A Wideband CMOS Mixer with Feedforward Compensated Differential Transconductor

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***Abstract* — A 2.4 to 10.7 GHz wideband mixer for multi-band orthogonal frequency division multiplexing ultra-wideband (MB-OFDM UWB) applications is designed using a TSMC 0.18μm CMOS technology. The designed mixer uses a LC folded cascode structure and a feedforward compensated high-linearity differential transconductor to improve the linearity. The measured results reveal that the proposed mixer achieves power conversion gain of 3.3 ± 1.5 dB, third-order input intercept point (IIP3) of 6.9 dBm, and input 1-dB compression point (P-1dB) of -2.8 dBm in the power consumption of 14.4mW from a 1.8V power supply. The chip area is 0.70 × 0.58 mm^2.**

***Index Terms* — CMOS mixers, folded-mixer, , differential transconductor, UWB.**

I. INTRODUCTION

The characteristics of UWB system are high data rate, low power consumption and low cost. UWB becomes new developing technology in the wireless personal network (WPAN). Under the trend of the WPAN, the usage of UWB may extensively makes life more convenient in the coming future. Direct conversion and low-IF wireless receiver architectures have attracted more attention in the past few years due to simplicity, easily integration with baseband, low power and potentially low manufacturing costs [1]-[5]. Fig. 1 shows the direct conversion receiver architecture.

Mixer is an essential building block in the receivers, which is responsible for frequency up-conversion and down-conversion. Also, it is an important component associated with the linearity of the front-end receivers. Nonlinearity causes many problems, such as cross modulation, desensitization, harmonic generation, and gain compression [6]. The even-order nonlinearity can be easily reduced by differential architecture. However, odd-order nonlinearity is difficult to be reduced, especially the third-order intermodulation distortion (IMD3). IMD3 is the dominant part of the odd-order nonlinearity.

Comparing passive mixers and active mixers, active mixers have better gain and isolation, but worse linearity. Passive mixers have superior linearity than active mixers. Gilbert cell is a typical type used in active mixers. The Gilbert cell mixer consists of three stages: transconductor stage, switching stage, and load stage. The linearity of Gilbert mixer is dominated by the transconductor stage.

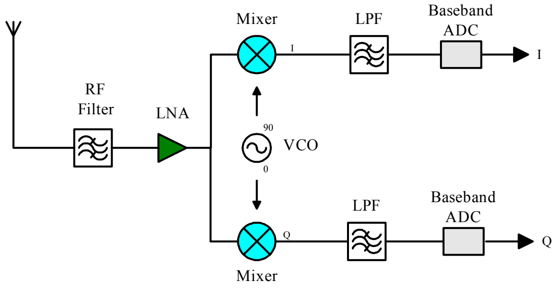

Fig. 1. Direct conversion receiver architecture

II. DESIGN METHODLOGY

The first stage of mixer must have high linearity to handle the large input signals from LNA without significant intermodulation [7]. To improve linearity in Gilbert mixer, many methods have being used such as adding source degeneration resistors below the gain stage [8], bisymmetric Class-AB input stage [7], multiple gated transistor [6], and common-source and common-emitter RF transconductors [9]. The designed mixer adopting modified feedforward compensated differential transconductor, as like as the transconductor stage in Gilbert mixer, is shown in Fig. 2. The transconductor consists of degenerate common-source stages (M1, M2) and degenerate common-gate stages (M3, M4). The input stage is the degenerate common-source stages and compensated by degenerate common-gate stages, which can achieve feedforward distortion linearization [10]-[11]. The feedforward compensated differential transconductor provides accurate input impedance and high intermodulation intercepts.

