LETTER

A 900 MHz RF Transmitter with Output LO Suppression

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SUMMARY This letter presents a 900 MHz ZigBee RF transmitter front-end with on-chip LO suppression circuit at the output. To suppress the LO leakage at the RF output, a novel LO suppression circuit is adopted at the up-conversion mixer. The RF transmitter implemented in 0.18 μm CMOS shows more than 28 dB of LO suppression over a wide range of the baseband signal power variation.

key words: *CMOS transceiver front-end, IEEE 802.15.4, LO leakage suppression, low power transmitter*

1. Introduction

Recently, the direct conversion architecture has gained increasing attentions for the low power, low complexity and high integration single chip radio. However, the direct conversion architecture raises a number of issues such as LO leakage, I/Q mismatch and so on. In the transmitter, LO leakage could saturate the power amplifier and overlap with the RF signal as well as being an inter-modulation noise source for adjacent channels. This letter present a novel LO suppression scheme that has been applied to the up-conversion mixer.

2. Circuits Design

The LO leakage in a double balanced mixer is caused by the mismatches in amplitude and phase of the baseband and LO signals as well as the mismatches of constituting components [1]. The mismatches in components can be translated in to the mismatches in DC bias, and also, as described in [1], the mismatches in amplitude and phase of the baseband and LO signal lead to mismatches in DC current as well. Therefore, correcting the mismatches in DC current can be an effective solution to suppress the LO leakage at the output of the mixer.

Perceiving this, up-conversion mixer with LO suppression circuit is designed, shown in Fig. 1. The proposed mixer consists of three parts; the switching stage, the transconductance stage and the LO suppression circuit. In Fig. 1, the switching stage has conventional double-balanced Gilbert cell configuration, the transconductance

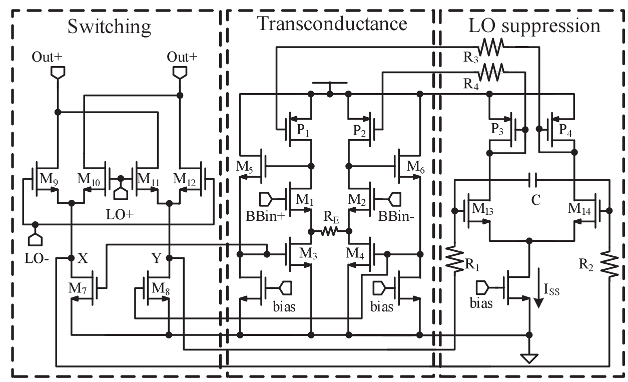

Fig. 1 Schematic of proposed up-conversion mixer.

stage adopts the linearization technique reported in [2]. The principle of the proposed LO suppression technique can be described as follows. It assumes that the mismatches, as described above, lead to the mismatch in DC drain currents of M7 and M8 in Fig. 1. The mismatch in drain currents will lead to the mismatch in DC drain voltages of M7 and M8 (nodes X and Y). As shown in Fig. 1, the DC node voltages at node X and Y are sensed by a differential voltage-to-current converter (M13 and M14). Then the difference in drain currents of P3 and P4 is mirrored to the transistors P1 and P2. Thus the differential DC currents through P1 and P2 correct the different DC voltages at nodes X and Y through the negatively fed-back transconductance stage. As a result, the DC drain current mismatch in M7 and M8 is corrected so that the LO leakage at the output can be suppressed.

The proposed mixer is optimized in 0.18 μm CMOS technology for 900 MHz application, which is cascaded with a cascode driver amplifier, shown in Fig. 2. In Figs. 1 and 2, the switching, transconductance, and LO suppression stage is designed to dissipate 2, 1.5, and 0.5 mA, respectively, while the driver amplifier dissipates 6 mA, from 1.8 V supply. Based on simulation, the LO amplitude at the mixer output caused by various mismatch effect is tested as a function of baseband signal. In the mixer, the increase in the strength of baseband signal, caused by the non-linearity of the transistors in the transconductance stage, leads to the increase in the DC current which in turn lead to the more significant mismatches in DC currents. Therefore, in general, the LO leakage at the output increases with increase in baseband signal.

To verify the LO suppression effect of the proposed

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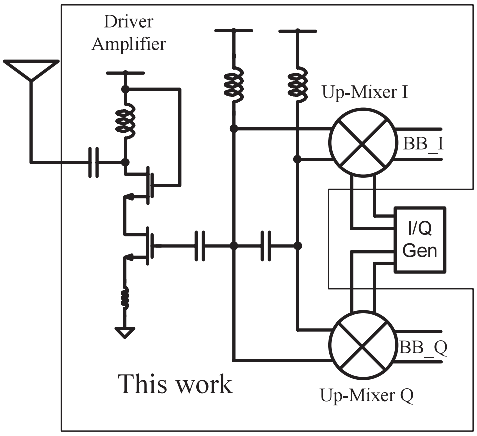

Fig. 2 Transmitter front-end.

