Low Noise Amplifier for Front End Transceiver at 5.8 GHz

M.H Che Halim[1] ,M. Z. A. Abd Aziz, [2] ,A. Rani Othman1[3] , S.A Sahingan[4] , M.F Selamat and [5] ,A.A Abd Aziz[6]

[1],[2],[3],[4],[5],[6]Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM)
Locked Bag 1200, Hang Tuah Jaya,75450, Ayer Keroh, Melaka,Malaysia,
[1]hafizzan@gmail.com,[2]mohamadzoinol@utem.edu.my,
[3]rani@utem.edu.my,[6]asreenanuar@gmail.com,[4]cyconx1@gmail.com, [5]faiesz84@gmail.com

Abstract

This paper presents the design of 5.8 GHz front end Low Noise Amplifier application for IEEE standard 802.11 systems for WLAN application. Revolution and demand of WLAN technology have urged development of low cost, low power and small size transceiver by using microstrip technology [1]. This paper is present design and simulation of single stage LNA circuits. This paper is focusing on development of Low Noise Amplifier operating at 5.75-5.85GHz (5GHz upper U-NII band) for WLAN application. The amplifier design used FHX76LP Low noise SuperHEMT from Eudyna Device USA Inc. The design circuit uses lumped elements to implement the matching networks. The purpose single stage of input and output matching network is to produces 50Ω impedance at the input and output port of the LNA. The matching network is used at both sides of the transistor [2],[3]. The target simulation are gain (S_{21}) with >10dB, noise figure with <10dB and input and output return loss <-10dB at 5.8 GHz. A single stage LNA has successfully designed with 15.924 dB forward gain , 0.552 dB noise figure, -11.182 dB output return loss(S22) and -13.246 dB input return loss(S11) by using ADS software.

1. INTRODUCTION

The IEEE 802.11 standard is used as references. The Low Noise Amplifier (LNA) system should meet this standard requirement and should operate properly for WLAN Bridge system [1]. The main requirements of the LNA are the lowest possible noise figure (NF) with a reasonable gain. The general topology of the LNA consists of three stages: the input matching network (IMN), the amplifier itself and the output matching network (OMN) [2],[3],[4]. The 5.8 GHz wireless LAN market

grows rapidly and offers various benefits to the user 5.8 GHz LAN technology supports multimedia services, real time voice and video transfer and other bandwidth intensive applications [5]. This paper presents two different designs of a LNA at 5.8GHz. The circuit design starts from FHX76LP Low noise SuperHEMT device designed for DBS application from Eudyna Device USA Inc amplifier using the microstrip technology. It is the LNA that mainly determines the noise figure of the system. Low power dissipation and small integrated area are also some important factors that must be considered in the design of the devices for wireless applications [6]. Based on S-parameters of the transistor and certain performance requirements, a systematic procedure is developed for the design of LNA. In LNA design, the most important factors are low noise, moderate gain, matching and stability [7]. Besides those factors, power consumption and layout design size also need to be considered in designed works.The characteristic of this commercialize Low Noise Amplifier are shows in Table 1 below:-

Table 1. FHX76LP characteristic

Component	Parameter	Value
FHX76LP	Frequency Range	5000-6000 MHz
	Associated Gain	12dB
	Noise Figure	0.4 dB
	Input IP3	8dBm
	Output P1dB	9dBm

2. SINGLE STAGE LNA

A single stage microwave transistor amplifier can be modeled by the circuit in Figure 1 where a matching network is used both sides of the transistor to transform the input and output impedance Z_A to the source and load impedance Z_S and Z_L. The most useful

gain definition for amplifier design is the transducer power gain, which accounts both source and load mismatch [4],[5],[6].
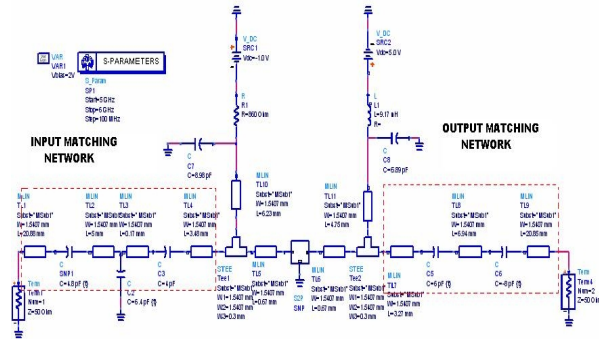

Figure 1: Single Stage LNA circuit

3. STABILITY CONSIDERATION

One of the most important factors in high frequency amplifier design is to determine stability of the given bias point. Equations in Table 2 and Table 3 are used to determine the stability and stability circle of the amplifier.