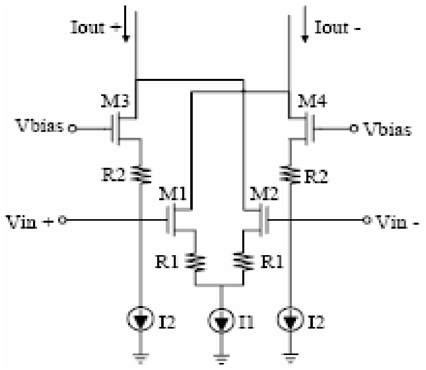

Fig. 2. Modified differential transconductor

The mixer gain is proportional to gm, and higher overdrive voltage leads to higher gain. To use feedforward compensated differential transconductor in Gilbert mixer, the supply voltage is critical to keep the driver FETs always in saturation region. In order to overcome this problem we using LC folded cascode circuit to get larger voltage headroom, and it can keep the driver FETs always in saturation region [6],[8],[12],[13]. The operation of the LC folded cascode mixer is similar to the Gilbert mixer. A LC folded cascode mixer with an added resistance is shown in Fig. 3. The parallel RLC tank is a tuned load that can be used to provide larger output swing. At DC, inductor is shorted and no voltage drop across the tuned load. Therefore, the more voltage headroom is provided. At resonating frequency of the parallel RLC tank, the inductor and capacitor are open circuit at output frequency while consuming no voltage drops. The Resonating frequency and 3dB bandwidth can be given by

$$\omega_0 = \frac{1}{\sqrt{LC}} \tag{1}$$

$$BW = \frac{1}{RC} \tag{2}$$

Fig. 4. shows the proposed mixer, which is composed of an LC folded cascode mixer and a feedforward compensated differential transconductor.

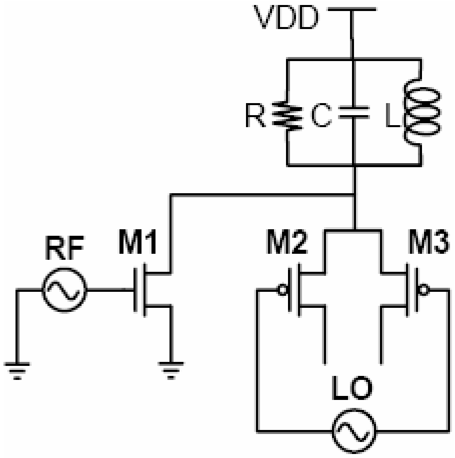

Fig. 3. LC folded cascade mixer with an added resistance

Functionally, input differential signal into the feed-forward compensated differential transconductor to amplify the input signal firstly. The small-signal voltage is converted to a small-signal current at this stage. The current signal is down-converted by the switching pair. Then the load stage provides loading to preceding stages and converts the current signals back to voltage signals. Finally, common sources are used as output buffers for testing and matching purposes.

