Dean&Francis
ISSN 2959-6157

Advantages and Disadvantages of LNA and PA in Wireless Communication

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Abstract:

Wireless communication technology has a wide range of applications in all walks of life Wireless communication makes the acquisition, transmission and sharing of information more convenient and rapid, and helps to promote the popularization and progress of education, medical care, public services and other fields. For example, telemedicine can provide timely diagnosis and treatment to people in remote areas through wireless communication technology. Moreover, with the development and popularization of wireless communication technology, more and more third world countries have begun to build more wireless communication base stations to improve people's living quality. This paper will first introduce the application and design of low noise amplifier. Then the applications of high-power amplifiers are discussed, with emphasis on the design and optimization of multistage Doherty amplifiers. The two amplifiers will be compared and analyzed to summarize their application advantages and limitations in wireless communication and analyze their applicability and potential improvement directions in different communication environments. Finally, the research content of this paper will be summarized, and the direction of future research will be proposed.

Keywords: Wireless communication; Low noise amplifier (LNA); High power amplifier (PA); Multi-stage Doherty amplifier (DPA).

1. Introduction

As wireless communication technology advances quickly, the demands for better performance and reliability in communication systems continue to rise. Low noise amplifier (LNA) and high-power amplifier (PA), as the key components in wireless communication system, play an important role in signal receiving and transmitting respectively. LNA is used to provide the necessary gain during the signal reception phase while minimizing noise interference, ensuring signal clarity and communication stability. PA is committed to providing sufficient output power and good linearity at the signal transmission stage to ensure communication coverage and transmission efficiency. Not only the research on the application of

ISSN 2959-6157

LNA and PA in wireless communication brings improvement to the overall performance of the communication system, but also helps to promote the development of communication technology to a more efficient and higher frequencbay nd.

For different wireless communication application scenarios, the design and optimization strategies of LNA and PA are very different. The design of low noise amplifiers needs to balance stability, noise figure and gain, and adapt to various frequency bands and communication standards. [1] High power amplifiers, especially multistage Doherty amplifiers, provide efficient power amplification in the wide band range to meet different communication needs. [2] Studying the performance and design methods of these amplifiers will help to better understand their role in modern wireless communication systems and improve future communication devices.

2. Intro to Amplifier

2.1 Application of Amplifier

2.1.1 Low Noise Amplifier

Low noise amplifiers (LNA) are widely used in modern wireless communication systems. The main role of LNA is providing the necessary gain during the signal reception phase while minimizing the interference generated by noise. The role of LNA makes it possible to integrate it into the following types of products. The structure of the LNA is shown in Figure 1.