Table 2. Stability determination by formula

Stability	Criteria
Unconditionally stable	$K > 1 \ \& \ \mid \Delta \mid < 1$
Potentially unstable	$K > 1 \ \& \ \mid \Delta \mid > 1$ or $K < 1 \ \& \ \mid \Delta \mid < 1$
Stability Factor	
$K = \dfrac{1 - \mid S_{11} \mid^2 - \mid S_{22} \mid^2 + \mid \Delta \mid^2}{2 \mid S_{12} S_{21} \mid}$	
Delta Factor $\Delta = S_{11} S_{22} - S_{12} S_{21}$	

Table 3. Stability determinations by stability circle

$\gamma_{in} = \left\| \dfrac{S_{12} S_{21}}{\mid S_{11} \mid^2 - \mid \Delta \mid^2} \right\|$ (Radius)	$\gamma_{out} = \left\| \dfrac{S_{12} S_{21}}{\mid S_{22} \mid^2 - \mid \Delta \mid^2} \right\|$ (Radius)
$C_{in} = \dfrac{(S_{11} - \Delta S^{*}{}_{22})^{*}}{\mid S_{11} \mid^2 - \mid \Delta \mid^2}$ (Center)	$C_{out} = \dfrac{(S_{22} - \Delta S^{*}{}_{11})^{*}}{\mid S_{22} \mid^2 - \mid \Delta \mid^2}$ (Center)

The input and the output circuits should be matched to deliver maximum power to the load. After stability of active device is determined, input and output matching circuits should be designed so that reflection coefficient of each port can be correlated with conjugate complex number as given below:

$$\Gamma_{IN} = \Gamma_S{}^{*} = S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22} \Gamma_L} \qquad (1)$$

$$\Gamma_{OUT} = \Gamma_L{}^{*} = S_{22} + \frac{S_{12} S_{21} \Gamma_S}{1 - S_{11} \Gamma_S} \qquad (2)$$

By combining the two formulas above, reflection coefficient of input/output matching circuits can be calculated by:

$$\Gamma_{SM} = \frac{B_1 - \sqrt{B_1{}^2 - 4 \mid C_1 \mid^2}}{2 C_1} \qquad (3)$$

$$\Gamma_{LM} = \frac{B_2 - \sqrt{B_2{}^2 - 4 \mid C_2 \mid^2}}{2 C_2} \qquad (4)$$

Where

$$B_1 = 1 + \mid S_{11} \mid^2 - \mid S_{22} \mid^2 - \mid \Delta \mid^2 \qquad (5)$$

$$B_2 = 1 + \mid S_{22} \mid^2 - \mid S_{11} \mid^2 - \mid \Delta \mid^2 \qquad (6)$$

$$C_1 = S_{11} - \nabla S_{22}{}^{*} \qquad (7)$$

$$C_2 = S_{22} - \nabla S_{11}{}^{*} \qquad (8)$$

$$\nabla = S_{11} S_{22} - S_{12} S_{21} \qquad (9)$$

The formulas above give source and load reflection coefficients to obtain maximum power gain.

4. NOISE FIGURE AND CONSTANT NOISE CIRCLE

Signals and noises applied to the input port of amplifier are amplified by the gain of the amplifier and noise of amplifier itself is added to the output. Therefore, SNR (Signal to Noise Ratio) of the output port is smaller than that of the input port. The ratio of SNR of input port to that of output port is referred to as noise figure and is larger or less than 1.Typically, noise figure of 2-port transistor has a minimum value at the specified admittance given by formula:

$$F = F_{min} + \frac{R_N}{G_S} |Y_s - Y_{opt}|^2 \qquad (10)$$

5. DESIGN FOR MINIMUM NOISE FIGURE

Low noise amplifier is important for receiver because noise figure of the amplifier of receiver affects noise figure of the whole system. To get minimum noise figure using 2-port transistor, source and load reflection coefficient should match with Γopt and load reflection coefficient should match with Γout with a complex conjugate number [9],[10] as formula below:

$$\Gamma_s = \Gamma_{opt} \qquad (11)$$

$$\Gamma_L = \Gamma_{out}^* = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1 - S_{11}\Gamma_s} \right) \qquad (12)$$

