Design of Wideband Low Noise Amplifier with Directional Coupler for Cognitive Radio Receiver and Navigation Applications

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Abstract— This paper presents a wideband low noise amplifier with low noise enhancement mode Pseudomorphic HEMT ATF-54143 transistor. The software Agilent Advanced Design System (ADS) was used for simulation of the operation of the amplifier. The performance of the amplifier were recorded and analyzed. The aim of the paper is to give low noise figure, high gain and unconditional stability. The simulation results show that the LNA using pHEMT is absolutely stable with in the band range of 1.1–1.7 GHz, which includes the band of GPS, satellite, navigation systems and cognitive radio.

Keywords— LNA, directional coupler, balanced amplifier technique, low noise amplifier, navigation application, wideband amplifier, ATF-54143, pHEMT, cognitive radio.

INTRODUCTION

Low noise amplifier is an electronic amplifier used to amplify weak signals captured by an antenna. Its location is usually close to the detection device to reduce losses in the feedline. Loss in the coaxial cable is very high in the microwave frequencies. The gain of the LNA reduces the effect of noise from subsequent stages of the receiver chain, while the noise of the LNA itself is added into the received signal. Thus, it is obligatory for an LNA to enhance the desired signal power with a precaution that minimum noise and distortion is added, so that the recovery of this signal is possible in the later stages in the system. A good LNA has following features a low NF, a large enough gain. Further criteria are operating bandwidth; gain flatness, stability and insertion losses.

At the present time, satellite navigation systems and cognitive radio systems are extensively used. So, the application of multi-band navigation receiver is becoming a trend with the development of satellite positioning technique. Wideband low noise amplifier is crucial in multi-band navigation system because the signal transmitted from antenna is distributed in different bands, and the use of wideband low noise amplifier can amplify signals within different bands by one low noise amplifier [1, 11].

GaN high electron mobility transistor (HEMT) are good choice for high power microwave electronics as it has large band gap, high saturation carrier velocity and good thermal conductivity[3]. Moreover, a low noise front end application increases interest for GaN HEMT because of low noise figure performance and high breakdown voltage characteristics.

LNA CIRCUIT DESIGN

The balanced low noise amplifier technique can guarantee the good input and output insertion loss while guaranteeing lower noise figure and better gain flatness [5–8]. There for it is a practical approach to improve the performance of low noise amplifier. As shown in the fig. 1. The balanced amplifier technique contains two low noise amplifiers and two 3 dB couplers. LNA 1 and LNA 2 are two low noise amplifiers having same structure and same performance. The 3dB coupler divides the input RF signal in to two signals having same power and 90◦ phase shift. Two outputs of first coupler are applied to the input of LNA 1 and LNA 2. LNA 1 and LNA 2 are amplifies this signals. When the performance and structure of LNA 1 and LNA 2 are same then the property of S11 and S22 will be good. The two signals after the two amplifiers will be synthesized by the second coupler at the output of the module, and the reflection signal of the balanced LNA will be absorbed by R2, it can also greatly reduce S22 of the amplifier circuit [1]. The gain of the balanced amplifier is the same to low noise amplifiers gain if the 3 dB coupler is lossless [6, 7]. There are many types of 3dB couplers, some of them are lange coupler, directional coupler and branch line coupler. As lange coupler requires bonding wire and lines are very narrow, its manufacturing cost is very high. As directional coupler doesn't require bonding wire, its manufacturing cost is very less & its fabrication is simple procedure. So in this paper we used directional coupler.

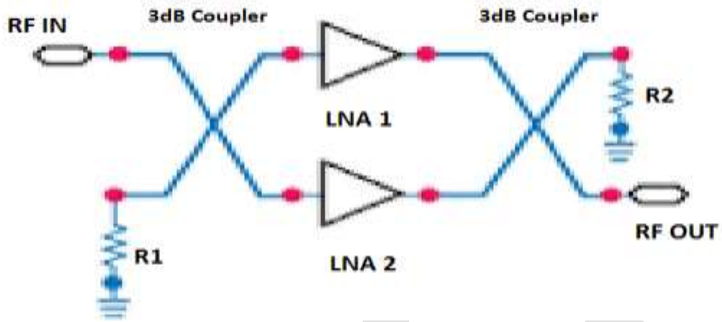

Fig. 1. Structure of balanced amplifier.

a) CHOICE OF TRANSISTOR

Choosing a transistor for an RF amplifier is very complicated. It involves choosing a transistor having an acceptable current rating with gain and noise figure capability that meets the requirements of the intended application. It is also important that the selected transistor has breakdown voltages which will not be exceeded by the dc and RF voltages that appear across the various junctions of the transistor and that permit the gain at frequency objectives to be met by the transistor. A first stage for the choice of transistor is to select the frequency range, because it may disturb other specifications [10].

