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I/Q mismatch calibration of a transmitter using local quadrature oscillator

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ABSTRACT

In this paper a calibration technique for I/Q mismatch of a transmitter is introduced. The calibration technique is based on the fact that all mismatches in I/Q paths can be modeled as the mismatch of the local oscillator quadrature outputs. Based on this fact, a simple tuning scheme for quadrature output of the oscillator is used to calibrate the mismatch of the I/Q transmitter. In addition to quadrature oscillator, gain mismatch of the I/Q paths and LO feedthorugh and leakage is calibrated by using a tunable linear Gm cell in the base band part. In order to demonstrate the proposed technique, a transmitter with 1.8 GHz carrier frequency is designed with auxiliary blocks to extract and cancel out the I/Q mismatches. The simulation results in 0.18 μm RFCMOS process show that the proposed technique can reduce amplitude of the image signal resulting from mismatches in I/Q paths about 18.5 dB in the transmitter output.

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1. Introduction

THE I/Q modulation scheme is ubiquitous in most of today wireless transmitters due to spectral efficiency of this modulation. The I/Q paths in a transmitter are subject to phase and gain mismatches which are the result of imbalance between different blocks and interconnections in I/Q paths. This imbalance can be from any block in transmitter chain and usually is rooted to layout and components mismatch in the circuit [1–3]. This mismatch in I/Q paths will generate an image signal in the spectrum of the output signal which will degrade the error vector magnitude (EVM) of output constellation.

A few methods have been introduced in literatures for mismatch calibration of I/Q transmitters. The loop back detector with a recursive algorithms [1] and 2D search algorithms [4,5] are two popular methods of I/Q calibration. The first method can take long calibration time and will consume large power and area concerning the IC implementation. This paper is utilizing the second method of calibration by using iterative search algorithm to calibrate the transmitter. In this paper, with a linear transconductance in the transmit mixer similar to the one used in [5] and also using a phase tunable oscillator with the quadrature outputs, a low power and small area calibration circuit has been devised. This paper contributions can be categorized in three distinct sections: 1) This paper demonstrates the feasibility of transmitter I/Q calibration by using quadrature oscillator. The simulation results show that considerable rejection in the output image signal is achieved by phase tuning of the quadrature oscillator. 2) Another important contribution of the paper is introduction of a technique for phase tuning of the quadrature outputs of the oscillator with minimum impact on the phase noise. 3) Third contribution of the paper includes the design and validation of different auxiliary blocks for I/Q mismatch detection and cancellation including the transmitter itself and elaborating the calibration process. Meanwhile some circuit design techniques in different blocks of the mismatch detection path was introduced.

This paper is organized as follows, Section 2 of the paper explains the overall block diagram of the transmitter including the calibration blocks and procedure. Section 3 presents the quadrature oscillator used as the key calibration element. Section 4 explains the detector block used in the mismatch detection and calibration process. Section 5 of the paper presents the simulation results of the quadrature oscillator and calibration process and demonstrates the operation of the proposed method; finally some conclusions are drawn in Section 6.

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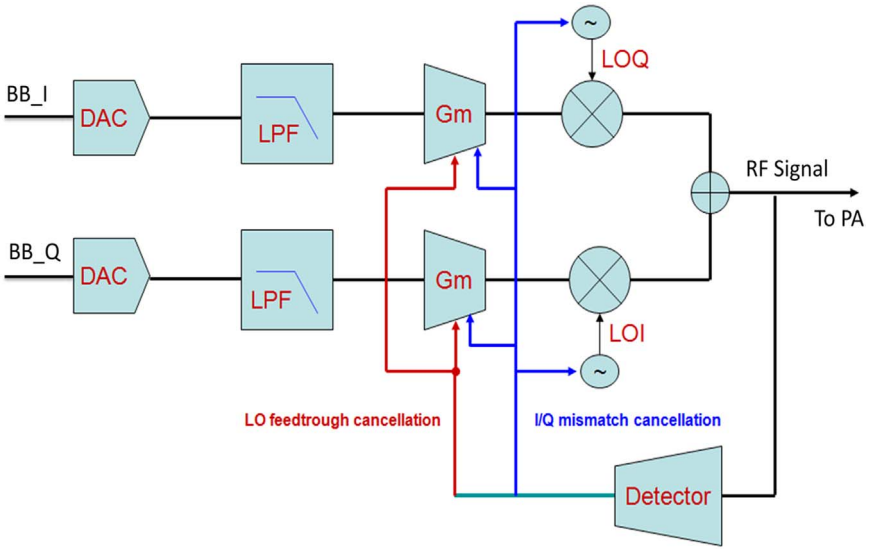

Fig. 1. Block diagram of the transmitter with calibration paths.