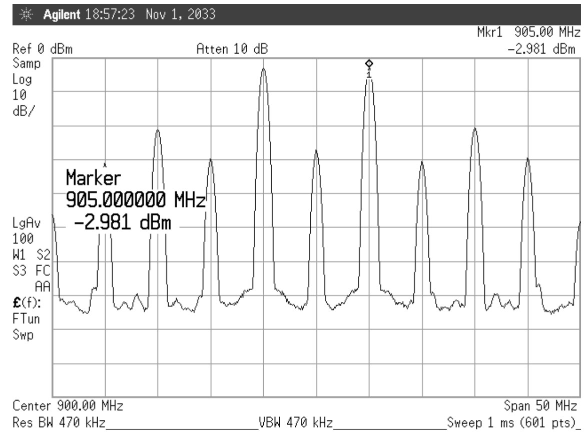

Fig. 4 Measured output spectrum of proposed transmitter front-end.

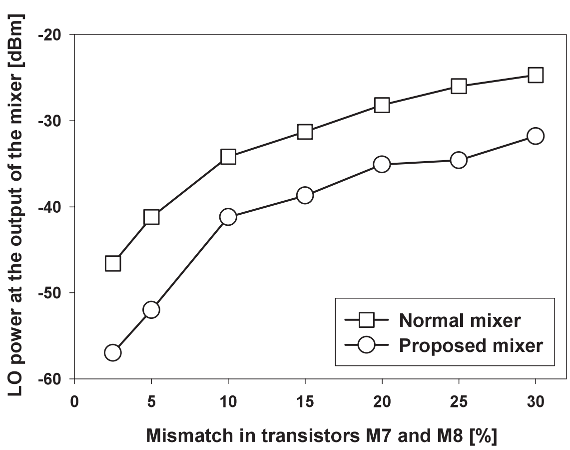

Fig. 3 LO leakage power at the output vs. mismatch in transistors M7 and M8.

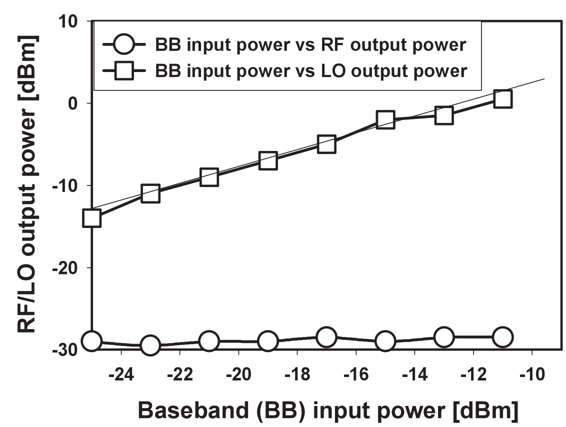

Fig. 5 Measured output power and LO leakage power vs. input power.

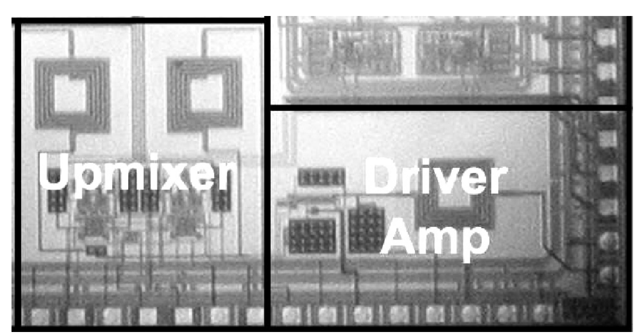

Fig. 6 Microphotograph of the fabricated transmitter front-end.

feedback circuit, the mixer shown in Fig. 1 has been tested by simulation for various mismatches in the constituting devices. The simulations show clear suppression of LO signal by adopting the proposed feedback circuit. Figure 3 shows the comparison of the LO leakage power at the output, with and without the feedback, as a function of the mismatches in transistors M7 and M8. As can be seen in Fig. 3, the feedback circuit provides more than 8 dB of LO suppression.

3. Measurements

The transmitter front-end shown in Fig. 2 with ESD protection is fabricated in a 0.18 μm CMOS technology. All the inductors are implemented on-chip. Figure 4 shows the measured output signal spectrum of the proposed transmitter front-end for the baseband and the LO signal of −15 dBm at 5 MHz and 0 dBm at 900 MHz, respectively. The RF output is applied to spectrum analyzer and the output spectrum is shown in Fig. 4. Since the measurement are done for only one side of the mixer (that is I or Q mixer only) the measured spectrum shows the both side of the up-converted signal (including the images). Considering the cable loss, the front-end offers 12 dB of power conversion gain and 28 dB of LO suppression. Figure 5 shows the measured transmitter fundamental and LO leakage power as the function of baseband input power. As can be seen in Fig. 5 the transmitter show 1-dB compression point of −1 dBm and the LO leakage stays constant, as an effect caused by LO suppression circuit, matching at very low power dissipation. Figure 6 shows the microphotograph of the fabricated transmitter front-end, where the die-area is $0.8 \times 1.5\,mm^2$.

4. Conclusions

A transmitter front-end that adopts a novel LO suppression circuit is proposed and implemented in 0.18 μm CMOS technology. The principle of the proposed suppression circuit is described and the measurements show 28 dB of LO suppression which is independence of the baseband signal amplitude. Measurements of transmitter front-end also show 12 dB power conversion gain and -1 dBm of output 1-dB compression point while dissipating 14 mA from 1.8 V supply.

Acknowledgments

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