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Integrated Design of Low Noise Amplifier and Notch Filter for Wireless Communications

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Abstract

This paper presents a design of low noise amplifier with notch filter for telecommunication system that can support wide range frequency from 3.1 GHz-10.6 GHz based on transistor InGaAs HEMT Avago Technologies (mgf4937) Mitsubishi. In this study, relevant amplifier theory, detailed descriptions of design and simulation process. There are three techniques which are single stage, balanced, and the feedback for the low noise amplifier is being used to achieve a wide bandwidth. Advanced Design System (ADS) software being used because it is the best software and very efficiently to design a power amplifier nowadays. Measurement results show good according to the simulation results for the amplifier. The best technique is a feedback amplifier based on the analysis showing that feedback amplifier has the highest gain and output power rather than the other technique which is balanced amplifier .The LNA provides an input return loss (S_{11}) which less than -8 dB and the gain (S_{21}) more than 20 dB and noise figure less than 2dB. LNA can be used on several types of application such as wireless local area network (WLAN) and personal area networks, ground penetrating radars, and medical applications.

Keywords: LNA, Microstrip .

1. INTRODUCTION

Communication systems now days is the most important technology in all over the world, which makes the world connect as one home Regardless of the distances. There are several technics to establishing connect, one of them witch this article will take into consideration is (low noise amplifier). This system (LNA) is in charge to extend the domain of the wave to make it reach to far-far away destination, but in the same time this method will amplify some unneeded signals. This study will shows how to remove that unneeded signals by using notch system in LAN structure model[1].

LNA with a vigorous notch filter is planned. The notch filter provides a deep rejection quantitative relation to attenuate the unsought frequency. every generation of networks take issue considerably in link-layer protocol standards from 2G to 2.5G/3G therefore 4G so it inflicting issues to subscribers, wireless network operators and instrumentation vendors. Subscribers area unit forced to buy new handsets whenever a replacement generation of network standards is deployed. With SDR technology, it may be accustomed implement military, industrial and civilian radio applications. a large vary of radio applications like Bluetooth, WLAN, GPS, Radar, WCDMA, and GPRS can also be enforced exploitation SDR technology. A portable radio device such as mobile phone may include more than one radio operating in a cellular band, and a radio operating in the ISM band. The wideband low noise amplifier which covers 1.7-2.7 GHz range includes wireless LAN 802.11b, ISM band and cellular band.

This environment presents a challenge since these radios may be in close physical proximity and located in the same physical instance. A high power interference such as cellular phone in the 1.9GHz frequency band may cause the ISM band receivers operating at 2.4 GHz to saturate since it is in close proximity to the 2.4 G Hz signal. This noise may cause a damaging consequence on the received wideband signal[2].

In operation, a cellular phone that support cellular and Wi-Fi services start transmitting in the 1.9 GHz spectrum during talks. If the Wi-Fi or Bluetooth radio goes to active and connect during this period, the 1.9 GHz cellular signals which have larger signal strength than the 2.4 G Hz ISM band spectrum may jam and interferes the Wi-Fi or Bluetooth signal. The high power interferes may degrade the operation of the LNA and mixer of Wi-Fi or Bluetooth receiver. Then, amplification of the Wi-Fi or Bluetooth signal may result in saturation in an Analog-to-Digital Converter (ADC). Some existing solutions may incorporate an on-board notch filter in the ISM band radio. This notch filter may be located between a low noise amplifier (LNA) and the mixer in the RF portion of the ISM band radio. This is to minimize the undesired interferences from other frequency bands.

The radio frequency of the low noise amplifier is well as to achieve the needed gain and supports low noise figure and the one which must important part as a different biasing circuit. The noise consideration in lower analog application, so in order to avoid that problem, this study propose to choose appropriate amplifier. Then get more knowledge about noise parameters for a particular application system, after that determine if the amplifier is indeed low noise[3].

Essentially The LNA design should achieve high gain flatness, lowest noise figure and acceptable input and output return loss cover for the entire band.

In this paper, LNA with notch filter using microstrip technology is proposed with Double stage cascaded implementing multisection input matching with negative feedback. The design meets the requirement of low frequency band which covers from 3.1 GHz to 10.6 GHz.

