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A Microwave Low Noise Amplifier for Long Term Evolution (LTE) Application

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Abstract: Wireless communication is a technology that plays an important role in current technology transformation. wireless communication is a method of telecommunication that are available for transmitting large amounts of data, voice and video over long distance using different frequencies. Specifically, Low Noise Amplifier which is located at the first block of receiver system, makes it one of the important element in improving signal transmission. This study was aimed to design a microwave Low Noise Amplifier for Long Term Evolution (LTE) application that will work at 5.8 GHz using high-performance low noise superHEMT transistor FHX76LP manufactured by Eudyna Technologies. The low noise amplifier (LNA) produced gain of 17.2 dB and noise figure (NF) of 0.914 dB. The input reflection (S_{11}) and output return loss (S_{22}) are -17.8 dB and -19.6 dB respectively. The bandwidth of the amplifier recorded is 1.2 GHz. The input sensitivity is compliant with the Long Term Evolution (LTE) standards.

Key words: *LNA, Radio Frequency, Long Term Evolution*

INTRODUCTION

Wireless Communication is greatly improved and developed in this modern technology. System plays a major role in today's communication by enabling constant connection in 5.8 GHz frequency. Developments in the wireless industry, internet access without borders and increasing demand for high data rate wireless digital communication moving us toward the optimal development of communication technology. Wireless communication is a technology that plays an important role in the development of the current transformation. Long Term Evolution (LTE) is a standard for wireless data communication technology and the evolution of the standard GMS/UMTS[1].

The Long Term Evolution (LTE) defined by the 3rd Generation Partnership Project (3GPP) in Release 8 provides users much faster data speeds than 3G is able to. Many consider that LTE should be labeled as 3.9G and according to them the first "true 4G" is LTE advanced defined in Release 10 and LTE advanced systems have a lot of advantages for both end users and mobile operator. According to high LTE requirement the interest in designing appropriate LTE devices has increased [2].

Usually the first active signal processing block after the antenna is Low noise amplifier (LNA). The amplitude of the received signal at the input LNA may vary from few nV that is less than -130 dBm for GPS signals to tens mV. The LNA should be capable of amplifying all these signals without causing any significant distortion. This requires that very little noise from the LNA be introduced to the entire receiver[3],[13]. Figure 1 is the basic to the structure of the RF receiver. As the first block is active after the antenna, LNA has the advantage of high and should be able to reduce noise in the system. The signal received from the antenna will be screened and will be amplified by the LNA and will be sent to the bandpass with a local oscillator. After the demodulated, modulated signal will be used for analog-to-digital (ADC) that converts analog signals to digital signals. Digital signal processing (DSP) will process the digital signal produces by an analog-to-digital (ADC). Therefore, a lot can affect the LNA parameter sensitivity and performance of the overall receiver noise.

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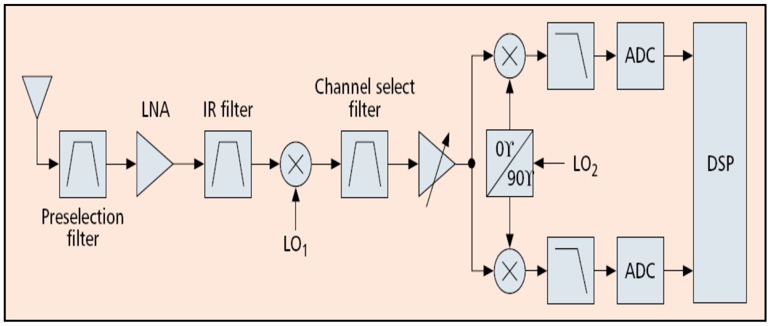

Figure 1: Structure of the RF receiver

The LNA is one of the most important components of in communication receiver. The LNA requires amplifying the received signal with sufficient gain and if possible having a little additional noise. Noise Figure has a major impact on deciding the system's overall in LNA. An LNA can be designed with different circuit topologies; each method proposes to accommodate a wide bandwidth through input and output impedance matching. Such as, shunt-series feedback topology is having broadband behavior as well as good input and output matching characteristics.

