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Design method for CMOS wide-band low noise amplifier for mobile TV application

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Abstract: A design method for wide-band CMOS low noise amplifier (LNA) is presented, which is suitable for mobile TV application. The proposed method integrates two kinds of wide-band LNA topologies by different switches, which can achieve better performance and avoid shortcomings when it operates at different modes. It can save the power consumption and improve the linearity at higher input signal power, and it also can reduce the noise at lower input signal power. The proposed wide-band LNA topology for mobile TV application is designed in TSMC 0.18-μm RF CMOS process.

Keywords: wide-band LNA, mobile application, linearity

Classification: Integrated circuits

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1 Introduction

The application of wireless communication is more and more popular and important, especially in mobile TV products. Therefore, the mobile receiver

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may be used in different places with different input power. Since people need to always carry the mobile receiver, it is required to have higher performance at low cost, low power consumption, high dynamic range, and smaller size. However, the application of mobile TV receiver system needs not only to meet the above demands, but also to meet the qualities of wider bandwidth, low noise, good gain flatness [1] and low input reflection coefficient. Because of these reasons, it is demanded to develop a new technology for the new mobile TV products.

At different input signal power, the mobile receiver has different requirements for different characteristics with several levels of importance. For example, the importance of mobile TV application is to deal with input signal. In this condition, we will try to reduce the power consumption and cost. In other words, we need more power consumption to improve the performance of gain and noise figure (NF) at low input signal power, but we will sacrifice the performance of the gain and noise figure to reduce the power consumption at high input signal power. It is because higher gain achieves too good signal-to-noise ratio at high input signal power compared with that at low input signal power, so the high input signal power does not need higher gain and better noise figure.

A well-designed LNA becomes very important because it is one of key circuit blocks in radio receiver system. Since the LNA can be directly added to the first stage in the receive path, it usually dominates the NF and bandwidth in the receiver, and a variable gain LNA can improve the dynamic range of the whole receiver. In addition, the traditional wide-band LNA technology is always designed based on inductors and capacitors for wide-band matching with larger size and higher cost [2, 3]. Based on the foregoing consideration, we design a LNA which can achieve the requirements of low noise figure, gain control mode, wider bandwidth, and less power consumption by switching different modes.

2 Proposed circuit

In this paper, we proposed a wide-band CMOS LNA, which integrates two kinds of topologies: resistor feedback [4] and input matching device noise cancelling [5] techniques. Fig. 1 shows the proposed wide-band LNA circuit. There are several switches to be added in proposed LNA, which allows the circuit to operate in resistor feedback technique or input matching device noise cancelling technique. The performance of wide-band matching and gain flatness can be reached by either of two topologies.

It is usually not a good design to add the switch components in LNA circuit. The turn on resistors and parasitic capacitances from the switch components may increase the noise and damage input reflection coefficient. In this paper, the proposed circuit which adds the switches at high impedance nodes, and the turn on resistance and parasitic capacitance can be ignored.

When the proposed LNA is operated in high gain mode, the switches S_1 is turned on, S_2, S_3 and S_4 are turned off, and matching device noise cancelling

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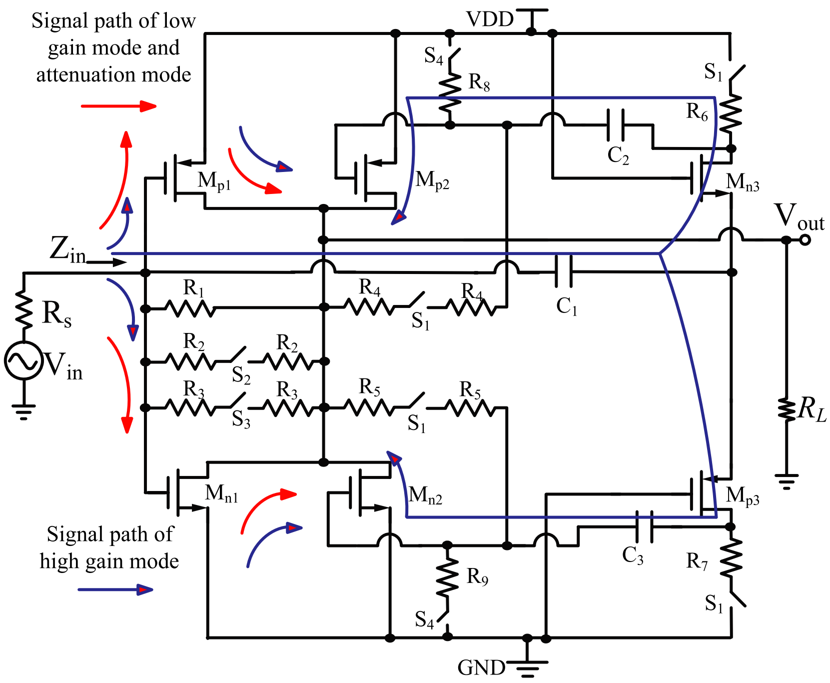

Fig. 1. The proposed wide-band LNA.

technique is used. It is to decouple the input matching with the noise figure by cancelling the output noise from the matching device. Although this matching device noise cancelling technique has a better gain and noise figure, it consumes more power consumption. Therefore, we allow it to operate at low input signal power. In this mode, the input matching is accomplished by setting (1/gm;Mn3)//(1/gm;Mp3) to 50 ohm.