Due to the design target, we choose a balanced LNA technique and Avago Technologies ATF-54143. ATF-54143 is a low noise enhancement mode PHEMT designed for use in low cost commercial applications in the 450MHz to 6GHz frequency range [9]. It has high gain, high linearity and low noise performance and so on, so that it can satisfy our requirement perfectly.

b) BIASING NETWORK DESIGN

The purpose of the bias network is to set the quiescent point that is the Vgs and Ids for a transistor that causes it to operate in the preferred region. In a general perspective there are several types of biasing networks although in LNA applications low complexity is desired and often sufficient typical passive and active bias networks can be seen [12].

In the entire design of the LNA, a strong and stable bias network to supply an appropriate quiescent operating point is important, since the bias network will also affect the noise figure (NF), stability, gain and so on. According to the datasheet, we choose the typical quiescent operating point, Vd = 3 V, Ids = 60 mA, Vdd = 5 V, Vgs = 0.59 V. The design of bias circuit as showed in Fig. 2 and it is similar to the shown in the datasheet [9].

c) STABILITY DESIGN

The design may fail if the LNA is unstable due to oscillation. There are two types of stability namely unconditional stability and conditional stability. Conditional stability in amplifier occurs when $K<1$ and stability depends on source and load termination. It can keep the system stable for a certain range of source and load impedances [4]. To the contrary, the unconditional stability in amplifier occurs when K>=1, ensures the network to be stable for all source and load impedances. For proper working of low noise amplifier, the designer should have an unconditional stability [4].

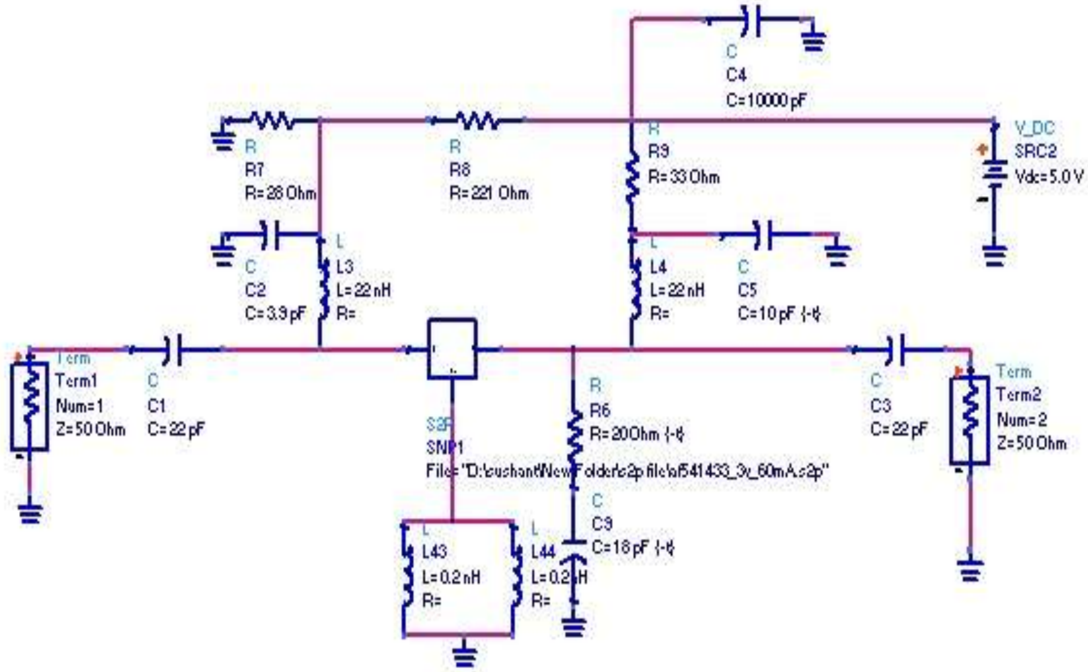

Fig. 2. Design of bias of circuit.

For this we add two small inductors in the source of ATF-54143 and also connect series combination of resistor and capacitor to drain of ATF-54143. After adding inductors we can get stability coefficient is more than 2.55 and the system is unconditionally stable.

d) MATCHING NETWORK DESIGN

In the design of low noise amplifier, the input and output matching network make the input and output impedance transform to 50ohm impedance in the condition of good noise figure and gain [1, 2]. Fig. 3 is the schematic diagram of balanced low noise amplifier; it includes bias network, stability network, input and output matching networks. For machining network two inductors and one capacitor at input and output sides are used. Stability is formed by two small inductors at source and series connection of resistor and capacitor at drain. Balanced amplifier is designed using the two 3dB directional coupler. EM simulation result of S31 and S21 of 3dB directional coupler is show in the fig. 4.

