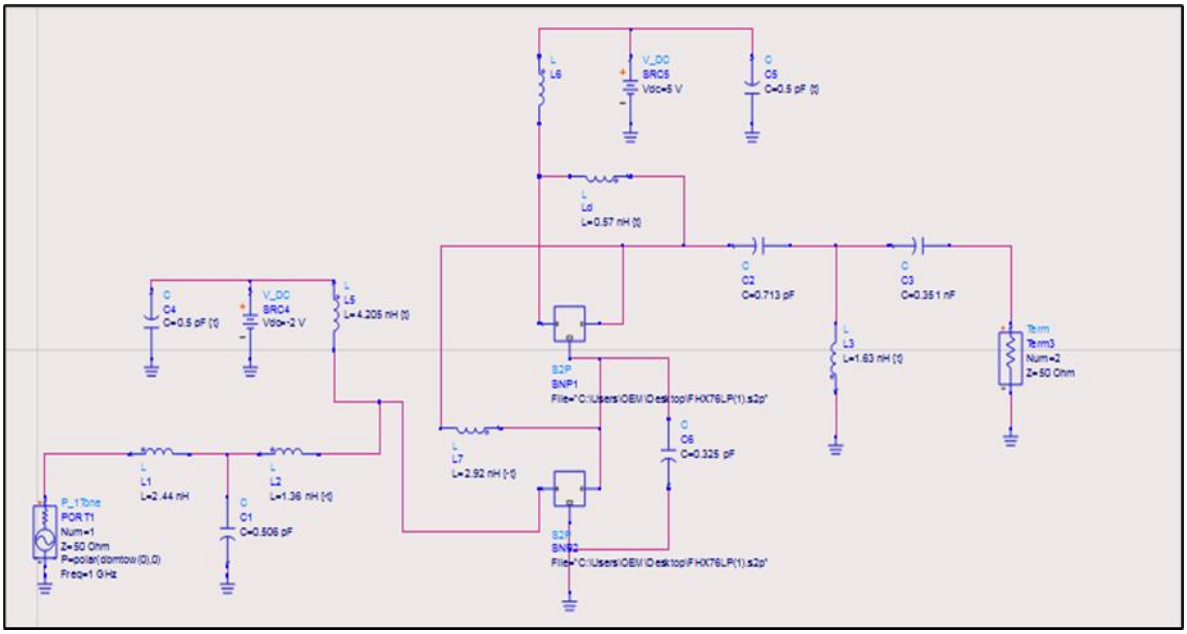

Fig. 2. The complete schematic diagram of cascode LNA with negative feedback

4. Results

The analytic analysis and simulation results of low noise amplifier build at 5.8 GHz are shown in this section. Analytic analysis, DC biasing, design matching network and S-parameter of ADS simulation are three key stages. The design employs high-performance low noise Pseudomorphic High Electron Mobility Transistor (PHEMT) FHX76LP developed by Eudyna Devices with reduced noise resistance, which lower noise performance sensitivity to distinct in matching input impedance. With the aid of the Smith Chart, the impedance matching network in this paper can be modelled graphically or mathematically. The design cascade Low Noise Amplifier with a matching network at 5.8 GHz was obtained. From the simulation it resulting, the input reflection coefficient ($\mathbf{S_{11}}$) obtained -14.354 dB meanwhile output reflection coefficient ($\mathbf{S}_{22}$) is -11.879 dB indicate the values acquire is better than the targeted which is adequate to the research. The output of and displays in Figure 3. In the meantime, the forward gain (S_{21}) achieve 20.887 dB with return loss (S_{12}) of -22.465 dB is acceptable and much better than the targeted parameter. The output of and displays in Figure 4.