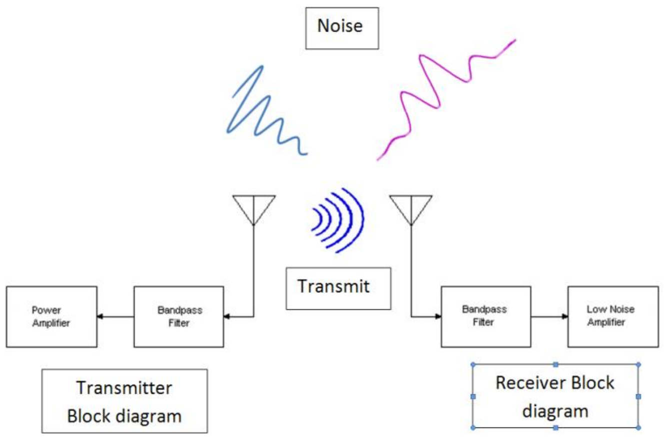

Figure 1: Transmitter and Receiver Block Diagram

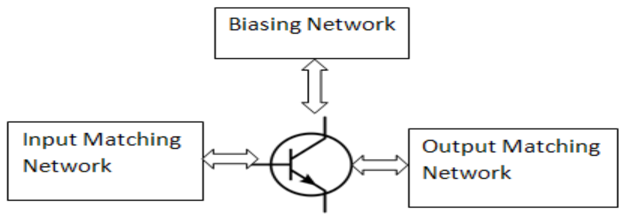

Figure 2: Simple Block Diagram of LNA

According to figure 1, LNA is the third block diagram of the receiver system. Wireless transmission is extremely exposed to atmospheric noise and other signal, so the signal transfer from transmitter experience lots of attenuation and distortion. In addition, it is the first system using active component that offers high gain with low noise figure to its frequency band needs which to strengthen weak signal received from transmitter throughout antenna. Furthermore, the use of external cable to connect from antenna to filter and filter to LNA would increase the noise. So, the LNA needs to be designed with lowest noise figure as a trade-off to the external noise. A general LNA is distinguishing in term of S – Parameter which consists of Gain, Input return loss and Output return loss followed by Noise Figure. However, the stability of the system also needs to be considered to prevent oscillation occurred. If oscillation occurs, the signal will oscillate throughout the system and did not process to other block diagram.

Designing LNA consist of several block diagrams such as input matching network, output matching network and biasing network as shown in figure 2. To propose UWB LNA, it is crucial to identify the technique to be used to design the wideband input matching and output matching in order to achieve high bandwidth which can cover ultra-wideband frequencies. Lastly, this designed should work efficiently in the wireless local area network (WLAN) environment[4].

DESIGN CONCEPT

In designing of LNA with notch filters, there are several steps that need to carry out.

A. Transistor type selection

Transistor selection is the first essential step in developing LNA. The low noise amplifier is created using diffusion Avago Technologies' MGF-4937 and stub matching is employed for it is output and input matching. The type of transistor is created by InGaAs HEMT Avago Solutions (MGF 4937) Mitsubishi, achieved through the use of Avago Technologies' GaAs Enhancement-mode pHEMT process which is worked with frequencies from 3. 1 to 12. 6 GHz. All corresponding components are fully included within the module. This kind of makes the MGF 4937 extremely easy to use.

When have chosen the described pHEMT transistor for amplifier design. Designing of amplifier in line with the specification of the transistor [5].

B. Biasing Network

Biasing network purposely uses to deliver optimum Vds and Identity in line with the datasheet. In datasheet, the manufacturer provides examination of gain and sound figure with different value of bias point. Simply by selecting optimum DC opinion circuit should demonstrate steady thermal performance. Bias point of Vds = 2V and Id = 12 mA been choose to give optimum performance to LNA. The design of bias network based on voltage divided circuit [6].

C. Parameter Identification

I. Stability Condition

In LNA design, single electric power transistor is the method to provide amplification at the specified frequency and the desired linearity-. For building LNA the stability of the amplifier must be concerted, because if the amplifier is unstable the signal will oscillate. Gowns why the need of the amplifier to be wholehearted stable, which situation can be calculated by using K test or Δ, and the K must be more than 1. In this design the amplifier according to the noise figure graph so it is unconditional stable transistor. The way of unconditional stability can be expressed in the following formula below [7].

$$\Delta = S_{11}S_{22} - S_{21}S_{12} \tag{1}$$

$$K = \frac{1+|\Delta|^2-|S_{11}|^2-|S_{22}|^2}{2|S_{12}S_{21}|} < 1 \tag{2}$$

The above mentioned equation refers to Rollet's Criteria for Unconditional stable, which is the important condition. The importance of K also can be found using simulation.

