Comparison Of Three CMOS Amplifiers Used in Communication

Wenzhuo Zhao *

Department of Electronic Information Engineering, Tiangong University, Tianjin, China

* Corresponding Author Email: 2110910424@tiangong.edu.cn

Abstract. With the rapid development of wireless communication technology, the low power consumption, low cost, and high efficiency of wireless communication equipment have become the development trend. Because of the increasing problems caused by power consumption, to meet the needs of people and the market, people should first understand the principle of low-power amplifiers and scientific research results to get inspiration. This paper summarizes the advantages and disadvantages of three kinds of amplifiers and draws some conclusions to better understand the low-power amplifier. Ultra-low power low noise amplifier circuit with high gain and low voltage operating at 5.2GHz. The folded cascade structure and forward substrate bias technology are used to reduce the operating voltage of LNA, and the input impedance matching of the first amplifier is achieved by the source inductance negative feedback technology. The second stage amplifier introduces the transformer negative feedback Transconductance enhancement technique. The second amplifier is 5.8GHz CMOS power amplifier**.** A computer-aided method for calculating device values in an RC feedback network is used to improve the stability of a power amplifier. The single-ended power amplifier is designed by using Shanghai 0.18μm CMOS technology. The lase one is ultra-low noise, high linear ultra-wideband low noise amplifier circuit operating at 3.1-10.6GHz. It mainly consists of two stages: the first stage is the input matching stage, which adopts the common gate structure to realize the broadband input matching; The second stage is an amplifier stage, which is composed of an improved common source common gate structure.

Keywords: Transconductance enhancement technique; RC feedback network; common gate structure.

1. Introduction

Wireless communication from the emergence (in 1896, the Italian Guglielmo Marchese Marconi invented the wireless telegraph) to the vigorous development of the experience of only a few hundred years, but the breakthrough and innovation at each stage have promoted the progress and development of society. From the original 1G (the first generation of mobile communication technology) to today's 5G, each generation of mobile communication technology has brought breakthroughs and changes [1, 2]. With the needs of people, the portability, low cost, low power consumption, and high performance of wireless communication equipment have become the mainstream today. Ultra-wideband (UWB) communication is a short - and medium-range wireless interconnection technology developed in recent years. Due to its high data transmission rate, less power consumption, and strong anti-multipath interference ability, it has become a hot spot in the research and development of today's wireless communication field and is regarded as one of the key technologies of next-generation wireless communication [3].

Wireless Local Area Networks (WLANs) are also growing rapidly. In this big situation, Wi-Fi (wireless fidelity) technology came into being. Wi-Fi technology has the advantages of wide coverage, fast transmission speed, and a low threshold for manufacturers to enter the field and has been rapidly developed. The RF transceiver system is an indispensable part of the application of Wi-Fi technology. With the continuous development of deep submicron CMOS technology, the channel length is also decreasing, and the cutoff frequency ft is increasing. For example, the cutoff frequency of MOSFET in IBM's 90nm RF-CMOS process has reached more than 100GHz. At the same time, the CMOS process also has the advantages of low price, low power consumption, and high integration compared with other processes, so it has been possible to use the CMOS process to achieve the GHz RF circuit, and it also has the characteristics of scaling down [4].

2. Principles of Three Amplifiers

2.1. Ultra-low Power CMOS Low Noise Amplifier

Current multiplexing technology is a common low-power design method, which makes MOS tubes stack together to share the current and reduce the power consumption of the circuit by reducing the current. Current multiplexing technology can effectively reduce the DC of the circuit, but it is based on the stack of MOS tubes, and the effect of reducing the power supply voltage is not great. In 2009, Zhang et al. designed a high-linearity low-power ultra-wideband low-noise amplifier operating in the 2.5-10GHz band. The circuit uses a current multiplexing common-gate structure to reduce power consumption and puts active nonlinear resistance in the drain of the first-stage common-gate tube to eliminate the influence of MOS tube nonlinearity, thus improving the linearity of the amplifier [4].

In low-power RF integrated circuit design, reducing the number of MOS tube stacks is the most effective way to reduce the power supply voltage. The use of single-layer MOS transistors to achieve circuit amplification can make the circuit operating voltage very low, which means that the same drain current may consume less power. The single-layer MOS tube technology can effectively reduce the power supply voltage of the circuit, but the amplifier needs the cascade of multiple amplifier tubes to increase the gain, and the mutual limitation between the gain and power consumption needs to be considered as a compromise.

The current mode design method takes the current as the signal variable. Because there is no need to design high-impedance nodes inside the circuit for current-voltage conversion, the power supply voltage and power consumption required by the circuit are low, so the current mode design method can be used in the general low-voltage and low-power RF integrated circuit design. Although the current mode design method is not widely used at present, it has a broad application prospect because of some performance advantages.

The low-power design of RF integrated circuits mainly includes current multiplexing technology, single-layer MOS tube technology, and current mode technology. The ultra-low power design mainly includes forward substrate bias technology and subthreshold technology, which are essential to reducing the operating voltage or DC of the circuit.