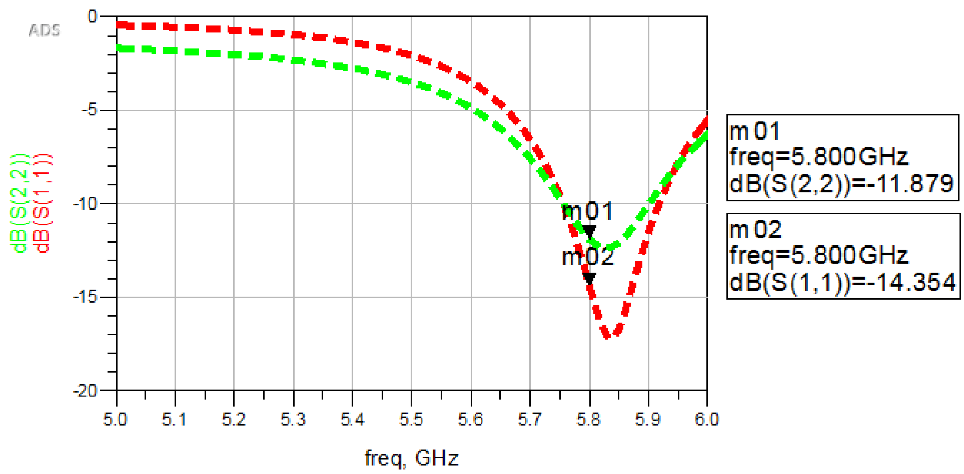

Fig. 3. The input and output of reflection coefficient of S_{11} and S_{22}

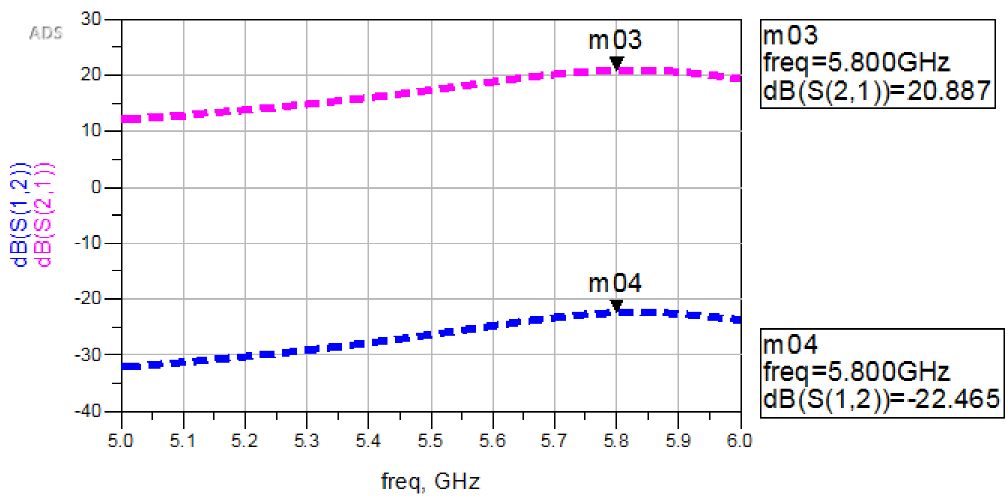

Fig. 4. Return loss and gain of S_{12} and S_{21} in S-parameter impedance simulation

The minimum noise figure is desired in order to secure maximum gain. Figure 5 shows the noise figure obtain which is 0.341 dB lower than targeted specification. Along with the frequency increase, the NF min value is affected by being reduced.

After matching occur at the load, stability factor (K) obtained is 1.001 at 5.8 GHz frequency range established in Figure 6. The value acquired is more than 1 which is in unconditionally stable state with no isolation occur which compatible with targeted result.

From Table 3, it can conclude the aggregated throughput represent the comparison of output obtained from simulation with the targeted specification for cascode LNA with double feedback performance. After the simulation of the circuit, the stability, output reflection coefficient and forward gain areas 1.001, -11.879 dB, and 20.887 dB. The input reflection coefficient is -14.354 dB, the reverse transmission coefficient is -22.465 dB and the minimum noise figure is 0.341 dB. The stability of the transistor amplifier is 1.001 which satisfies the equation (1) which determined by Rollett stability factor K>1 for unconditionally stability. The stability is therefore maintained as the oscillation arise where the output impedance and load impedance or at the source end are incorrectly aligned with forwarding gain drastically achieved more than needed.

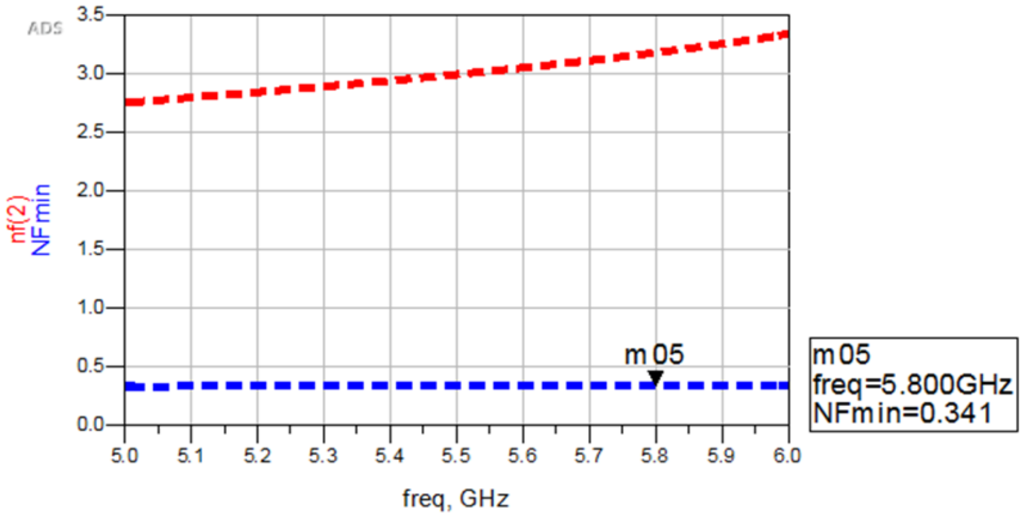

Fig. 5. The noise figure (NF)

