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A multi-band low noise amplifier with wide-band interference rejection improvement

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ABSTRACT

In this paper, a differential multi-band CMOS low noise amplifier (LNA), operated in a range of 800–1700 MHz, is proposed. In this design, the LNA is integrated wide-band interference rejection (input band selection technology) and capacitive cross-coupling topologies, which can improve the interference rejection and noise figure preference. Moreover, the conventional notch filter technology only rejected the specified frequency. In this experiment, by using the proposed wide-band interference rejection technology, the LNA can reject unwanted signals (out-of-band signals) and image signals from different frequency. Thus, the LNA has good linearity and interference rejection performance. With the increasing use of frequency spectrum, the proposed technology is even more important. The post-simulation results of proposed LNA show that the voltage gain is 13–17.5 dB, the noise figure (NF) is less than 3.4 dB, and the third-order intercept point (IIP3) is 7.36 dBm. The LNA consumes 8.96 mW under 1.8 V supply voltage in TSMC 0.18-μm RF CMOS process.

1. Introduction

In recent years, there has been a tendency towards of wireless communication with several functions integrated on a chip, so the receiver that can support different wireless standards is highly required [1–6]. However, the conventional narrow-band LNAs has poor performance to support different wireless standards [1,7,8]. Thus, the wide-band LNA and multi-band LNA are suitable to replace conventional narrow-band LNAs to provide different wireless standards on a chip.

A wide-band LNA can satisfy different standards at the same time [9], but it also has the poor performance on linearity, interference rejection, and image rejection [10]. Thus, several kinds of multi-band LNAs are proposed [11–13]. However, the multi-band LNA is usually implemented with wide-band input matching technique that must receive input signals from different frequency. Those powers of input signals are integrated and amplified by the LNA. Therefore, the LNA circuit is very easy to be saturated, because the power of unwanted signals is too large. Base on this reason, the wide-band input matching technique has poor performance for interference rejection and linearity. Especially in the state of the out-of-band channels constantly in use, the performance requirement of out-band interference rejection will be more obvious [14]. Some papers use notch filter to improve the interference rejection; however, the notch filter [15] only rejects single interference frequency, so it does not meet the requirement of wide-band interference rejection. For those reasons, this paper proposes a multi-band LNA to improve the wide-band interference rejection performance.

2. Proposed method

When more and more wireless communication systems are used, the power spectral density will be increased. In-band signal power of the LNA must be integrated. It can be derived as

$$\text{Input power} = \int_{f1}^{f2} S_x(f)df \tag{1}$$

And the total in-band signal power has been amplified by the LNA

$$\text{Output power} = A\int_{f1}^{f2} S_x(f)df \tag{2}$$

where $f1$–$f2$ is the operation band-width of LNA, and A is the power gain of LNA. For above reasons, the linearity performance of the LNA will be highly required when more and more wireless

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communication systems are used, because the out-of-band interferences may severely degrade receiver's sensitivity and linearity. On the contrary, the LNA with wide-band interference rejection can reject a lot of out-band interference signal power, which will cause the LNA circuit not easy to saturate.

In order to meet the trends to support different wireless standards, and to improve the interference rejection, noise figure and linearity performance, the proposed CMOS differential multi-band LNA integrates three techniques, a common gate, a tunable LC-tank load, and a capacitive cross-coupling. The proposed multi-band LNA has higher selectivity and sensitivity performance than the other traditional multi-band LNA, because the proposed LNA includes several narrow-band operations. Therefore, the proposed multi-band LNA has both the advantage of narrow-band matching technique and the advantages of multi-band matching technique.

2.1. The principle of input band selection technology

The out-of-band interference noise can severely degrade receiver's sensitivity [16]. The multi-band LNA architecture, which uses the conventional common gate matching technique to cover each operating frequency, is shown in Fig. 1. The proposed multi-band LNA architecture, which uses the common gate LNA technique and tunable parallel LC tank load technique to select input frequency, is shown in Fig. 2. Compared to the conventional common gate LNA architecture (shown in Fig. 1), the proposed multi-band LNA architecture (shown in Fig. 2) can reject out-of-band signals (unwanted signals) by the proposed input band selection technology. For example, the conventional LNA cannot select the input signals, because its input matching circuit of Fig. 1 is an inductor (large inductance), which provides high impedance in a wide frequency range. However, the proposed LNA can select the input signals, because its input matching circuit of Fig. 2 is a LC tank circuit. The LC tank circuit only provides high impedance at resonance frequency, and provides low impedance at non-resonance frequency. Therefore, some out-of-band interference signal powers of the proposed LNA are grounded, and the operating frequency of the proposed LNA can be selected.

The proposed LNA operating in common gate LNA technique at LC-tank resonance frequency provides a good performance of S11.

