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DESIGN SINGLE STAGE LNA USING L-MATCHING NETWORK FOR WIMAX APPLICATIONS

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ABSTRACT

This paper presents a design single stage low noise amplifier(LNA) using L-matching technique for WiMAX applications. The amplifier use FHX76LP Low Noise SuperHEMT FET. The LNA designed used L-matching network consisting of lump reactive element at the input and the output terminal. The LNA produced gain of 18.34dB and noise Figure (NF) of 1.34dB. Furthermore, the input reflection (S_{11}) and output return loss(S_{22}) are -16.25dB and -7.52dB respectively. The bandwidth of the amplifier recorded is 1.24GHz. The input sensitivity is compliant with the IEEE 802.16 standards.

Keywords: LNA, matching network, L-Matching technique, WiMAX.

1. INTRODUCTION

The last few years, modern wireless communication systems demand high data rate and high mobility performance (Bao, M *et al.*, 2005). World Interoperability for Microwave Access (WiMAX) is a novel wireless communication technology (A.B. Ibrahim *et al.*, 2012). It is due to high transmitting speed up to 70Mbs and up to 30 miles for long transmitting distance communication (Hsu, M.T et al, 2006). The system is based on IEEE 802.6 standards and use 5.8 GHz to transmit data. Many researchers (Adabi, E et al., 2007)(Nasar, M et al., 2007) (Paurakbar, M et al., 2008) (Pozar, D.M et al., 2000) had tried their best to define the solution but the issues is remained the same. It will be optimize the matching network of LNA and identify the best matching.

LNA is an electronic amplifier used to amplify possibly very weak signals such as captured by an antenna. It is usually located very close to the detection device to reduce losses in the feed line. It's also used as a transmission point for input and output matching network and this amplifier more focus on high gain and noise efficiency. A proper impedance matching needs to be designed at the input and output of LNA to fulfill the performance in high gain and low noise. The best matching network can optimize the performance of the LNA. The design of LNA in WiMAX application can performed the standard specification of wireless communication that needs the stability of small signal gain and bandwidth to satisfy a good performance (Lee, C.S *et al.*, 2012). The design needs to match input and output impedance, enough power gain and low noise (NF) within the required band.

2. LNA DESIGN

The main of this LNA design is based on the FET transistor (FHX76LP) to fulfill all the criteria of targeted specification. This single stage LNA designed is also based on the S-parameters were obtained from calculation and simulation using Ansoft Designer V2.2 (Table-1). These parameters were measured at V_{dd} = – 2V and I_{DS} = 10 mA which sets the biasing of the transistor.

Table-1. S-Parameter of single stage LNA for FHXLP76LP.

S-Parameters	Freq: 5.8GHz	
	Mag	**Angle**
S_{11}	0.712	-86.539
S_{12}	0.065	33.878
S_{21}	8.994	178.66
S_{22}	0.237	-10.456

Figure-1 shows the circuit layout for single stage LNA with gate and DC biasing of FET.

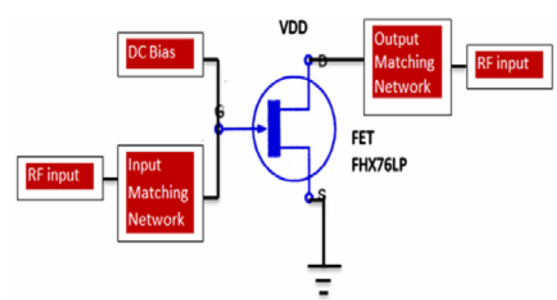

Figure-1. Biasing circuit for LNA.

2.1 Impedance Matching

The single stage LNA performances is determined by calculating the transducer gain G_T, noise Figure (NF) and the input and output standing wave ratios, $VSWR_{IN}$ and $VSRWR_{OUT.}$ The optimum, Γ_{opt} and Γ_L were obtained as Γ_{opt} = 17.949 + j48.881 and Γ_L = 79.913 - j7.304 [8].