Therefore the higher gain is achieved when the power consumption is low. An inductive load which improves the output noise performance as well as overcomes the gain degradation at higher frequencies is employed. Another inductor is added in series with feedback to give an additional gain at higher frequencies. The inductive degenerated topology had a superior performance as compared to its common gate. Also this topology provides simultaneous input matching and minimum Noise Figure[1,2,16]

LITERATURE REVIEW

The design of a microwave low noise amplifier satisfying all these requirements in a wide bandwidth of the different parameters affecting noise, gain and linearity. To achieve this goal one needs to develop an accurate mathematical model for the low noise amplifier and find the analytical expression for Noise Figure, input impedance match, gain and linearity of the inductive source degenerated cascade low noise amplifier [6]. The Noise Figure is the ratio between the total output noise power due to all noise sources and the output noise power generated by the source internal resistance [4]. Although there are many ways to evaluate the linearity of the low noise amplifier, to measure the third-order intercept point(IP3) is the most commonly used methods. The IIP3 is obtained graphically by plotting the output power versus the input power both on using logarithmic scales. Two curves are drawn; one for the linearly amplified signal at an input tone frequency, one for a non linearity product. Both curves are extended with straight The feedback resistor can be implemented either directly between the gate and drain of the input transistor or connected through a source-follower buffer stage[8,12].

Figure 2 shows the general transistor amplifier circuit that are useful for amplifier design. There are a few types of two-port network such as Z-network, S-network. All systems can be represented as two-port network[5,7,11,15].

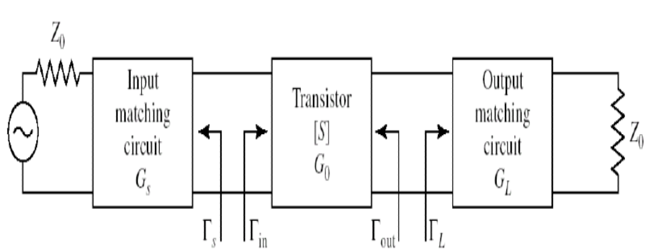

Figure 2. The general transistor amplifier circuit

Two-port network connected to source and load impedances Z_S and Z_L respectively. The derivation expressions for three types of power gain in term of s-parameters of the two-port network are shown below:-

- Power Gain: $G = P_L/P_{in}$ is the ratio of power absorbed in the load Z_L to the power through the input of the two-port network. This gain is independent of Z_S.
- Available Gain: $G_A = P_{AVN}/P_{AVS}$, is the ratio of the power available from the two-port network to the power available from the source. This assumes conjugate matching of both source and the load, and depends on Z_S.
- Transducer Power Gain: $G_T = P_L/P_{AVS}$, is the ratio of the absorbed in the load Z_L to the power available from the source. These depend on both Z_S and Z_L.

These definitions differ primarily in the way the source and load are matched to the two-port device, if the input and output are both conjugated matched to the two-port. Then the gain is maximized and $G=G_A=G_T$.

Where Z_{in} is the impedance seen looking into port 1 of the terminated network. Similarly the reflection coefficient seen looking into port 2 of the network when 1 is terminated by Z_S is

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \quad (1)$$

The available power gain is

$$G_T = \frac{P_{avn}}{P_{avs}} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)}{|1-S_{11}\Gamma_S|^2 \ (1-|\Gamma_{out}|^2)} \quad (2)$$

The available transducer power gain is

$$G_T = \frac{P_L}{P_{avs}} = \frac{|S_{21}|^2(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|1-\Gamma_S\Gamma_{in}|^2 \ |1-S_{22}\Gamma_L|^2} \quad (3)$$

A special case of the transducer power gain occurs when both the input and output are matched for zero reflection. Then $\boldsymbol{\Gamma_L} = \boldsymbol{\Gamma_S} = 0$, and reduces to

$$G_T = |S_{21}|^2 \quad (4)$$

Impedance matching using inductor and capacitor is a common practice for RF circuit design[9]. Since traditional RF applications utilize only a small piece of frequency band, the impedance transformation can be easily realized around the specific frequency. However, the impedance transformed by the matching network will vary with frequency because the impedances of inductors and capacitors have a frequency itself. Therefore different way to need for broadband impedance matching.