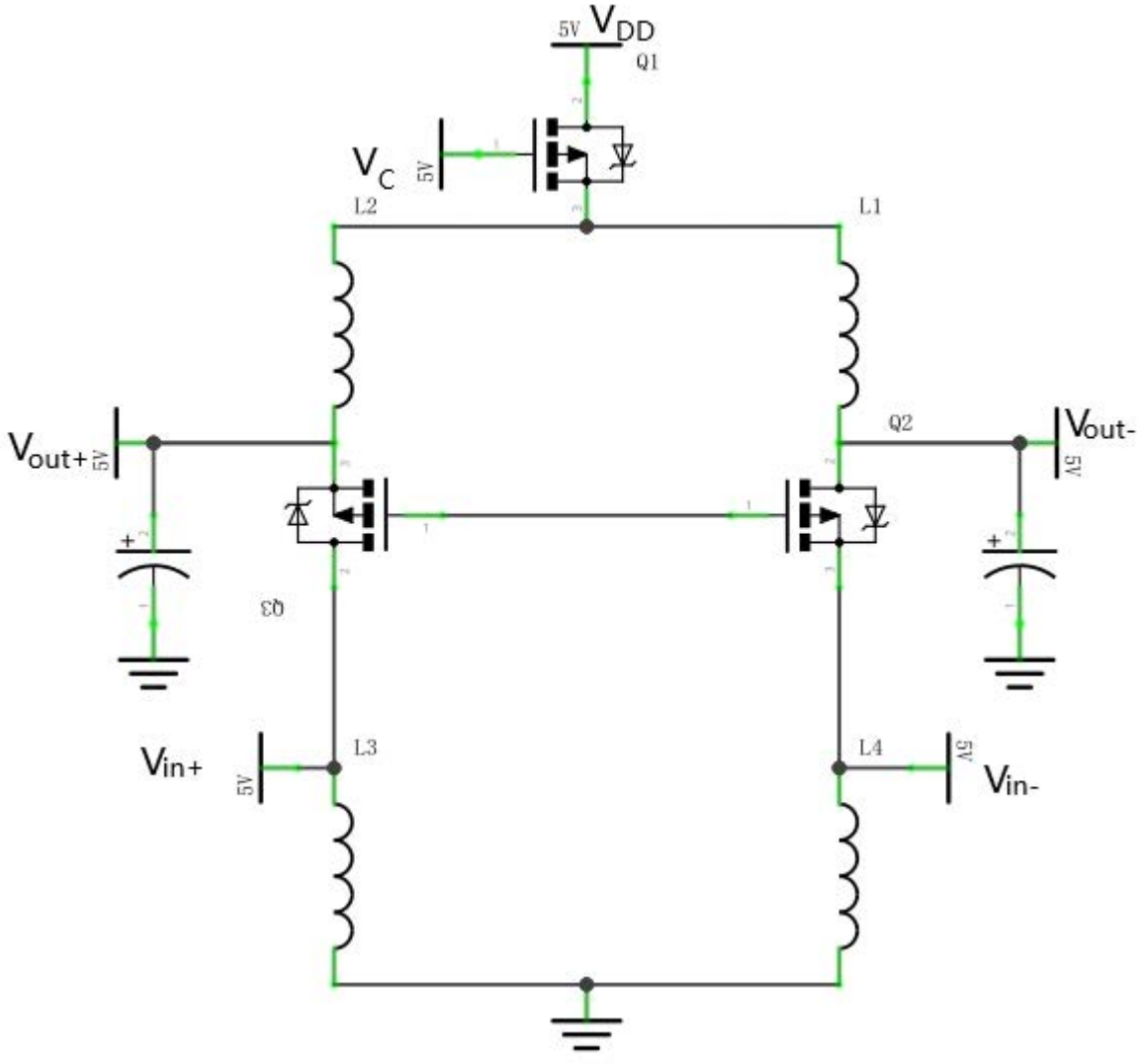

Fig.1 Low Noise Amplifier structure diagram

In the field of mobile phones and smartphones, LNA is often used to amplify the received signal as part of the

signal reception. In wireless LAN applications, such as Wi-Fi routers, LNA is often used to enhance signal reception quality. In automotive safety systems, LNA is used in the vehicle's on-board radar to detect obstacles and the vehicle's surroundings. In addition, by comparing the operation of LNA at 2GHz and 10 GHZ frequencies, it is shown that LNA can be used in most modern communication devices or systems in these frequency ranges [3].

With the development of wireless communication technology, LNA design needs to adapt to different frequency bands to meet the requirements of different communication standards.

For example, in the third generation of mobile phone equipment, people will use low noise amplifiers at the frequency of 1.9-2.2GHz. In the latest wireless Lans, people usually choose low noise amplifiers in the 2.4-5GHz frequency [3]. At the same time, LNAs are often used in vehicle radar systems in automobiles, where low noise amplifiers usually operate at 77GHz [3].

In addition, LNA usually adopts integrated design, which helps to realize the miniaturization of devices and meet the needs of portable and mobile devices [4]. For example, in the actual use scenario, the LNA is typically positioned at the front of the receiving chain, near the antenna, and its role is to amplify the weak incoming signal, while reducing the noise as much as possible to ensure the clear signal. As part of the RF front-end module, the LNA works with other components such as filters and mixers to ensure efficient signal processing and transmission.

