5-6 GHz Front End Low Noise Amplifier

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Abstract –This paper presents 5-6 GHz front end Low Noise Amplifier application for IEEE standard 802.11 system for WLAN application. This amplifier uses FHX76LP Low noise SuperHEMT device designed for DBS application from Eudyna Device USA Inc. This paper is present design and simulation of single stage LNA circuits. A single stage LNA has successfully designed with 26.92 dB forward gain and 1.32 dB noise figure, which stable along the UNII frequency band.

Keyword: Wireless LAN; Low Noise Amplifier; Gain; Noise Figure; Matching Circuit.

I. 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

II. LNA Circuit Design

A 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 [8].
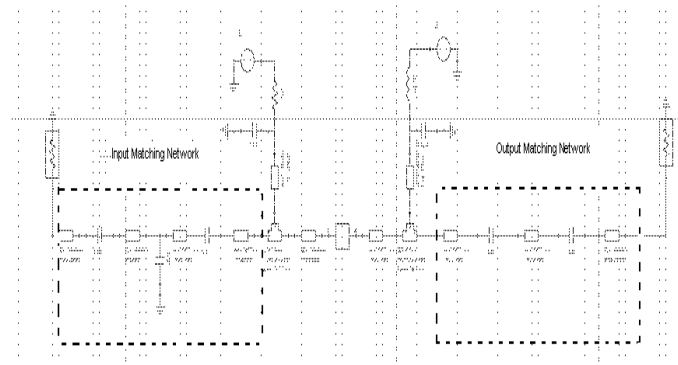

Figure 1: Single Stage LNA circuit

Various type of matching technique can be applied to implement the matching network. The lump element matching is selected for this research work. The purpose of the calculation process is to predict the result for LNA design. MATLAB is used to simplify the calculation process. The calculation process begins with S-parameter selection for frequency 5 GHz to 6 GHz. In this paper, S-parameter is selected at bias point Vds= 2V and Ids= 10 mA from data sheet.

B   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 determination 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.

C   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:

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

D 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 Γ_{opt} and load reflection coefficient should match with Γ_{out} with a complex conjugate number [9],[10] as formula below:

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

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

III. RESULT AND DISCUSSION

For the proposed single stage LNA shown in Figure 1, the simulation result is shown in Figure 2 to Figure 5. 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 Ansoft Designer. 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 3.
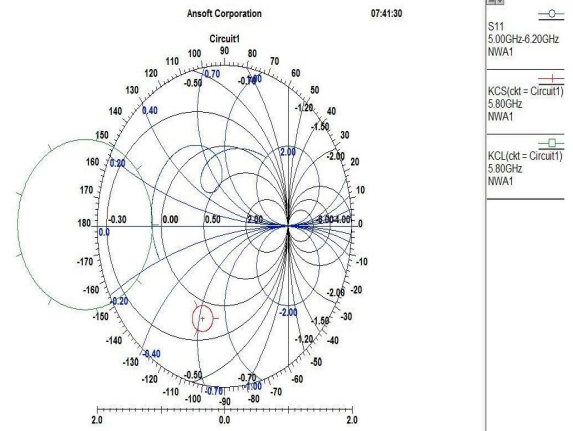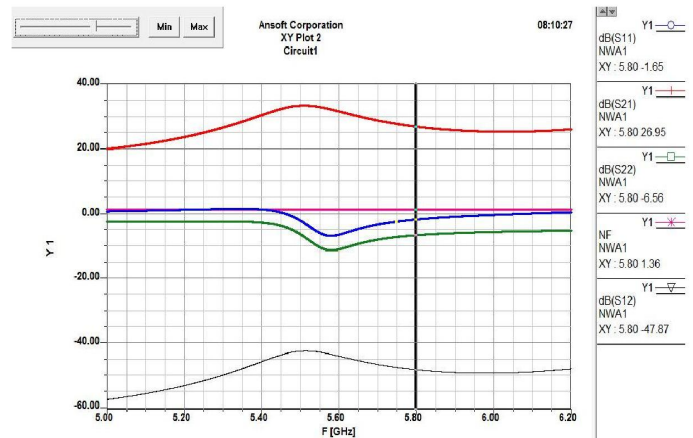

Figure 3: LNA stability circle

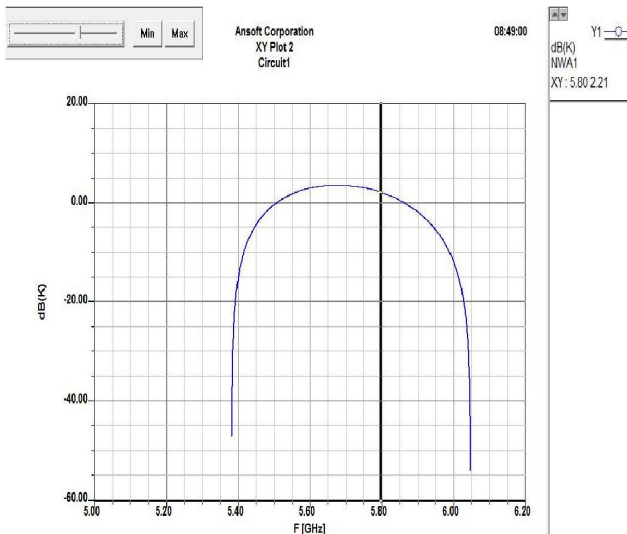Figure 4: LNA simulation result at 5.80 GHz

Figure2: LNA stability
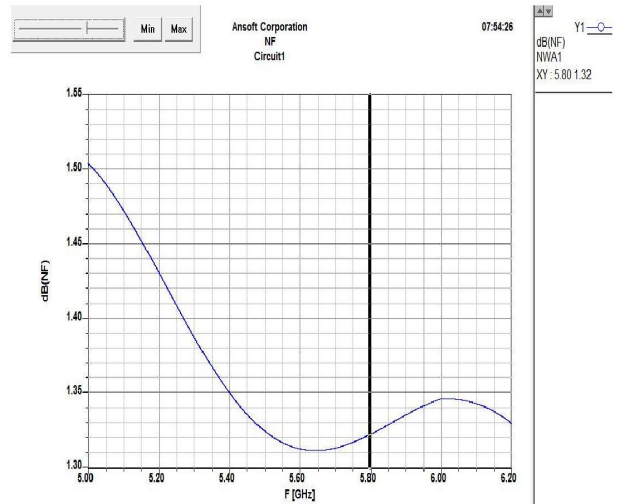
Figure 5: LNA noise figure

TABLE 3
S-Parameter simulation result

Frequency	S11	S12	S21	S22
5.75Ghz	-2.27 dB	-47.19 dB	27.76 dB	-7.26 dB
5.80Ghz	-1.63 dB	-47.90 dB	26.92 dB	-6.24 dB
5.85Ghz	-1.15 dB	-48.41 dB	26.28 dB	-6.18 dB

A 5.8GHz low noise single stage amplifiers based on FHX76LP Low noise SuperHEMT transistor was designed and the prototype was tested at room temperature. At 2V collector bias on 5.8 GHz , this LNA has noise figure 1.32dB, with input return loss of -1.63dB, insertion loss of -47.90dB and output return loss of -6.24dB. 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 [9].

IV. CONCLUSION

The research work has yield a new Low Noise Amplifier (LNA) circuit' design for frequency of 5.75 GHz to 5.85 GHz and circuit simulation were done in Ansoft Designer. LNA has successfully simulated with 26.92 dB gain and 1.32 dB noise figure at frequency 5.8 GHz

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