The Figure 3 shows the basic idea of impedance matching network placed between a load and the source is the essential requirement. The matching network is ideally lossless to avoid unnecessary loss power and is usually designed so that looking into the matching network is Z_0. Then reflections on the transmission line to the left matching network, although there will be a reflection of matching network and the load. Impedance matching is important for the following reason:

a) Maximum power is delivered when the load is mismatched to the line (assuming the generator is mismatched), and power loss in the feed line is minimized.
b) Impedance matching sensitive receiver components (antenna, low-noise amplifier, etc.) improves the signal to noise ratio of the system.
c) Impedance matching in a power distribution network (such as an antenna array fee network) will reduce amplitude and phase errors.

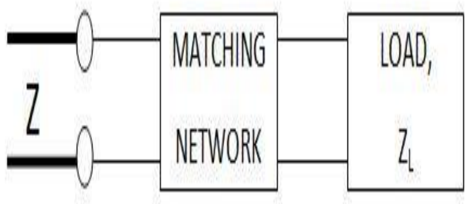

Figure 3. lossless network matching networks arbitrary load impedance to a transmission line.

DESIGN OF LNA

Figure 4 shows, the complete schematic circuit of a microwave Low noise amplifier. It was simulated using the Advanced Design System (ADS) software to fine and further optimized for a better performance. The component L_1, L_2, C_1 and C_2 are matching network for input matching network port, while the L_3 and L_4 are the matching network uses for output port respectively to provider the good performance in term of stability, power gain and s-parameter. The goals in LNA design are to maximize its gain and minimize its noise figure with sufficient linearity and impedance matching [7,8,13,14]. In order to achieve the key demands for LTE receiver characteristics, a LNA is designed should be met are the noise figure less than 3 dB and power gain should be more than 15 dB. Also good input and output impedance matching to achieved the s-parameter values.

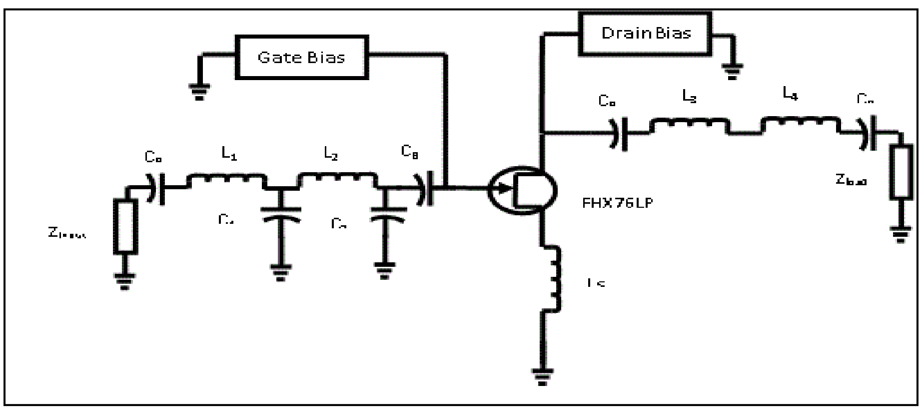

Figure 4: The Circuit for Microwave Low Noise Amplifier

SIMULATION RESULT

The simulated results of s-parameter output of the microwave LNA are shown in Figure 5. It is simulated using Advanced Design System (ADS). The simulation recorded that the power gains S_{21} is 17.2 dB. The input return loss S_{11} is -18.9 dB, overall noise figure (NF) of 0.914 dB and the output return loss S_{22} is -19.6 dB. The reflection loss S_{12} is -19.9 dB. These values were within the design specification and were accepted. Figure 5(a) shows the forward transfer and output return loss. While, Figure 5(b) shows the input reflection and the output reflection loss. Figure 5(c) and (d) are shows the Noise Figure and Stability Factor respectively. Impedance matching is also good at both ports, S11 and S22 have value lower than -10dB. The amplifier isolation is also great, the parameter S12 value is -10dB. The average noise figure of microwave LNA is 0.914 which is excellent for one stage.