2.1.1 Output Matching

As mentioned in (Inder, J. Bhar *et al.*, 2003) the suitable matching impedance for the load is by using a quarter-wave transformer matching because the transformer can converts the complex impedance into real impedance. However, there are other types of matching network that can be applied to match the Γ_L but the techniques that used required more capacitors and inductors to match this LNA. For simulation design, the capacitor value is fixed and available in the market, so it is easy to match the input and output load instead of adjustable capacitor which is more complex in this LNA design. The coupling capacitors 7.5 pF is selected which was at least 10 times the value of C_1 (Paurakbar,M *et.al.*, 2008). For the output load matching technique the quarter-wave transformer is selected because it more simple. The matching component values for output matching were calculated as shown in Table-2.

Table-2. Component value at output matching.

Components	**L_1 (10 mm)**	**L_2 (7.5 mm)**	**L_3 (16 mm)**
Values	1.39 nH	1.32nH	0.66nH

2.1.2 Input Matching

The input matching load Γ_{out} is required to provide high load Q factor for best sensitivity (Adabi, E *et al.*, 2007). Several types of matching techniques had been tested for input matching. The criteria that is taken into consideration for choosing the most suitable matching network include available gain, noise Figure (NF) and stability (K) (Asgaran,S et al., 2007). The matching techniques that used in this design is L-Matching and it is applied at input matching of LNA.

2.3 Single Stage LNA with Matching Network

By using Ansoft designer V2.2, the single stage LNA is design based on targeted S-Parameter as shown in Table-1. Table-3 shows the substrate parameter of Duroid 5880 TYL-5A-CH/Ch. Meanwhile, the schematic circuit for the single stage LNA is drawn and shown in Figure-2. This circuit was simulated and the optimization of the LNA performance is achieved.

Table-3. Duroid 5880 TYL-5A-CH/Ch substrate parameter.

Dielectric	**Metallization**			
H=0.508mm	**Material**	**Resistivity**	**Thickness**	**Unit**
$\varepsilon_r = 2.2$	Copper	1.724138	0.0175	mm
TAND = 0.0018				

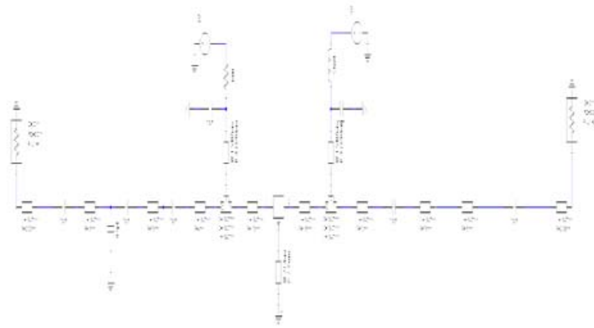

Figure-2. Schematic layout of L-matching network.

2.4 Matching Network Design

2.4.1 L-Matching Technique

By using the Ansoft Designer software with microstrip technology and lump elements, the required L-matching for amplifier is defined (see Figure-2). For the best result on simulation, the inductances need to be converted to microstrip line for both input and output matching network. The component value is shown in Table-4.

Table-4. LNA Component parameters at input side for L-network.

Components	**Values**
L_1 (nH)	0.66
L_2 (nH)	1.32
L_3 (nH)	1.32
L_4 (nH)	0.86
C_1 (pF)	7.5
C_2 (pF)	7.5
C_3 (pF)	7.5
C_4 (pF)	0.5

After the suitable width and length from the reflected component were obtained, the schematic diagram of the single stage is simulated. The circuit was fine-tuned to increase the gain which exceeds 17dB and maintaining the noise Figure of less than 3dB. Tuning was performed on the design by varying the microstrip matching line of inductor. Table-5 shows the width and length of matching component using microstrip lines of L-Matching.

Table-5. Width and length of matching component of L-matching.