II. Noise Figure

The critical part of designing LNA is around noise optimization. Mainly, the perfect technique to recognize the best optimized noise number is via noise circle and gain circle which used to verify the input and output representation coefficient out of the circuit. The noise figure of the transistor can be calculated according to several parameters given by the maker such as f min, Rn and Yopt at the particular frequency by the following formula below [8].

$$F = F_{min} + \frac{R_N}{G_S}\left|Y_S - Y_{opt}\right|^2 \tag{3}$$

$$N = \frac{\left|\Gamma_S-\Gamma_{opt}\right|^2}{1-|\Gamma_S|^2} = \frac{F-F_{min}}{4R_N/Z_0}\left|1+\Gamma_{opt}\right|^2 \tag{4}$$

In the 2 port network linked to a source and loaded impedance correspondingly, few types of power gain can be specific in term of the S- parameter and expression coefficient of source and load.

III. Power, Transducer, Available Power Gain

First is typically power gain that's the magnitude relation connected with power dissipated within the load ZL on the power transported to your input within the two-port network. For the accessible power attain would be the magnitude relation within the power accessible on the two-port network on the power accessible on the provision. transducer power attain would be the apointed magnitude relation within the power transported to force on the power accessible on the provision [9].

$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2(1-|\Gamma_L{}^2|)}{(1-|\Gamma_{in}{}^2|)|1-S_{22}\Gamma_L|^2} \tag{5}$$

$$G_A = \frac{P_{avn}}{P_{avs}} = \frac{|S_{21}|^2(1-|\Gamma_S{}^2|)}{|1-S_{11}\Gamma_S|^2(1-|\Gamma_{out}|^2)} \tag{6}$$

$$G_T = \frac{P_L}{P_{avs}} = \frac{|S_{21}|^2(1-|\Gamma_S{}^2|)(1-|\Gamma_L{}^2|)}{|1-\Gamma_S\Gamma_{in}|^2|1-S_{22}\Gamma_L|^2} \tag{7}$$

CIRCUIT DESIGN AND SIMULATION

According to previous style, it may be concluded the design specification that requires to be achieved so as to design LNA with a notch filter. Table 1 below shows the design specification for LNA with a notch filter.

Table 1: Design specification

Specification	Value
F∘ (GHz)	3.1 – 10.6
Input Return Loss S_{11} (dB)	<-5
Gain S_{21} (dB)	> 15
Noise Figure (min)	<0
Noise Figure (2)	*<2*
Stability	>1
Bandwidth (GHz)	7.5
Notch NF	71.703 dB @ 5.6GHz
Notch Attenuation (dB)	-56.550

In the planned design, 2 sorts of techniques are used so as to realize the design specification occur for LNA that is feedback for design architecture and multisection L – matching network for input and output matching.

a. Negative feedback

In order to get leaner gain as flat line and wideband LNA, feedback technique is used. So by implementing feedback the stability of transistor will improve as K>1. However, the feedback resistor reduces the Q-factor of the series equivalent input circuit by count an additional resistive contribution. Furthermore, a slight noise figure has been sacrificing in order to improve other parameters [10].

In most cases, parallel feedback by itself aids balance in cheaper RF frequencies but weakens the item in the larger frequencies. Sequence feedback can decrease balance very much sooner than parallel feedback in fact it is definitely not advised intended for RF software. On the other hand, if we'd like ripped broadband achieve as well as excellent impedance fit at the same time within the RF array, we should instead apply equally sorts of feedback. Considering that bad feedback can merely reduce the simple |s21| from the lively product, we should instead pick a transistor which has a sufficient 50Ω achieve to meet the target.

b. Multisection matching

The matching is designed based on conjugate matching at the input of the active device will satisfy the condition (Z_S= Z_{opt}) in order to achieve least noise figure. Typically, results in matching networks of high loaded Q-values result a narrowband matching networks. To design wideband matching network, at least two or more matching type need to be combined at different frequency resulting new topologies such as LC-ladder or Chebyshev filter [11].