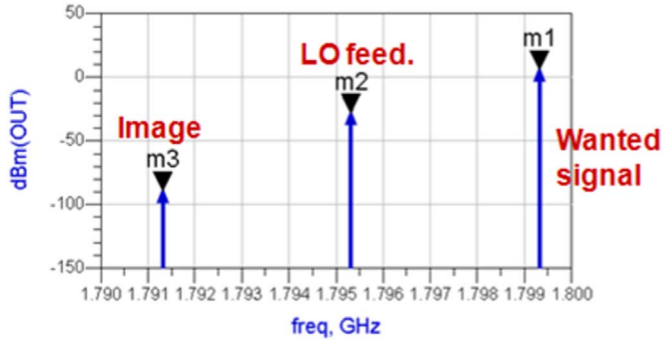

Fig. 2. Transmitter output spectrum with images signal resulted from mismatches in I/Q paths and LO feedthrough.

2. Calibration process

Fig. 1 shows the transmitter block diagram along with calibration loops. The direct-conversion architecture using only one I/Q transmit mixer is opted for the transmitter. Transmitter circuit includes two calibration loops which take the signal back from the output of the up conversion mixer through a block entitled as detector. The detector block is used to down convert the output signal for further filtering and extraction of the necessary tone; this block will be explained further in continue of the paper. The signal extracted from output of the detector is used as the residue of the image signal and criteria for effect of the calibration process on the I/Q mismatches. In addition to I/Q calibration, the output of this detector block can be used for LO feedthrough (LOFT) reduction which is shown in Fig. 1 as a red calibration signal and

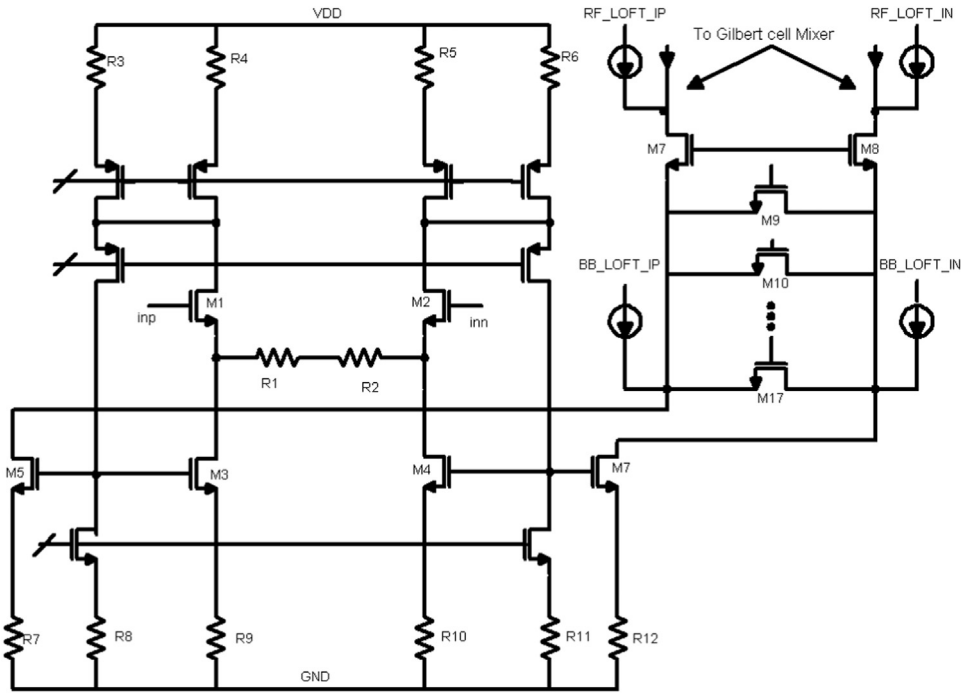

Fig. 3. The circuit schematic of the linear transconductance used in the transmitter.

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