Component	**Width (mm)**	**Length (mm)**
L_1	1.5407	20.88
L_2	1.5407	16
L_3	1.5407	7.5
L_4	1.5407	4

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From Table-5, the result showed that the stability of the circuit performance is affected when the width and length of inductor that connected from source amplifier is varied meanwhile the capacitor value is fixed. This is because the dimension line is very important to match the input and output of LNA. (see Figure-2)

The width and length of L_S (FET inductor source) which stand for inductor source (see Figure-2) is varied to find a high gain and low noise Figure as shown in Table-6. After consider all the possible matching network parameter, the optimum design with good compensation of gain and noise Figure is achieved.

Table-6. The output gain and noise figure of L-network.

Network Matching	L_S Width (mm)	L_S Length (mm)	Gain (dB)	Noise Figure (dB)
	1.5407	2.35	18.34	1.34 (C_4= 0.6pF)
L-Matching	1.5407	2.38	18.11	1.08
	1.5407	3.38	17.11	1.08
	1.5407	4.35	15.81	1.07
	1.5407	4.38	15.77	1.07

From the Table-6, the result showed that the width and length of dimension lines were influenced the high gain instead of maintain the low noise Figure except the length = 2.35mm and width= 1.5407mm. This is because, when the value of capacitor C_4 is increased to 0.6 pF, the performances of power gain and noise Figure also increase. From all the possible value of component and dimension line, it is showed that the component L_S can control the output performance and stabilized the LNA. The simulated S Parameters output of the amplifier on Ansoft is shown in Figures 2.3 and tabulated in Table-7. From the simulated results of Ansoft, it was observed the total gain S_{21} is 18.34 dB for X1 and noise Figure is 1.34dB for X2(see Figure-3).

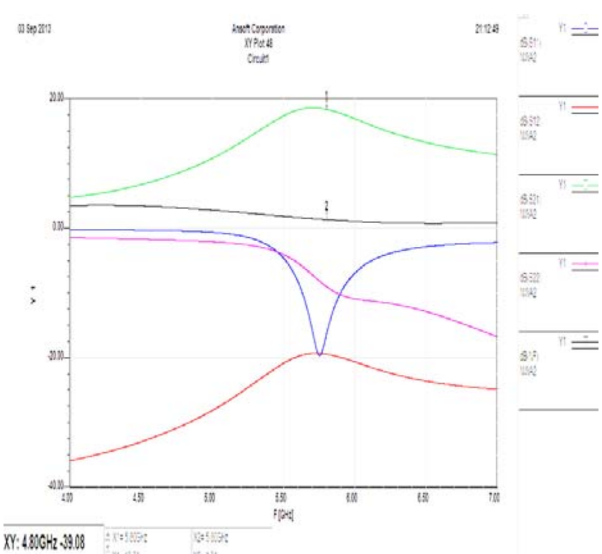

Figure-3. S-Parameter output of LNA and noise figure for L-Network.

Table-7. S Parameter output and targeted parameter of LNA.

S Parameter (dB)	Simulation Result from Ansoft V2.2 software
Input Reflections S_{11}	-16.25
Return Loss S_{12}	-19.17
Forward Transfer S_{21}	18.34
Output Reflection Loss S_{22}	-7.52
Noise Figure (NF)	1.34
Bandwidth MHz	1240

From Table-5 the data showed that the L-matching network can improve the gain but the stability is not achieve, which K<1 and will isolate. With possible of dimension line of inductor the stability can improve without decreasing the gain.

CONCLUSIONS

A low noise amplifier has been simulated and developed successfully with IEEE standard 802.16 WiMAX. It is observed that from simulated S-parameter results the amplifier achieved the targeted. It is important to take note when designing the amplifier to match the amplifier circuits. The design LNA has been developed successfully and the circuit contributed to the front end receiver at the described frequency. At a frequency of 5.8GHz LNA amplifiers using L-matching technique recorded gain S_{21} of 18.34dB. While input Insertion loss S_{11} is - 16.25dB and the output insertion loss S_{22} is -7.52dB. The S_{12} reflected loss is -19.17dB. The gain and noise Figure (NF) was 18.34dB and 1.34dB respectively. 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(Inder, J. Bhar et

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al., 2003). Higher gain would expand the coverage or communication distance.

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