2.1.2 High-Power Amplifier

In addition, there is another type of amplifier that is being widely used. Unlike low-noise amplifiers, which focus on reducing noise, these amplifiers focus on reducing power consumption. In wireless communication systems, low-power amplifiers can provide sufficient output power and good linearity while maintaining high efficiency to meet the needs of modern communication equipment. The basic structure of high-power amplifier is shown in Figure 2:

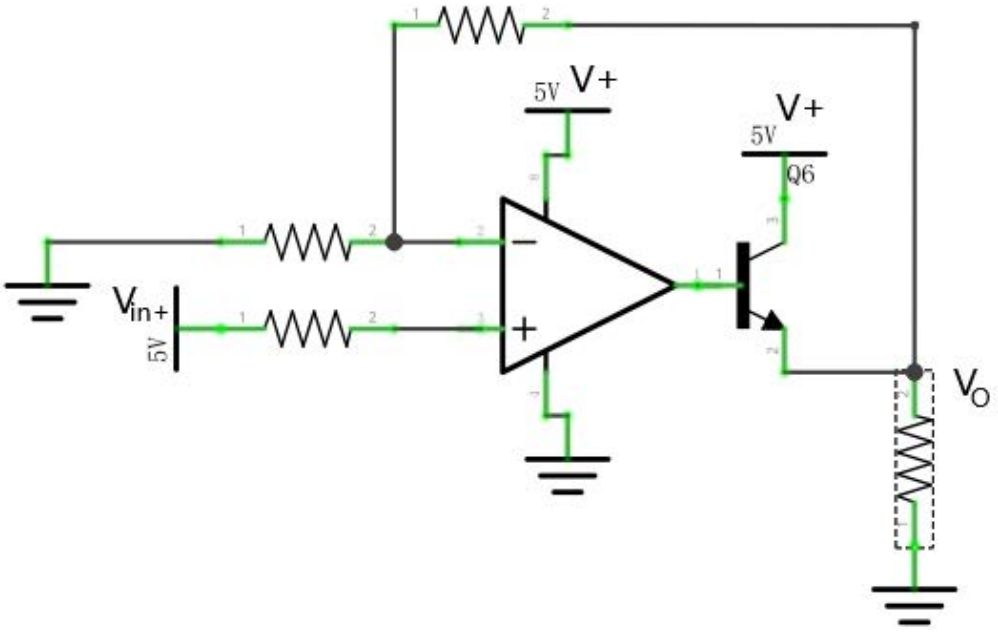

Fig.2 Basic structure of high-power amplifier

High power amplifiers, especially multistage Doherty amplifiers, are designed for wireless communication systems. It is mentioned that it meets the requirements of wideband Code division multiple Access (WCDMA) [5]. WCDMA is a wireless communication standard that is widely used in a variety of products and systems. For example, in mobile phone applications, smartphones and most portable devices require low power amplifiers. In the field of communications, wireless communication base stations also need to use power amplifiers to expand the range of signal coverage. Similar to low noise amplifiers, low power amplifiers are also used in wireless local area networks to enhance wireless signals. In addition, satellite communication technology also requires the use of efficient low-power amplifiers to ensure that the signal remains stable over long distances.

The efficiency of power amplifier directly affects the overall energy consumption of communication system. Traditional power amplifiers are less efficient at less than full power output, especially in wireless communication systems. To solve this problem, the concept of multistage Doherty amplifiers has been proposed, which is to im-

ISSN 2959-6157

prove efficiency through the number of stages of the amplifier [5].

First, a three-stage Doherty amplifier was designed, and the corresponding design equation was derived [5]. These equations are not only applicable to three-stage amplifiers but can also be extended to more stages of Doherty amplifiers. The performance of the designed three-stage Doherty amplifier is analyzed in detail. At 6-dB and 12-dB output power regression, the PAE of the amplifier reaches 42% and 27%, respectively, which is a significant improvement over single-stage linear power amplifiers. In addition, the amplifier can deliver up to 33 dBm of output power and maintains excellent adjacent channel power leakage ratio (ACLR) at 5 MHz and 10 MHz offsets [5].