Fig. 3 shows the simplify circuit of the proposed differential multi-band LNA, and the proposed LNA can achieve multi-band function by tunable LC-tank resonance frequency. As shown in Fig. 3, the source terminal is used as an input terminal. The impedance can be written as the following equation:

$$Z_{\text{in}} = \frac{1}{gm_{M1}} // Z_{\text{eq}} \quad (3)$$

where gm_{M1} is the trans-conductance of device M_1. The resonant circuit (L_2 and C_b) provides high impedance (Z_{eq}) at the desired frequency (ω_r), and the impedance is given by

$$\left|Z_{\text{eq}}(s = j\omega)\right|^2 = R_r^2 = \frac{\left(\omega_r^2 L_2^2 + R_{2,\text{ind}}^2\right)}{R_{2,\text{ind}}^2 C_b^2 \omega_r^2 + \left(1 - L_2 C_2 \omega_r^2\right)^2} \quad (4)$$

Eq. (4) shows that the resonant circuit only provides high impedance at ω. The magnitude of Z_{eq} in Eq. (2) reaches peak value ($Z_{\text{eq}} = R_r$) in the vicinity of $\omega = \sqrt{L_2 C_b}$. Moreover, the magnitude of Z_{eq} has some dependency on R_{ind}, where $R_{2,\text{ind}}$ is the parasitic series resistance of the inductor L_2. The R_r can be approximated to

$$R_r = \sqrt{\frac{{R_{2,\text{ind}}}^2 + \omega^2 L_2^2}{{R_{2,\text{ind}}}^2 C_b^2 \omega^2}} \quad (5)$$

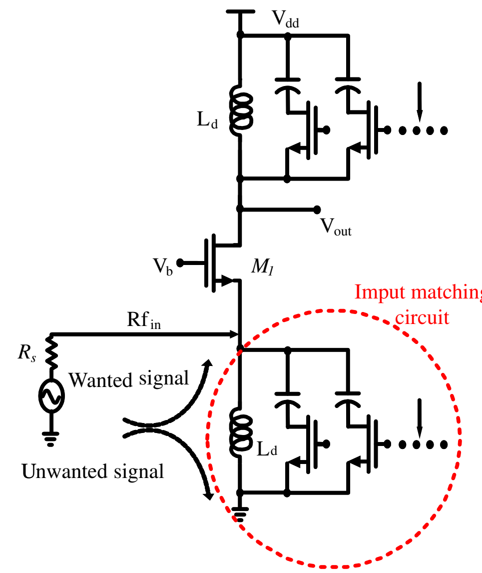

Fig. 2. The principle of proposed technique.

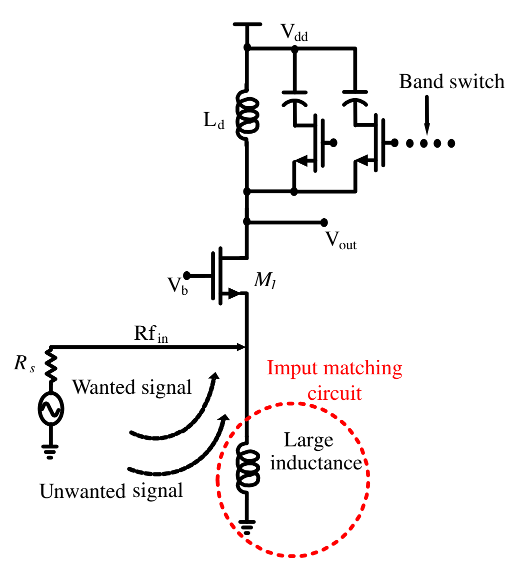

Fig. 1. The principle of conventional common gate multi-band LNA.

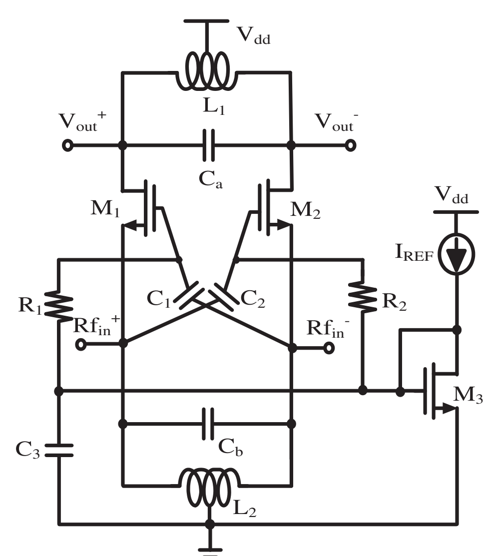

Fig. 3. The simplify circuit of proposed multi-band LNA.