In order to overcome the gain drawback from using negative feedback, cascaded amplifier is implemented For Input matching network and output matching network, L–matching network is designed using smith chart tools provided by Advanced Design System (ADS) software to achieve a better accuracy rather that construct manually.

For multisection input matching, the L–matching network is designed at several frequencies inside LNA. Figure 3 shows the full schematic diagram of LNA with notch filter by using the negative feedback architecture and using multisection matching.

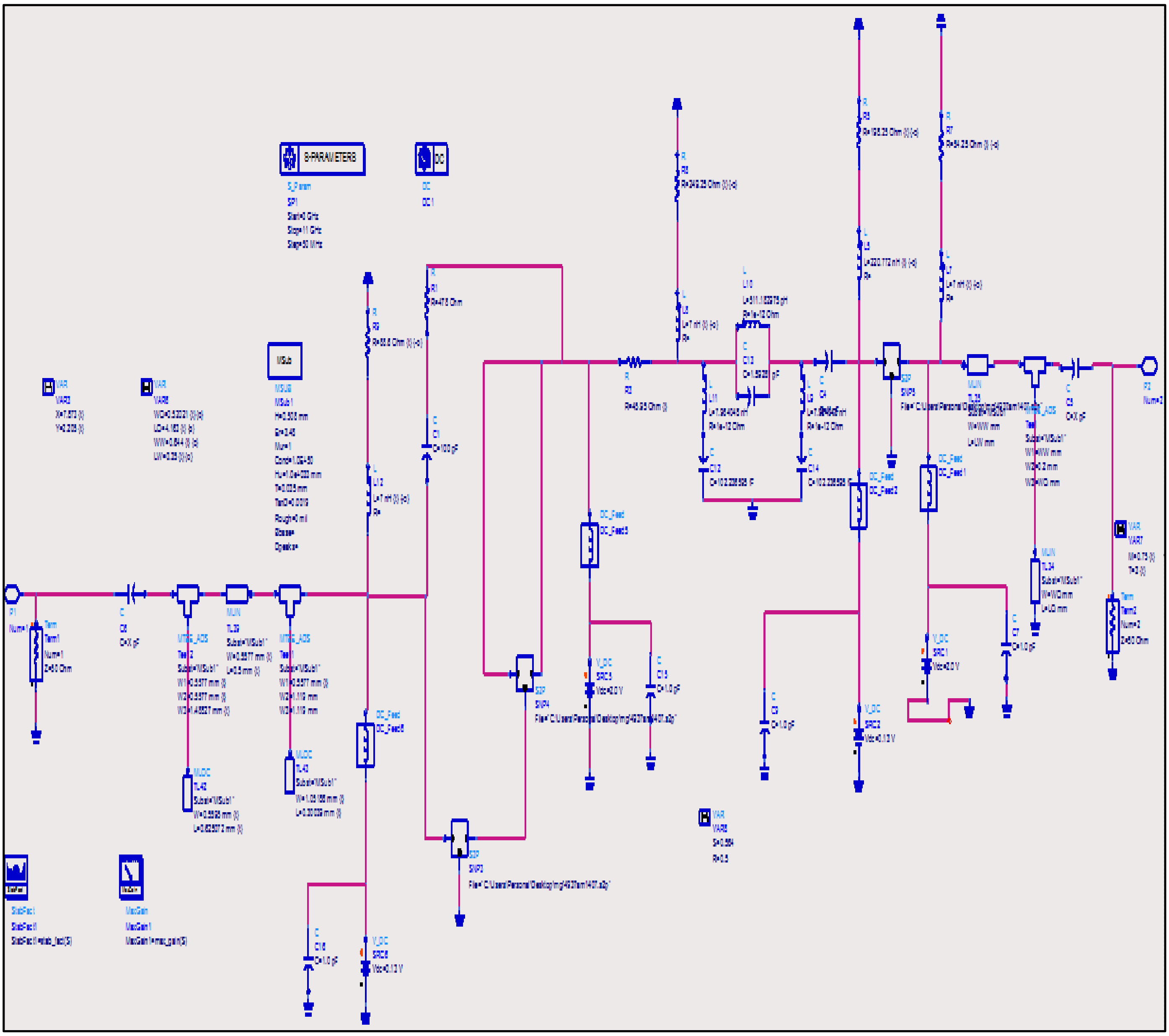

Figure 3: full schematic diagram of LNA with notch filter.