2.2. 5.8GHz CMOS Power Amplifier

In 2009, Zhang et al. designed a high-linearity low-power ultra-wideband low-noise amplifier operating in the 2.5-10GHz band. The circuit uses a current multiplexing common-gate structure to reduce power consumption and puts active nonlinear resistance in the drain of the first-stage common-gate tube to eliminate the influence of MOS tube nonlinearity, thus improving the linearity of the amplifier [5].

5.8GHz CMOS power amplifier circuit structure: The circuit structure of CMOS RF power amplifier mainly includes a common source circuit, Cascode (common source common gate) circuit, and differential circuit structure. The advantage of the cascade circuit structure is that it has a relatively large output resistance, which is greater than the common source level circuit and can improve the isolation between input and output. The advantages of the differential circuit structure are to reduce the influence of noise on the circuit, improve the output voltage swing, reduce the sensitivity of the amplifier to the package parasitic effect, and reduce the influence of the power amplifier on other circuits in the system.

The design of CMOS RF power amplifier performance improvement mainly focuses on the following aspects: In the design of CMOS RF power amplifiers to improve linearity, according to the current literature, the technologies to achieve integrated linearization mainly include diode linear technology, capacitance compensation technology, multi-transistor parallel technology, and charge pump linearization technology. Based on the literature analysis, researchers are keen on the power amplifier design technology with DAT structure to improve the power of the power amplifier. Ichiro Aoki proposed the power synthesis method of this structure in 2002 and designed a 1W DAT structure power amplifier operating at 2.4GHz using CMOS technology.

2.3. Rf Front-end Circuit of UWB Wireless Communication System

The first structure is filter input matching structure UWB LNA. The input-matching structure of the band-pass filter is developed from the classical source-level inductive negative feedback structure which matches both impedance and noise in narrowband design. The source inductance negative feedback structure is classical in the narrowband field. Based on this traditional structure, the input terminal is added to the network to meet the design requirements of UWB low noise amplifier ultra-wideband filter structure can achieve better matching, gain, and noise performance in a wide band. However, due to the excessive use of passive devices such as inductors and capacitors in the input end, the noise performance will be degraded in the high-frequency band, and the circuit complexity and chip area will be increased.

The second structure is resistance negative feedback structure UWB LNA. The resistance negative feedback is a classical design method of wideband, which can match the input impedance obtain flat gain in a wide band and improve the circuit stability. In UWB design, obtaining comprehensive performance by using resistor negative feedback technology alone is difficult. The input impedance matching is usually achieved by combining the filter structure, and the circuit gain is generally low due to the existence of an input feedback path.

The third structure is common gate structure UWB LNA. The common-gate structure uses the input impedance of the common-gate amplifier to realize the wideband input impedance matching. The input impedance of a common-gate amplifier is about the reciprocal of the transconductance of the input transistor. By adjusting the channel width of the tube and the bias voltage, the input impedance can be well-matched in the UWB frequency band. Because the input impedance of the common gate structure is constant, it has unparalleled broadband matching performance of other structures, there is no feedback capacitance, and it has good isolation and stability. In addition, the common gate structure also has the characteristics of high linearity and low power consumption, but the noise coefficient of the structure is high, so how to reduce the noise coefficient remains to be studied.

Reference proposes a folding 3.5-10ghz UWB mixer with low power consumption and low flicker noise using a 0.18[m] process. The folding structure is adopted to obtain broadband frequency response and low DC power consumption, and the bias current of transconductance and local oscillator stages is different, and the bias current of PMOS tube is switched near zero point, which greatly reduces the DC offset caused by device mismatch [6].

3. Comparison of Three Amplifiers

3.1. Advantages and Disadvantages of the First Amplifier

An ultra-low power and low noise amplifier circuit with high gain and low voltage operating at 5.2GHz is proposed. The circuit adopts a single-layer folded cascade structure and forward substrate bias technology to reduce the operating voltage of the amplifier, and the first stage common source amplifier uses the source inductance negative feedback technology to complete the low noise input impedance matching. The second stage common-gate PMOS amplifier adopts the transconductance enhancement technology of transformer negative feedback to improve the gain. The LNA has high gain, low power consumption, and good overall performance, which is very suitable for application in ultra-low power receivers.

An ultra-low power ultra-wideband mixer circuit with high linearity and low voltage operating in the frequency range of 1.5-11.5GHz is proposed. The circuit is an improvement of the traditional Gilbert mixer, which uses the negative feedback common source structure in the low noise amplifier to improve the linear performance of the mixer. The mixer has good linear performance, low operating voltage and power consumption, and good comprehensive performance, which is very suitable for application in ultra-low power ultra-wideband receivers [7].

Some properties of the proposed ultra-low power low noise amplifier circuit are optimized, and its structure is improved. For example, it is a narrow-band amplifier, and the applied frequency band is relatively limited. The circuit structure can be improved to broaden its bandwidth. The novel transformer negative feedback structure is adopted. Many factors need to be considered in transformer chip modeling, which is a problem worthy of further study, so further work needs to be done on transformer layout design and flow plate.