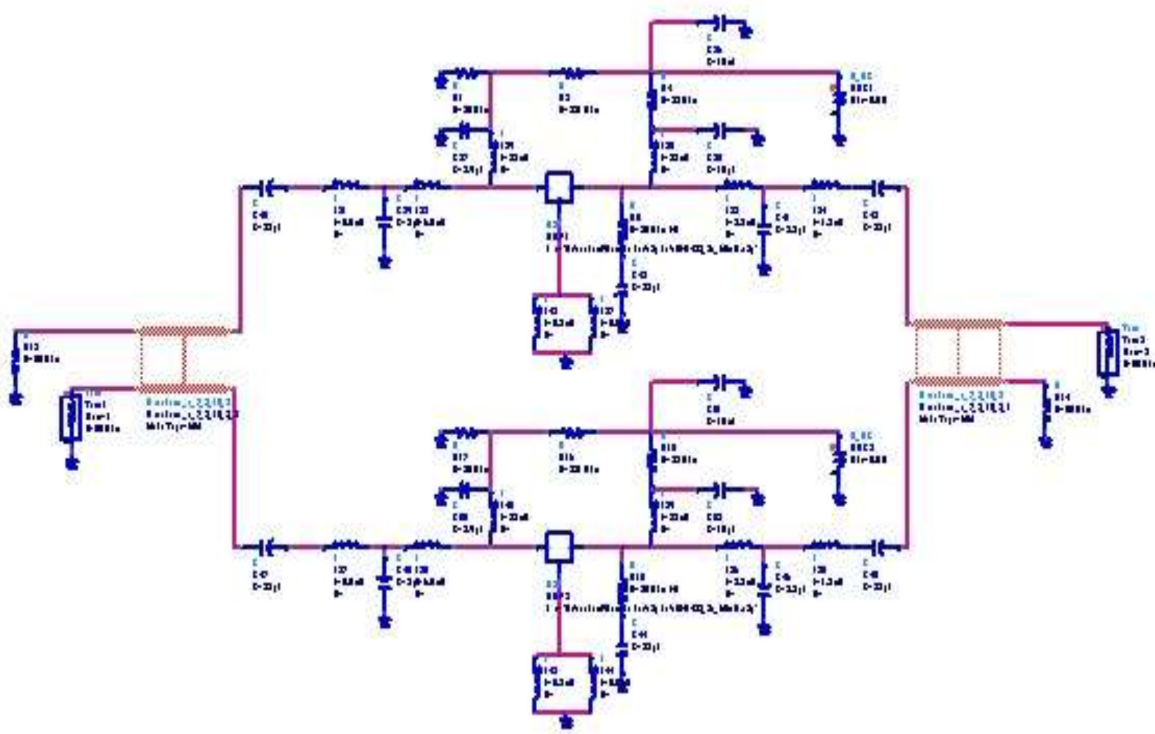

Fig. 3. Balanced LNA.

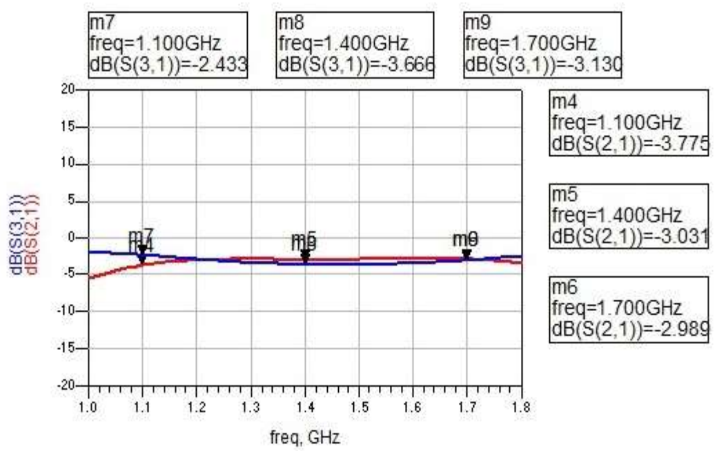

Fig. 4. S31 and S21 of directional coupler

SIMULATION RESULTS

The simulation results of the balanced low noise amplifier circuit are shown in Figs. 5–9. Fig. 5 and 6 shows that S11 and S22 of the LNA are less than −14 dB and the performance of matching network are very well. As shown in Fig. 7, the gain is more than 13.3 dB in the required frequency range of 1.1–1.7 GHz. From Figs. 8 and 9, we can see that, the max value of the noise figure is 0.76 dB, the stability factor of LNA is bigger than 2.55 and the system is unconditionally stable.