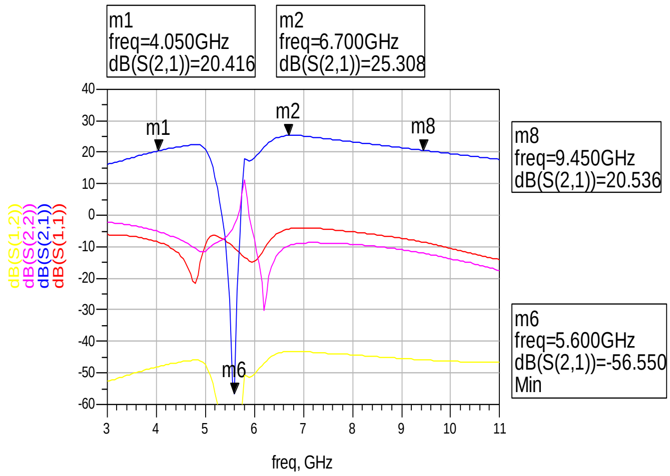

Figure 4: S – Parameter of LNA with notch filter

Table 2: comparition between privous achievement and the current work of LNA with notch filter.

Parameter	[4]	[12]	[8]	**Current work**
Frequency (GHz)	3.5	20	3.3 – 11	**3.1– 10.6**
Notch Frequency (GHz)	5 - 6	27.5 - 31	5 – 6.5	**5.6**
Max Gain (S21) (dB)	20	24.3	11.5	**25.308**
Input return loss (S11) (dB)	-18	<-10	<-10	**<-7.467**
Min Noise figure (dB)	4	1.9	5	**1.822**

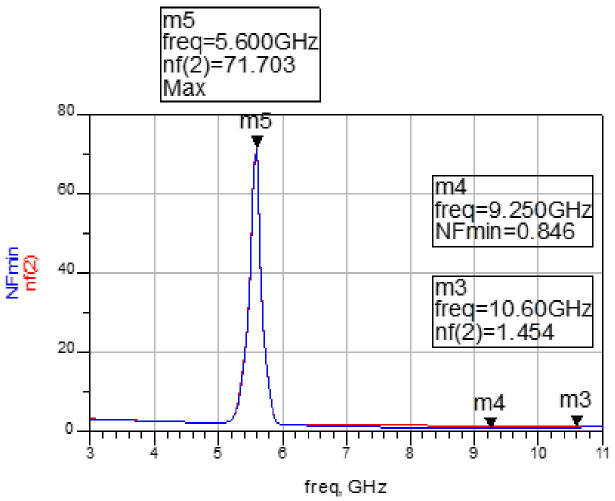

Figure 5: Noise Figure of LNA with notch filter

The achieved S – Parameter specification and noise figure that describe the amplifier is shown in figure 4 and 5. From figure 4, it's seen that the amplifier gain is 25.308 dB with ±20 dB flatness from 3.1 GHz to 10.6 GHz. Moreover, the input return loss (S11) achieves under -10 dB. This defines that the designed amplifier is LNA with a notch filter. Figure 5, shows that the noise figure obtained for the projected LNA with notch filter is in closeness to the minimum noise figure over 3.1 GHz to 10.6 GHz and therefore the noise figure maximum value within the notch frequency vary is 71.703 dB at 5.6 GHz.

CONCLUSIONS

The designing of the propsed low noise amplifier enforced feedback and multisection matching to realize the low noise amplifier with notch filter has been projected, designed and simulated. The designed LNA is biased at Vds = 2V and Id = 10 mA. The result shows that the come back return loss achieves below -10 dB for the whole band and most gain is at 25.308 dB. Moreover, the noise figure is unbroken under 2awdB for entire LNA frequencies. The look is compared with previous accomplishment that designed exploitation microstrip technology as shown in Table 2. The bandwidth achieves is wider compared with different style, whereas maintaining high gain, low noise figure throughout the band. The implementation of notch filter and style technique with microstrip elements is one amongst the difficult aspects in rising band radio frequency (RF) systems. the design of low noise amplifier with notch filter introduces new difficulties that need lots of issues like one-dimensionality, efficiency, gain, insertion loss and return loss.

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