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A differential multi-band CMOS low noise amplifier with noise cancellation and interference rejection

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ABSTRACT

In this paper, a differential multi-band CMOS low noise amplifier (LNA), operated in a wide range from 1350 to 2900 MHz, with input matching device, noise cancellation and interference rejection technology, is proposed. Traditional wideband LNAs have poor performances on interference rejection or image rejection. In this design, a multi-band CMOS LNA with matching device noise cancelling, matching device current reuse and source inductance device reuse technologies is proposed, it can improve noise figure, wideband match and interference rejection. There exists a switch-mode notch filter to enhance the interference rejection performance and it does not need additional inductors. A prototype of proposed multi-band CMOS LNA was designed to work at 1450–1490 MHz, 1680–1685 MHz and 2635 HMz–2660 MHz. The simulation results show that the gain is between 18 and 19 dB at L-band application (1450–1685MHz) and between 25.8 and 26.1 dB at CMMB Satellite application (2635 HMz–2660 MHz), the noise figure is 3.1–3.3 dB, and the third-order intercept point (IIP3) is −7 dBm. It consumes 27.35 mW under 1.8 V supply voltage in TSMC 0.18-μm RF CMOS process.

1. Introduction

The application of wireless communication is more and more popular and important, especially in high speed communication systems and consumer electronic products. There is a tendency toward integrated several function on the chip, so the receiver which can support different wireless standards is required. Common receiver architectures use the wide-band LNA or the multi-band LNA, which amplifies the input signal with minimum addition of noise, and matches input impedance for maximum power transfer. The 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 [1]. The multi-band LNA has a high selectivity and sensitivity when it is constituted of several narrow-band operations at the single input frequency. Since the narrow-band LNA can reject unwanted signals (out-of-band signals), image rejection and interference rejection of the receiver will be improved. The in-band common-mode noise also can degrade receiver's sensitivity. It plays an important role in determining system sensitivity [2]. For this reason, to reduce the noise sensitive of LNA is necessary, and the differential structure has been widely used, because it put for a plan for improving the common-mode noise rejection performance of LNA's structure. In this paper, we have initiated research of differential multi-band LNAs.

Mobile TV is recently emerging all over the world such as DVB-H and DVB-T in Europe and Taiwan; T-DMB in Korea, China, and Europe; DMB-T and CMMB in China; and DAB in Europe. China recently announced the adoption of local mobile TV standard CMMB based on satellite-terrestrial interactive multi-service infrastructure (STiMi), and CMMB utilizes two S-band satellites to cover the digital video broadcasting (DVB) over the wide area. The satellite and terrestrial complementary network are combined to create a single frequency network using 470–793 MHz band (terrestrial) and the 2635–2660 MHz band (satellite) [3]. The market is moving toward the integration of different functions in the same terminal, such as DVB-H, DAB, and CMMB [4]. For those reasons, the CMOS differential multi-band LNA which can be integrated 1450–1490 MHz, 1680 –1685 MHz (L-band, for DAB or DVB-H) and 2635–2660 MHz (CMMB Satellite) applications are required.

The difficulty in designing a multi-band LNA comes from the fact that it has to provide different functions. So, to design a multi-band LNA, it must satisfy different specifications at different standards. For example, it usually has higher input signal power when the L-band terrestrial broadcasting channel is used, so the interference rejection and the gain flatness should be considered. Moreover, it usually has smaller input signal power when the satellite channel is used, so the higher gain should be considered due to the use of satellite band.

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2. Review of existing multi-band LNA techniques

Traditional multi-band LNA architectures utilize separate LNAs in parallel to cover each operating frequency shown in Fig. 1(a) [4,5]. This type of receiver needs integration several narrow-band LNAs, so it usually can yield implementations with a large area and great power consumption. Nowadays, most multi-band LNAs are also based on the narrow-band topology presented in Fig. 1(b), and the circuits are shown in Fig. 2(a) for multi output LNA [6] and Fig. 2(b) for single output LNA [7]. Its topology uses source inductive degeneration to provide real input impedance and signal gain at a specific frequency. The source inductive degeneration amplifier [8–10] is the most popular matching method in the design of multi-band LNA. It employs an inductor in series with the source of the MOS to generate a real R_s resistance at the input of the LNA (R_s is the input impedance). So, the source inductive degeneration technique needs input matched inductors L_g, L_d and capacitor C_d (Fig. 2(a) and (b)), and it will consume a large area to integrate inductors and capacitor on the chip, when the circuit is designed to operate at low frequencies will be more serious.

3. Proposed circuit

In this paper, we proposed a CMOS differential multi-band LNA, which employs several techniques on its implementations. By the previous introduction we know that an on-chip CMOS LNA with wide-band matching, in band gain flatness and interference rejection is required at L-band application; therefore, the high gain LNA is suitable for CMMB Satellite application. Fig. 3 shows the proposed differential multi-band LNA circuit, and it can meet our specifications. The analysis of this circuit is shown as follows.