When the proposed LNA is operated in low gain mode, the switches S_2 and S_4 are turned on, S_1 and S_3 are turned off, and resistor feedback amplifier technique is used. It has a good bandwidth and low power consumption, but it has the inherently low trans-conductance of MOS which not only degrades the gain performance but also prohibits the noise figure. However, the resistor feedback amplifier technology provides low gain and higher linearity. Therefore, we allow it to operate at medium input signal power. And the gain of the proposed LNA operating in resistor feedback technique is derived as

$$A = -[(g_{m,Mn1} + g_{m,Mp1}) - \frac{1}{R_f}](R_L//R_f) \tag{1}$$

Here $g_{m,Mn1}$ and $g_{m,Mp1}$ are the trans-conductances of devices M_{p1} and M_{n1}, R_f (when the circuit is operated in low gain mode, $R_f = 2R_2$; when the circuit is operated in attenuation mode, $R_f = 2R_2$ // $2R_3$) is the feedback resistance. According to equation (1), when we reduce the feedback resistance appropriate for the design, the gain of proposed LNA will be set to -6dB, so the circuit will provide a function of attenuation. When the circuit is operated in attenuation mode, we only turn on the switch S_3 compared with low gain mode. In these modes, the input matching is accomplished by resistor feedback technique, which is usually used in wide-band LNA circuit design.

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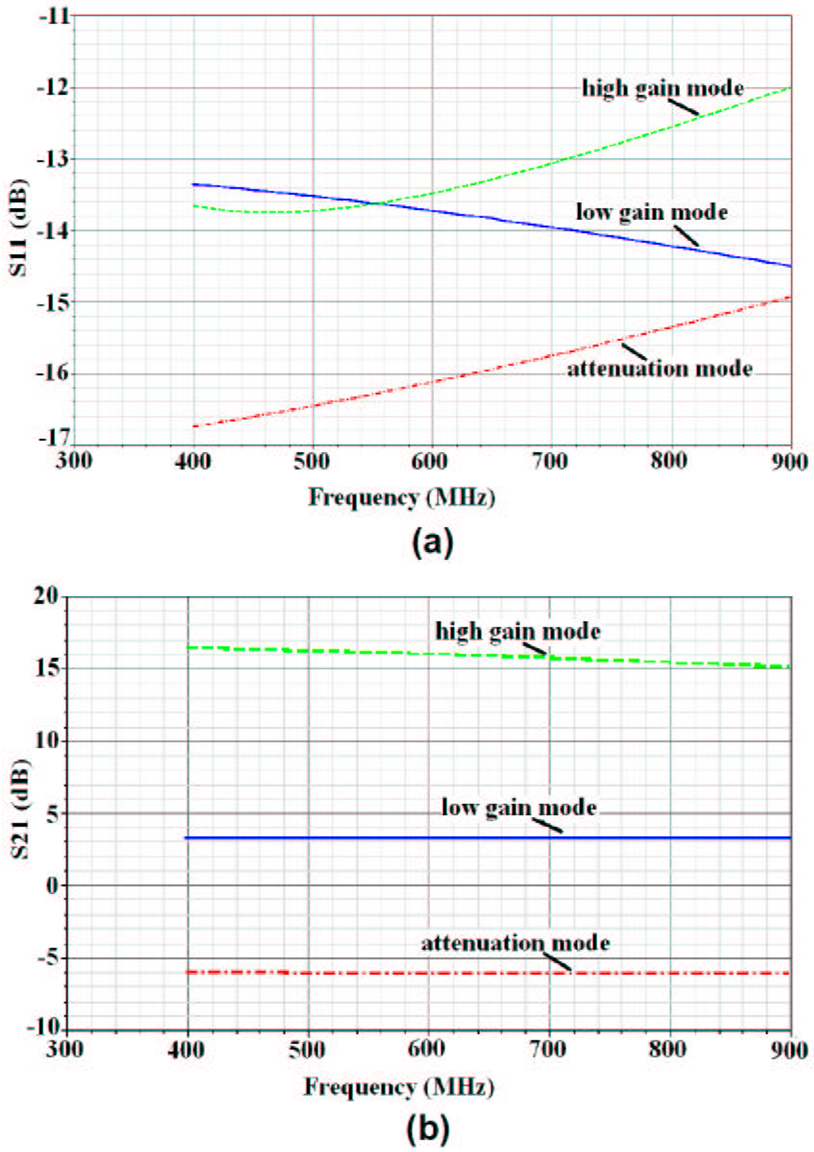

Fig. 2. (a) Simulated input reflection coefficient at different mode. (b) Simulated power gain at different mode.

3 Simulation results

This proposed method was used to design a 400 MHz∼900 MHz wide-band LNA suitable for mobile TV application. It is simulated by Cadence's EDA-Spectre RF using TSMC 0.18-μm RF CMOS process. Fig. 2 (a) shows the simulated input reflection coefficient (S11) that verifies the input impedance in Fig. 1, which is close to 50 ohm over the band between 400 MHz and 900 MHz. Fig. 2 (b) shows the simulated power gain (S21) of the wide-band LNA which has different gain control mode, and it has a good performance of the gain flatness. Table I lists the simulation performance of the proposed LNA. The results show that the design of the proposed LNA can save the power consumption and improve the linearity at higher input signal power, but it also can reduce the noise and improve the gain at lower input signal power.

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4 Conclusion

By using the design method of switching mode wide-band LNA technique, a low noise figure, wider dynamic range, wider bandwidth, and less power consumption LNA is achieved. This design method provides a good way to adapt the requirements of mobile TV application.

Table I. The specification of proposed LNA.

Specification	*High gain mode*	*Low gain mode*	*Attenuation mode*
Operation Frequency (MHz)	400∼900		
S11 (dB)	−12	−13.3	−14.9
Gain Variable (dB)	1.32	0.08	0.08
S21 (dB)	15	3.2	−6.1
NF (dB)	2.35	5.2	11.1
IIP3 (dBm)@500 MHz	−2.68	9.5	13
Power Dissipation (mW)	20.86	9.28	9.28

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