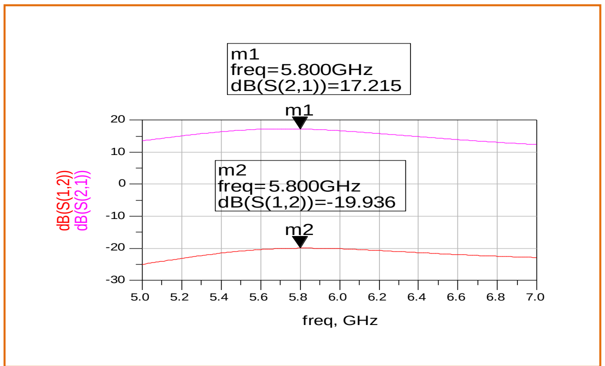

Figure 5(a): S_{21} and S_{12}

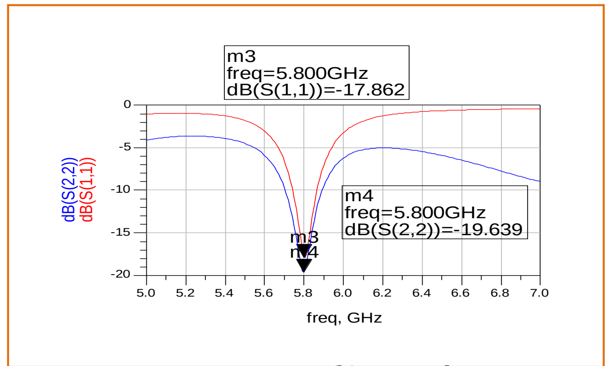

Figure 5(b): S_{11} and S_{22}

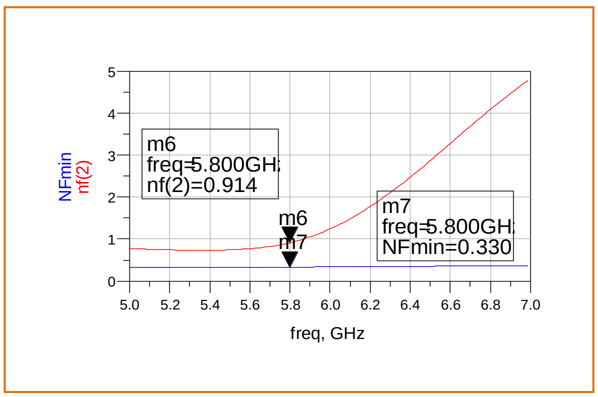

Figure 5(c): Noise Figure

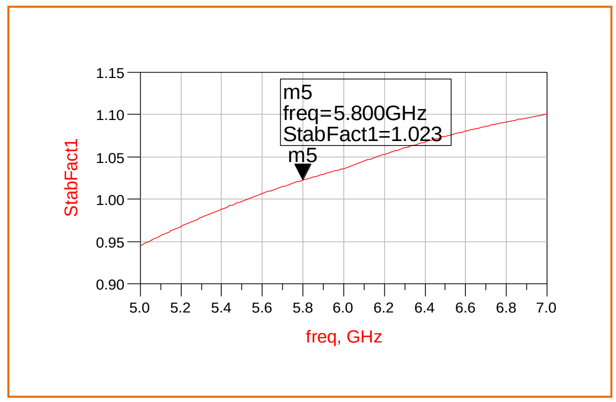

Figure 5(d): Stability Factor

CONCLUSION

The microwave low noise amplifier with ladder matching network has been simulated and designed. It's observed to compliant with LTE applications. It is observed that the simulated results giving almost the same figure as required. It observed that the gain of the measured analysis is 17.2 dB. It is important to take note when designing the amplifier to match the amplifier circuits. A microwave LNA has been developed successfully and the circuit contributed to the front end receiver at the described frequency. The LTE expect further improvement. Accordingly, all devices intended to LTE systems must enhance their performances. In the current trend, further research will be to developing low noise amplifier and other devices of the LTE receiver front-end with improved performances including better linearity, low cost and higher energy efficiency. For better performance in gain of the amplifier, it can be achieved by increasing the number of stages to improve the gain and noise figure of the design [9,10,16,17].

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