3.1. Current reused and noise-cancelling technique

Nowadays, feedforward [11] and matching device noise cancelling [12,13] techniques are often used in LNA design. In the proposed paper, the matching device noise cancelling technique is proposed, it is to decouple the input matching with the noise figure by cancelling the output noise from the matching device. Fig. 4 illustrates an example, which is based on a common-gate LNA. The input matching is accomplished by setting $1/gm_{Ma1}$ to 50 ohm. In order to meet the $1/gm_{Ma1}$ to 50 ohm, the current flowing through M_{a1} must be large enough. So, it is imperative to reduce the current flowing through M_{a1}. The proposed half schematic of LNA and the principle of noise cancelling technique are shown in Fig. 5 which incorporates PMOS M_{p5} with NMOS M_{n7} in the common-gate stage to realize the cancellation of second-order distortion. Also, the DC bias current of the PMOS-NMOS cascode is reused. We compare the input impedance and trans-conductance (gm) from Figs. 4 and 5.

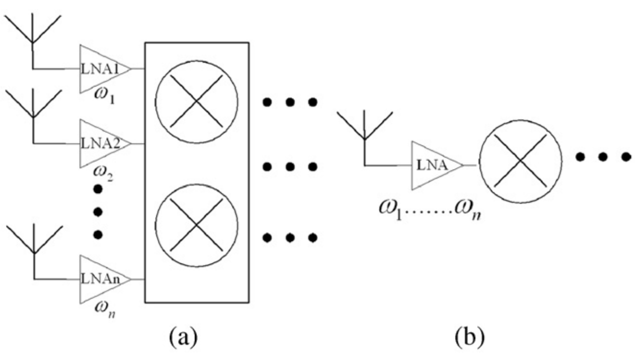

Fig. 1. Different multi-band receiver architectures.

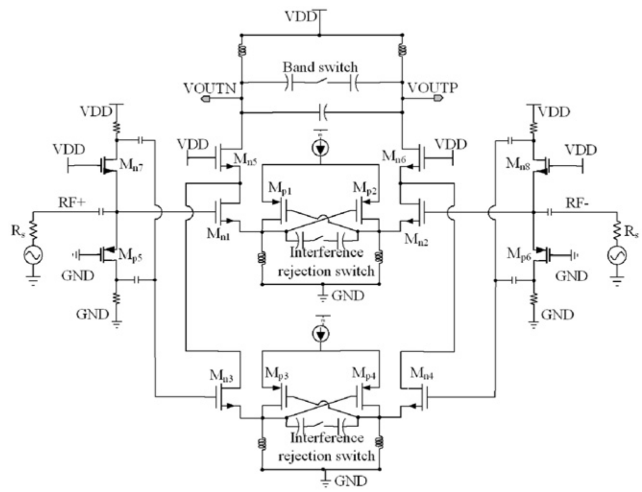

Fig. 3. The schematic of the proposed multi-band LNA circuit.

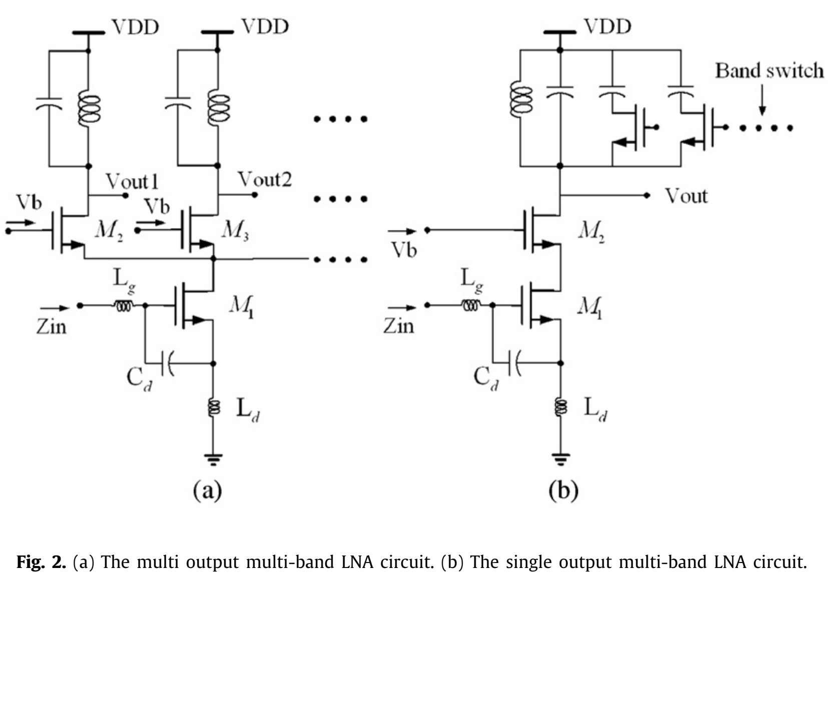

Fig. 2. (a) The multi output multi-band LNA circuit. (b) The single output multi-band LNA circuit.