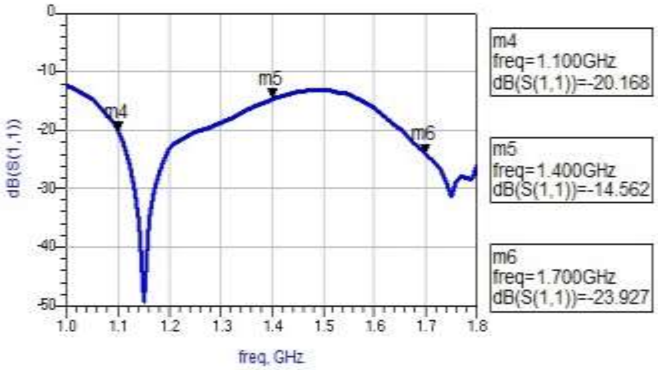

Fig. 4. Simulated s11 of LNA.

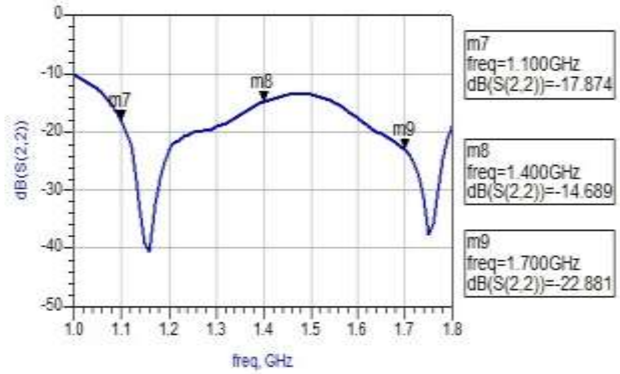

Fig. 5. Simulated S22 of LNA.

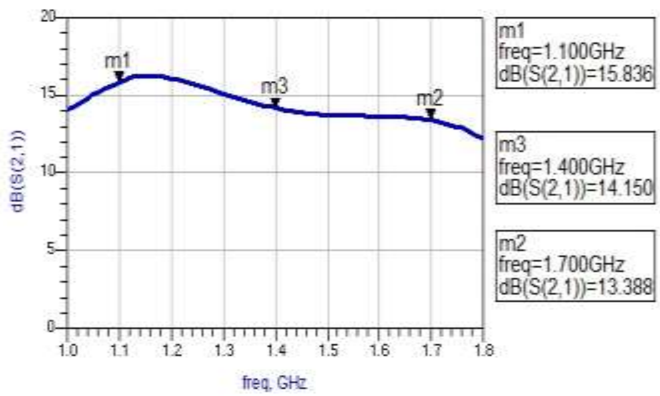

Fig. 6. Simulated gain of LNA.

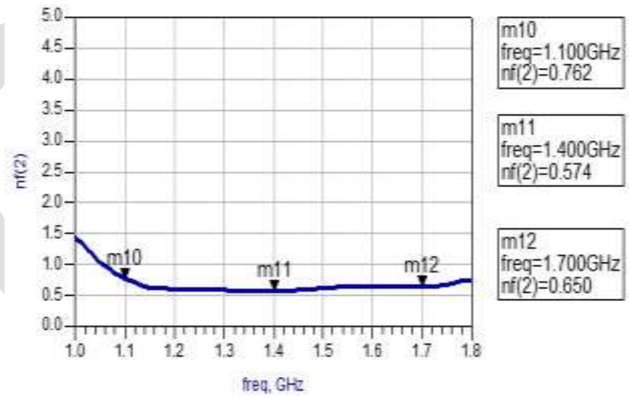

Fig. 7. Simulated noise figure of LNA.

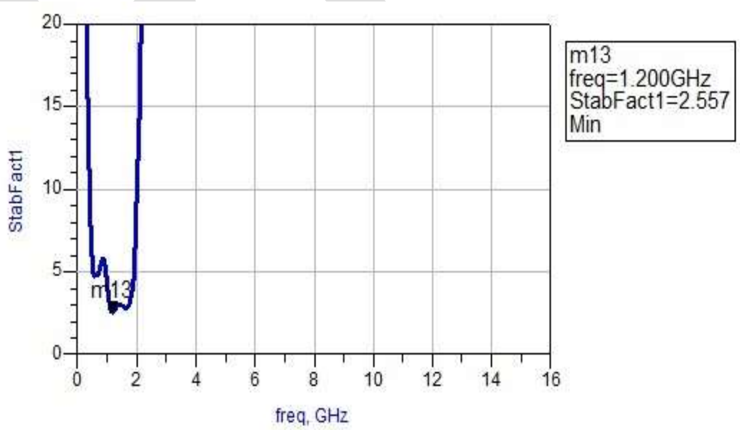

Fig. 8. Simulated stability factor of LNA.

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CONCLUSION

We designed the low noise amplifier with the balanced amplifier technique in Agilent's ADS tool to get high gain, low noise figure and unconditional stability. From above simulation results it is clear that LNA is unconditional stable, noise figure is below 0.76dB, gain is above 13.3 dB and input matching (s11), output matching (s22) parameters are below -14db.

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