Some properties of the proposed ultra-low power mixer circuit are optimized. For example, the proposed mixer conversion gain is general, the circuit noise factor is large, and the required local oscillator signal power is higher. The proposed ultra-low power and low noise amplifier and mixer circuit are fluidized, and then the circuit is packaged and tested.

3.2. The Advantages and Disadvantages of the Second Amplifier

Through a large number of literature research and reading, it understands the application of CMOS process-based power amplifiers and domestic and foreign research status. Some challenges and improvement methods of CMOS technology for power amplifier design are understood, and methodological guidance is provided for the following power amplifier circuit design and research.

Several linearization techniques of power amplifiers and stability research of power amplifiers are discussed from the perspective of integrated circuit chip design, and a computer-aided algorithm to improve the value of circuit stability feedback network device is proposed. Based on the research of other electronic engineers, a new linearization method for power amplifiers is proposed.

The difficulty and challenge of designing a power amplifier in CMOS technology are described. To solve these challenges in CMOS technology, a 5.8GHz single-ended power amplifier is designed in this paper. The power stage of the amplifier adopts a thick gate device, and the driver stage adopts a self-biased common source and common gate structure. This not only increases the gain and reverse isolation but also effectively alleviates the problems caused by gate oxygen breakdown and hot current carrying effect.

Guide circuit design from the perspective of power amplifier productization. As far as possible, the effects of package parasitism, PAD parasitism capacitance, and bonding line parasitism inductance into the circuit are taken into account in the circuit-level design of the power amplifier to ensure the product rate of the chip design. To further study the linearity, power, efficiency, frequency bandwidth, and reliability of the power amplifier to improve the performance of the power amplifier. The influence of temperature change, process deviation, and power supply voltage deviation on the circuit is statistically analyzed to ensure the practicability of the designed power amplifier chip [8].

3.3. The Advantages and Disadvantages of the Third Amplifier

A novel ultra-low noise high linear ultra-wideband low noise amplifier, ultra-low power high linear mixer circuit, and ultra-wideband frequency synthesizer are presented. An ultra-low noise and high linear ultra-wideband low noise amplifier circuit are presented respectively. The utility model relates to an ultra-low power consumption high linear mixer circuit for application; An ultra-wideband low noise amplifier circuit with high gain and low power consumption is provided; The invention relates to an all-new all-band ultra-wideband frequency synthesizer circuit.

The RF tube model is very complex, so it is necessary to study the RF tube simulation model carefully in the future to calculate the noise and parasitic parameters more accurately. The first LNA amplifier proposed has high linearity and low noise coefficient, but the power consumption is relatively high and needs further optimization. The mixer is used to insert the common source node into the network, which not only improves the gain and linearity but also introduces too much noise, which can be further optimized to reduce the noise coefficient.

Reduce the voltage and power consumption of UWB frequency synthesizer and reduce the need for subcircuit modules to reduce the power consumption of the circuit; Considering the interface with analog, the cascade test with baseband signal processing chip is realized, and real-time video data transmission is attempted. This is important for further integration in the future [9]. Table 1 compares these three amplifiers.

Table 1. Comparison of these three amplifiers

	Advantage	Disadvantage
5.2GHz amplifier circuit	High gain, low power consumption, and good overall performance	The frequency band is limited. The circuit noise factor is large. The required local oscillator signal power is high.
5.8GHz CMOS power amplifier	It increases the gain and reverse isolation and effectively alleviates the problems caused by gate oxygen breakdown and hot current-carrying effects.	The linearity, power, efficiency, frequency bandwidth and reliability of the power amplifier can be further improved
Rf front-end circuit	High gain and low power consumption.	RF tube model is very complex. It introduces too much noise.

4. Conclusion

In this paper, the advantages and disadvantages of the three amplifiers are compared, and the importance of ultra-low power design of RF integrated circuits is expounded. With the continuous development of technology, single-chip integration of process-based wireless communication systems is possible. New ultra-low noise high linear ultra-wideband low noise amplifier, ultra-low power high linear mixer circuit, and ultra-wideband frequency synthesizer for RF transceiver front end. The application and research status of CMOS-based power amplifiers at home and abroad are discussed. Some challenges and improvement methods of CMOS technology for power amplifier design are understood.

The first amplifier is 5.2GHz amplifier circuit. The LNA has high gain, low power consumption, and good overall performance, which is very suitable for application in ultra-low power receivers. The frequency band of the narrow-band amplifier is relatively limited, the proposed mixer conversion gain is general, the circuit noise factor is large, and the required local oscillator signal power is high

The second amplifier is 5.8GHz CMOS power amplifier. A new computer-aided algorithm is proposed to improve the circuit stability by negative feedback and a novel linearization method for power amplifiersThere is no analysis circuit affected by temperature change, process deviation, power supply voltage deviation. There is no test evaluation of the power amplifier circuit coming back from the convection plate

The third amplifier operates on ultra-low noise high linear ultra-wideband low noise amplifier circuits. The LNA circuit mainly consists of two stages: the input stage adopts the common gate structure to realize the broadband input matching; The amplifier stage is composed of an improved common source common gate structure. It can further reduce the voltage and power consumption of the UWB frequency synthesizer and reduce the need for sub-circuit modules to reduce the power consumption of the circuit.

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