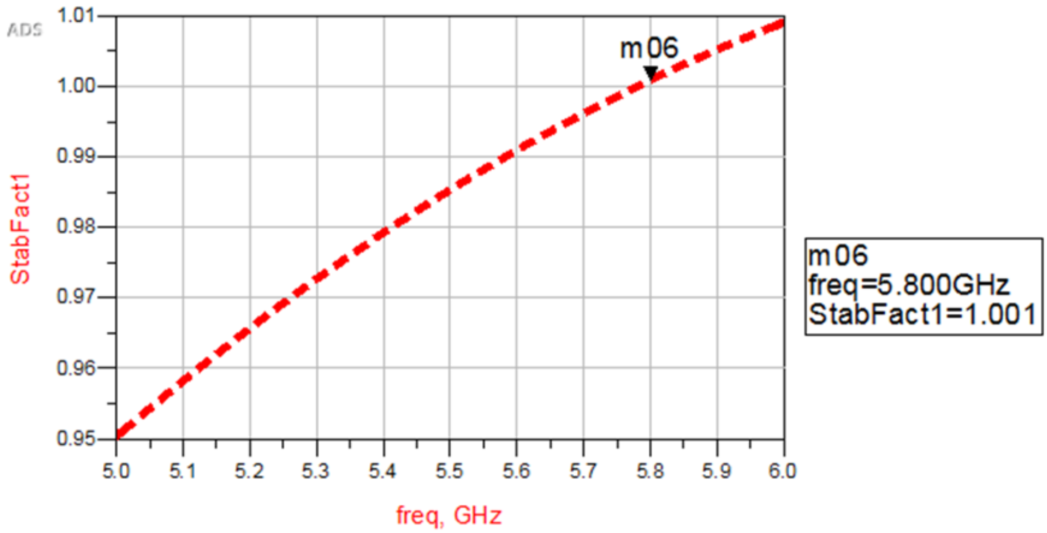

Fig. 6. Stability Factor

Table 3
Comparison of performance parameters

Design Parameter	Targeted	Simulation
Input reflection coefficient $\mathbf{S_{11}}$ (dB)	−10	−14.354
Return loss $\mathbf{S_{12}}$ (dB)	−10	−22.465
Forward Gain $\mathbf{S_{21}}$ (dB)	20	20.887
Output reflection coefficient $\mathbf{S_{22}}$ (dB)	−10	−11.879
Noise Figure (dB)	<3	0.341
Stability (K)	>1	1.001

$$Stability\ factor, k = \frac{1 - (|S_{11}|)^2 - (|S_{22}|)^2 + (\Delta)^2}{2\ (|S_{12}|)\ \ (|S_{21}|)} > 1 \qquad (1)$$

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

Several authors have previously focused on refining and study of low noise amplifier. Following the references [13], [14], [15], [16]and [17] authors working on LNA optimization. However, according to the cited reference, the works reaches minimal noise figures with maximum power gain besides concludes that the input and output return loss coefficients are matching based on S-parameter resulting from ADS simulation. The authors have been worked to gives minimal noise figures within the frequency band of 5 – 6 GHz. Comparing with other cited LNA's, Table 4 illustrated the results overview of this designed LNA.

Table 4
Comparison of performance summary of designed LNA with other cited LNA's

Author (Year)	Topology	Frequency (GHz)	Gain, S_{21} (dB)	Noise Figure (dB)	Input Return Loss, S_{11} (dB)
[13]	Two stage cascade with inductive degeneration	5.8	17.04	0.972	-17
[14]	Single stage with ladder matching network	5.8	17.2	0.914	-19
[15]	Single stage with resistive shunt feedback	6	15.16	0.801	-15
[16]	CMOS Low Noise Amplifier	5-5.8	>16	2.00	<-10
[17]	Cascode X-Band LNA	6-8	18	1.3	<-10
Proposed	Cascode with double feedback	5.8	20.887	0.341	< -10

5. Conclusion

The cascode LNA with double feedback technique has been developing and stimulated with long term evolution (LTE) standard for frequency 5.8 GHz by using ADS. Observation from the results, the proposed amplifier has met the specification to obtain maximum power gain with minimum noise figure with the implementation of T-matching at the input and output port and uses of double feedback technique. Based on tabulated values, this LNA achieves parameters target with forwarding gain (S_{21}) of 20.887 dB, input return loss (S_{12}) of -22.465 dB, input reflection coefficient (S_{11}) of -14.354 dB, output reflection coefficient (S_{22}) of -11.879 dB. Meanwhile, the noise figure (NF min) 0.341 dB and stability 1.001 obtained respectively. To summarize, this research is a good candidate for low power and low noise wireless applications and there are scopes for any improvement to fulfil performance satisfaction.

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