The performance of multistage Doherty amplifiers in practical application scenarios has been discussed. It has been pointed out that to achieve ideal Doherty amplifier operation and minimize distortion, an accurate calculation of the amplifier's device size is required [5]. In addition, dynamic bias adjustment is required to optimize amplifier performance at different power levels. To validate the theoretical analysis, the authors designed and tested a three-stage WCDMA DPA prototype. The test results show that the amplifier meets the linearity requirement of WCDMA at the frequency of 1.95 GHz. By adjusting the peripheral size and bias of the device, the performance of the prototype amplifier at the maximum output power is very close to the analysis results under ideal conditions.

3. Amplifier Comparison

3.1 Pros and Cons of Low Noise Amplifier

Low noise amplifier and high-power amplifier are widely used in the field of wireless communication, and they have their own advantages and disadvantages.

The advantages of low noise amplifiers are high gain, low noise, stability, adaptability and technical diversity. [6] High gain and low noise figure of LNA is crucial for improving the performance of the communication device. The stability of LNA is shown in that the design of LNA avoids self-excited oscillation and ensures the reliability of the communication system. Adaptability also means that the LNA can be customized for different applications and frequency bands. [7] In addition, LNA is designed by a variety of technologies and manufacturing processes, such as SiGe, GaAs, CMOS, etc., providing a variety of options. [8]

However, low noise amplifiers also have drawbacks. The first is that the design of the LNA is complex. The design of LNA needs to consider many factors, like noise figure, matching, stability, which increases the complexity of the design. [9] The second is the high cost of LNA. High-performance LNA may require the use of expensive materials and manufacturing processes, resulting in increased costs. The third is that LNA are very sensitive to temperature. LNA performance can be affected by temperature changes, requiring additional heat management measures.

LNA plays an irreplaceable role in wireless communication system, and its design and application should consider many factors such as gain, noise factor, stability and integration degree. Despite challenges such as design complexity and cost, the performance of LNA continues to improve through technological innovation and optimization, providing strong support for the improvement of wireless communication technology. As the arrival of 5G and future communication technologies, the design and application of LNA will be further developed to meet higher performance requirements and a wider range of application scenarios.

3.2 Pros and Cons of High-Power Amplifier

The advantages of high-power amplifier applications are high efficiency, wide frequency band, high output power and good universality of design. Multistage Doherty amplifiers achieve higher efficiency at low output power levels than traditional Doherty amplifiers. The multistage Doherty amplifier design presented in this paper meets the uplink standard specification of wideband Code Division Multiple Access (WCDMA), which shows that it has good broadband performance. High-power amplifiers have high output power. It is able to deliver up to 33 dBm of output power. At the same time, the AM-AM distortion can be reduced, and the amplifier performance can be improved by optimizing the peripheral size and bias adjustment of the high-power amplifier equipment. In addition, the design equation derived in this paper can be extended to multistage Doherty amplifiers, which is helpful to achieve a wider output power regression level.

However, high-power amplifiers also have certain limitations. The design of multistage Doherty amplifier needs to consider the cooperative work and matching of multiple amplifiers, which increases the complexity of the design. [5] In addition, the design of multistage Doherty amplifiers requires precise analysis and selection of appropriate device peripheral dimensions to ensure that the amplifier will work properly at different power levels. [10] Moreover, in order to optimize performance, the amplifier bias may need to be dynamically adjusted, which may increase the complexity of the design and the difficulty of implementation. Using multiple amplifiers at the same time and complex matching networks can increase the cost of amplifiers.

4. Summary

Two different amplifiers are compared in this paper. By establishing a common application scenario, that is, the application in wireless communication. Low noise amplifier can improve the stability and reliability of communication system. But low noise amplifiers are complex to design and are sensitive to temperature. The output efficiency of high-power amplifiers is higher, the energy efficiency is better, and the design is also better. However, high power amplifiers also have the disadvantages of complex design and high cost.

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