6. RESULT

For the proposed single stage LNA shown in Figure 1, the simulation result is shown in Figure 2 to Figure 6. The design LNA required two 2 V supply voltage and consumes 4.5mW. In the beginning of the simulation process, the transistor is modeled in schematic using data sheet provided by manufacturer. The simulation result might not be accurate because the library has no data and modeled of the transistor FHX76LP Low noise SuperHEMT in ADS software. However Duroid 5880 is being used as the microstrip substrate and the characteristic of this substrate. The comparison S-parameter simulated result as shown in Table 4.
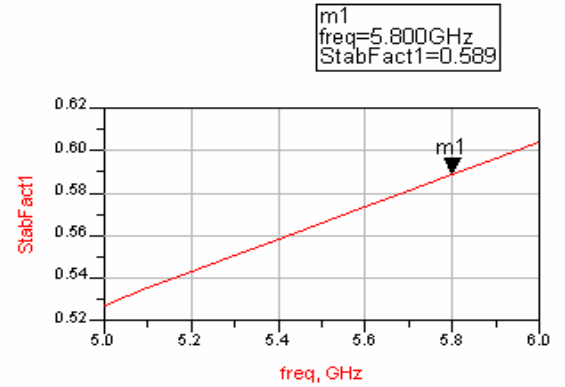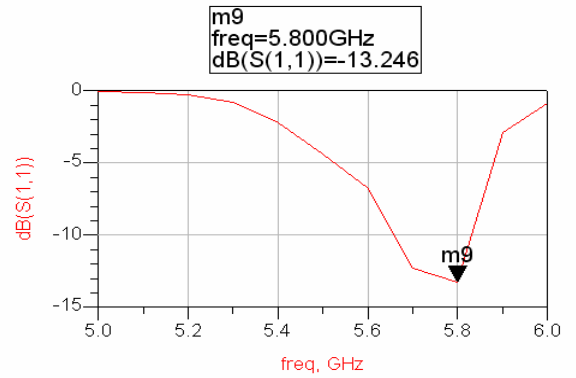

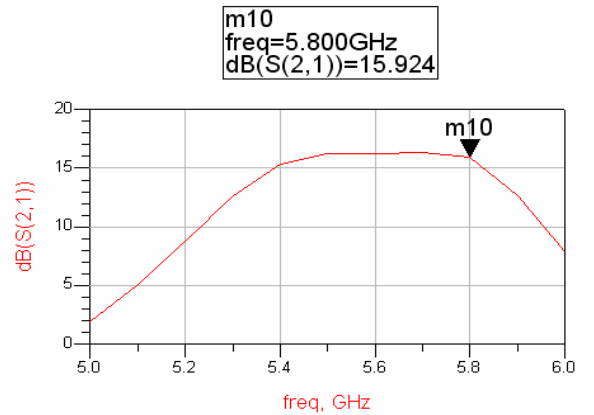**Figure 2: LNA stability**
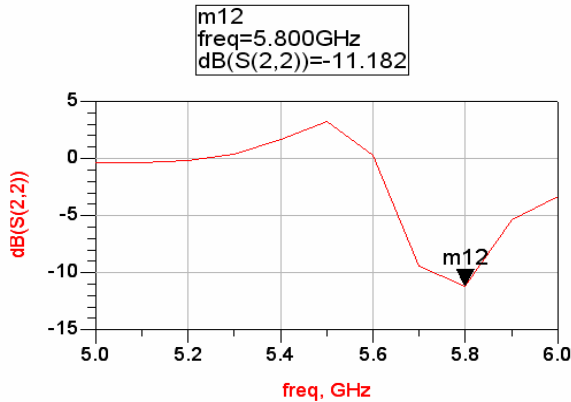

Figure 3: Input Return Loss

Figure 4: Forward Gain

m12
freq=5.800GHz
dB(S(2,2))=-11.182

Figure 5: Output Return Loss

m13
freq=5.800GHz
NFmin=0.552
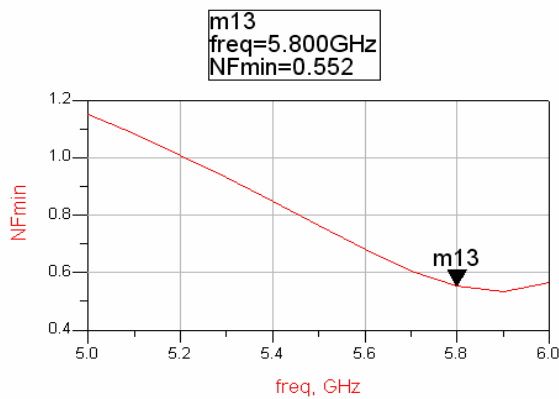
Figure 6: Noise Figure

Table 4. S-parameter simulation result

Features	Simulation (dB)
$S_{11 (Input\ Return\ Loss)}$	-13.246
$S_{12\ (Isolation)}$	-21.503
$S_{21(\ Gain)}$	15.924
$S_{22(Output\ Return\ Loss)}$	-11.182
Stability	0.59
Noise figure	0.552

A 5.8GHz low noise single stage amplifiers based on FHX76LP Low noise SuperHEMT transistor was designed and simulated by using ADS. At 2V collector bias on 5.8 GHz , this LNA has noise figure 0.552 dB, with input return loss of -13.246 dB, insertion loss of -21.503 dB and output return loss of -11.182 dB. Usually, as long as the stability factor and delta factor are known as unconditionally stable, the stability circle is necessary to be proved because the amplifier is stable at all area within the smith chart [8],[9].

7. CONCLUSION

The research work has yield a new Low Noise Amplifier (LNA) circuit design for frequency range of 5.75 GHz to 5.85 GHz and circuit simulation were done in ADS software. LNA has successfully simulated with 15.924 dB gain and 0.552 dB noise figures at frequency 5.8 GHz

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