ABSTRACT

In this paper, a differential multi-band CMOS low noise amplifier (LNA), operated in a wide range from 800MHz~1700MHz, with wide-band interference rejection, linearity improvement and the capacitive cross-coupling technology, is proposed. The proposed differential multi-band CMOS low noise amplifier with high linearity performance and good interference rejection performance. The post-simulation results of proposed LNA show that the gain is 13~17.5 dB, the noise figure (NF) is less than 3.4dB, the third-order intercept point (IIP3) is 9.98dBm. The LNA consumes 8.96mW under 1.8V supply voltage in TSMC 0.18-um RF CMOS process.

Categories and Subject Descriptors
B.7.1: [Integrated Circuits]: Types and Design Styles – VLSI (very large scale integration)

General Terms
Design, Experimentation.

Keywords
LNA, multi-band, linearity, interference rejection.

1. INTRODUCTION

In recent years, there has been a tendency towards of wireless communication with integrated of several functions on the chip, so the receiver which can support different wireless standards is required. However, the conventional narrow-band LNAs has poor performance on improving S11 offset for input matching components process variation and multi-standard support, because it is difficult to change the inductances and capacitances of input matching network, especially for the inductance of chip inductor which is not easy to be adjusted by digital or analog control [1][2][3]. Moreover, a wide-band LNA can satisfy different standards at the same time [4], but it also has the poor performances on interference rejection or image rejection [5]. For those reasons, the multi-band LNA is usually implemented with wide-band input matching, which has been discussed in the previous chapters. And the wide-band input matching technique must withstand the input power from different frequency. In other words, the broadband input power is integrated and amplified, and the circuit will be saturated easily. Therefore, the more broadband circuit can be saturated by other channel signals more easily. Therefore, the wide-band input matching technique has poor performance on interference rejection and input stage linearity. Especially in the state of the out-of-band channels constantly in use, the out-band interference rejection and input stage linearity will be more obvious [6]. Moreover, the narrow-band notch filter [7] only rejects single interference frequency, so it does not meet the wide-band interference rejection.

2. PROPOSED MULTI-BAND LNA

In this paper, a CMOS differential multi-band LNA, which employs common gate, tunable LC-tank load and capacitive cross-coupling techniques on its implementations, has been proposed. The wide-band input matching operations are more sensitive to out-of-band unwanted signals due to the use of out-of-band channels. These out-of-band interferences can severely degrade receiver’s sensitivity and linearity. The proposed multi-band LNA has a high selectivity and sensitivity when it is constituted of several narrow-band operations at the single input frequency.
2.1 The theory of proposed LNA and tunable LC-tank load technique

The LNAs with wide-band operations are more sensitive to out-of-band unwanted signals (blockers) due to the transistor nonlinearity. These out-of-band blockers can severely degrade receiver’s sensitivity [8]. Figure 1 shows the conventional multi-band LNA architectures utilize wide-band input matching technique to cover each operating frequency, and figure 2 shows the proposed multi-band LNA architectures utilize common gate LNA technique and tunable parallel LC-tank load technique to selecting input frequency. To compare figure 1 and figure 2, some out-of-band interference signal power is short to ground because the LC circuit is to provide low impedance at anti-resonance frequency. Moreover, some out-of-band interference signal power is eliminated by this path. In other words, the proposed LNA is operated in common gate LNA technique at LC-tank resonance frequency, and the circuit is provided a good performance of S11.

\[ R_r = \omega_0^2 L_2^2 / R_{ind} \]  

Based on those reason, the input impedance of the proposed differential multi-band CMOS low noise amplifier can be derived as

\[ Z_{in} = \frac{1}{g_{m1}} / Z_{eq} \]  

\[ Z_{eq} = \left( L_2 C_2 \right)^{-1} \left( \frac{1}{R_{ind}} + \frac{1}{R_1} \right) \]

The equation 2 shows that the impedance does not go to infinity at any \( s=j\omega \). We say the circuit has a finite Q (quality factor). The magnitude of \( Z_{eq} \) in equation 2 reaches a peak \( (Z_{eq}=R_r) \) at desired frequency \( (\omega_0) \), and the impedance has been used as the load, which is given by

\[ Z_{eq} = \left( \frac{\omega_0^2 L_2 C_2}{\omega_0^2 L_2 C_2 + R_{ind}} \right) \]

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

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

\[ Z_{in} = \frac{1}{g_{m1}} / Z_{eq} \]  

Where \( g_{m1} \) is the trans-conductance of device M1, and the resonant circuit \( (L_2 \text{ and } C_2) \) provides high impedance \( Z_{eq} \) at desired frequency \( (\omega_0) \), and the impedance has been used as the load, which is given by

\[ Z_{eq} = \left( \frac{\omega_0^2 L_2 C_2}{\omega_0^2 L_2 C_2 + R_{ind}} \right) \]

In other word, if the input signals frequency is far away from the resonance frequency, the \( Z_{in} \) will be close to zero. Therefore, the input signals power will be short to ground.
3. SIMULATION RESULTS

The multi-band LNA is simulated with Cadence’s EDA-Spectre RF using TSMC 0.18-um RF CMOS process. The following figures give us the results respectively.

Figure 4 shows the simulated result of voltage gain parameter, which is operated in different standards by different capacitances (C_a and C_b shown in figure 3). The voltage gain of the LNA is more than 13dB, and the gain variable is about 4.5dB. It is operated in the range from 800MHz to 1700MHz.

Figure 5 shows the simulated result of S11 in Fig. 3 that S11 parameter is smaller than -18dB at the wanted switching mode, so the input impedance matching is close to 50ohm between 840MHz and 1700MHz. Figure 6 shows the simulated NF of the entire LNA, and the NF is below 3.42dB over the bandwidth.

Figure 7 shows the simulated result of interference rejection improved of proposed LNA, and the result is compared with the conventional common-gate LNA. It manifests that the proposed LNA has the performance of wide-band interference rejection.

Therefore, the out-band interference rejection and input stage linearity will be improved.

4. CONCLUSIONS

This paper presents a new technique which can improve the multi-band input matching, wide-band interference rejection and input stage linearity by proposed technique. When more and more channels are used, the performance of proposed LNA will be highlighted. Moreover, it is manifested that the multi-band input reflection coefficient (S11), multi-band output voltage gain, and wide-band interference rejection have been improved.

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6. REFERENCES


