Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 3, No. 2, 2022

Ultra-wideband Reconfigurable Low-noise Amplifier Based on 5G Communication

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Abstract: For 5G communication, both sub-6G and millimeter wave bands have their own advantages, while low-noise amplifier (LNA) is an essential component of the first stage of 5G receiving system, and its performance plays a crucial role in the overall performance of the receiving system. Therefore, LNAs applicable to ultra-wideband reconfigurable can make full use of both high and low frequency bands, which is one of the research focuses of 5G communication development at this stage. In this paper introduces ultra-wideband low-noise amplifiers and their methods of achieving reconfigurability, explaining the development advantages and limitations of each method separately.

Keywords: 5G communication, Ultra-wideband, Low-noise amplifier, Reconfigurable.

1. Introduction

The application of the millimeter wave band has greatly enriched the available bandwidth resources for 5G communication, but due to the short wavelength of the high frequency band, there are serious path propagation loss and blocking loss problems in communication, and the cost of achieving continuous coverage is high, which makes millimeter wave communication has not been able to completely replace low frequency communication, and communication within the sub-6G bandwidth is easy to achieve effective coverage, and it is still the core frequency in 5G communication[1]. Both low-frequency and high-frequency communications have their own advantages and disadvantages, so it makes sense to design transceiver systems that can be used in both high and low frequency bands [2]. According to the hexagonal rule of radio frequency chip design, the design of the transceiver chip requires a compromise between the following six aspects: noise figure (NF) power consumption, operation frequency, gain, supply voltage, and linearity. When the chip is required to be able to work in both the low-frequency and millimeter-wave bands, it means that its bandwidth is particularly large, and accordingly, other performance will have to be sacrificed. If a single narrowband LNA is used as the basis for channel multiplexing multiple LNAs, it is possible to make the chip have good performance in each narrowband, but the system designed using this approach is often more complex and larger in area.

The LNAs, as the first stage of the wideband receiver system, play an important role in the overall performance of the receiver system, especially in determining the anti-noise performance of the whole system. Therefore, we propose to design LNAs that can operate in both sub-6G and millimeter-wave bands, and the chip itself can perform multiple band switching, which can be applied to the first stage of transceivers for 5G communications.

2. Traditional Implementation Methods

Traditional reconfigurable amplifiers can be mode reconfigurable, gain reconfigurable, or frequency reconfigurable amplifiers, where frequency reconfigurable LNAs can be converted at multiple center frequencies so that the performance of each band is close to narrowband and can be extended to the entire broadband, constituting LNAs superior to traditional broadband LNAs. Frequency reconfigurable techniques include pathway parallel reconfigurable, load network reconfigurable, and matching network reconfigurable. When designing ultra-wideband frequency reconfigurable LNAs, it is necessary to combine multiple techniques simultaneously to continuously improve the overall performance of the circuit.

A. Pathway parallel reconfigurable

The pathway parallel technique [3-4] refers to the formation of multiple narrowband LNAs into arrays, each of which is individually designed according to the application criteria and frequency bands with independent DC bias and signal paths, i.e., separate amplification of signals at different frequencies, which is the most traditional scheme for realizing band reconfigurable LNAs. Obviously, the pathway parallel reconfigurable technique is easy to design and has high flexibility to design the optimal size, bias point and input/output impedance matching of each LNA

independently according to different frequency bandwidth requirements, and it is easy to obtain better NF and linearity, however, direct parallel connection of individual pathways has two obvious drawbacks that limit the application of this technique in practice:

(1) Large area. Since each path of the LNA is designed to correspond to an operating band, a large number of sub-paths occupy an exponentially larger chip area to achieve ultra-wideband reconfigurable LNAs. Such as source degradation inductor Cascode as the main body of the LNAs, for a narrow-band design will need to refer to at least three on-chip inductors; if the multi-stage amplification structure, it will introduce a larger chip area, and the layout should be carefully designed to reduce inter-stage coupling and parasitic effects; more serious and even deteriorate the LNAs gain and NF performance.

(2) High power consumption. Directly parallel band reconfigurable LNAs need to provide the appropriate bias voltage or current for each path, which consumes a lot of power.

B. Load network reconfigurable

The load network reconfigurable technology is based on the main circuit fixed, and the load network part is reasonably set up so that it can amplify for signals of different frequencies[5-8]. Multiple independent load networks are combined into an array, and the switching array is invoked to control the operating state of each load path to amplify for the desired frequency band in a specific mode. The load reconfigurable technique requires only the load network part to be designed for different frequency bands, thus requiring fewer devices, small chip area and low power consumption. However, switching deteriorates the NF and gain performance of ultra-wideband reconfigurable LNAs, and the insertion loss and impedance mismatch caused by switching needs to be minimized and the isolation improved to effectively reduce the performance deterioration introduced by switching.

LNAs tend to be relatively easy to achieve matching in the broadband, general LNAs often have N-stage amplification circuit, only in the first stage to achieve ultra-broadband matching, and in the later circuit used to amplify the signal to add the load network reconfigurable technology, it is easier to achieve ultra-broadband matching, excellent anti-noise performance and high gain in different frequency bands at the same time.

C. Matching network reconfigurable

The matching network design of LNAs is important, only good input and output matching performance can achieve good anti-noise performance and gain[9]. In the design of LNAs, its matching network can use variable resistors, variable capacitors, transformers and other passive devices to change the equivalent impedance of input and output to achieve the function of LNAs applied to multiple independent frequency bands.

MOSFETs can also be used as a tuning device, the gate voltage of transistor can change the gate capacitance, thereby changing the matching effect, but the adjustable range of the gate capacitance of a single MOSFET is small, it is difficult to achieve ultra-broadband matching. Another way is to use the MOSFETs as a switching resistor, the impedance of the MOSFETs on is approximated as a small resistance, and when off is approximated as an equivalent small capacitance, using the control voltage to MOSFETs corresponding to different frequencies to switch different resistance or capacitance on and off, so that it can achieve ultra-broadband matching[10].

The matching network reconfigurable technique requires fewer passive devices, high circuit utilization, and low power consumption, but it can only amplify narrowband signals at the same time, which is not suitable for simultaneous operation in multiple frequency bands; in addition, similar to the load network reconfigurable technique, the on-state resistance of MOSFETs deteriorates the NF.

3. Conclusion

In summary, the pathway parallel reconfigurable LNAs, faces the problem of low circuit utilization and oversized, which limits its application in 5G communication transceiver systems, while the load network reconfigurable technique and the matching network reconfigurable technique, both of which share part of the pathway, can better solve this problem, but the load network reconfigurable technique introduces switches, and the matching network reconfigurable technique also has to focus on variable devices The matching network reconfigurable technique also focuses on the design of variable devices.

High frequency and low frequency have their own advantages and focus, and how to use both synergistically will be a hot spot for 5G communication research. In addition to the coverage of sub-6G band, the millimeter wave band resources can be fully utilized to accelerate the better and faster development of the communication field.

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