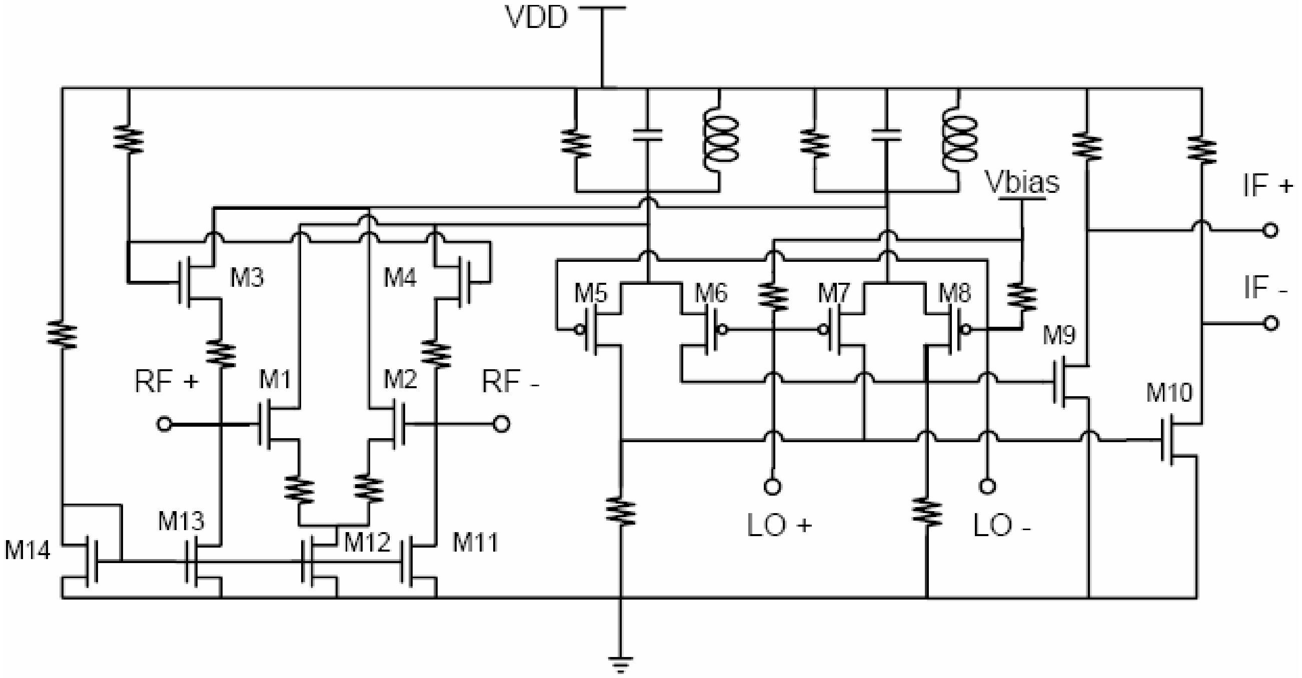

Fig. 4. Schematic diagram of the proposed mixer

III. MEASUREMENT RESULTS

The measurements were performed with the chip directly mounted on a 28×28 mm^2 and thickness of 20 mil RO4003 microwave substrate with SMA connectors. Fig. 5 shows the test board with die mounted on it. The chip microphotograph is shown in Fig. 6. The die size is 0.70×0.58 mm^2 including pads.

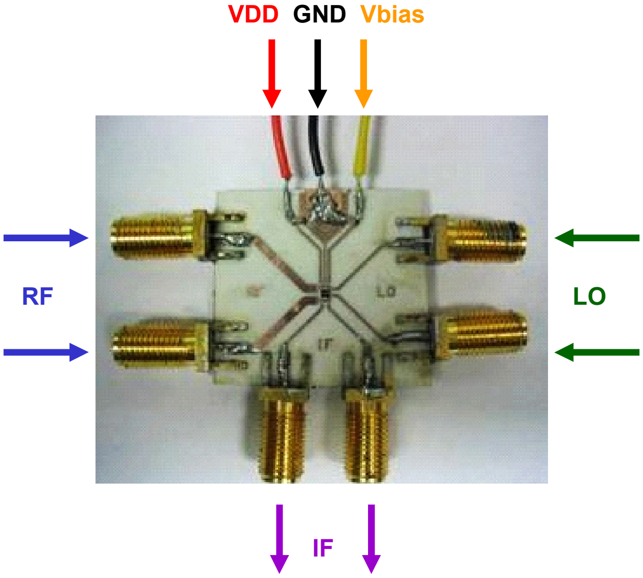

Fig. 5. Die bonded to the PCB

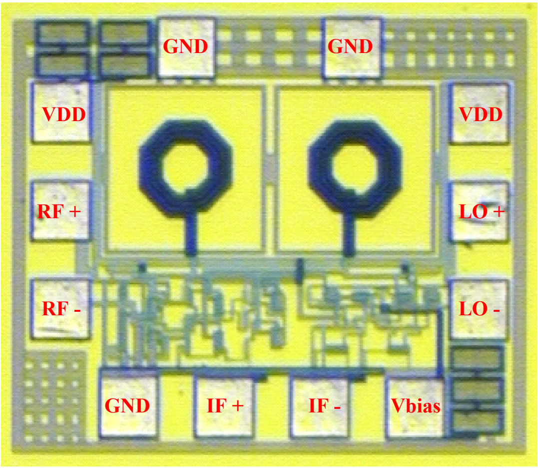

Fig. 6. Microphotograph of the proposed mixer

The mixer is designed using TSMC 0.18μm CMOS technology. All measurements were done at 1.8 V and 1.2 V supply voltage and the power consumption is 14.4 mW including the output buffer. Fig. 7 illustrates the conversion gain versus the RF frequency with both RF and LO ports swept in frequency from 2 to 12 GHz, a fixed IF frequency of 50 MHz, RF power of -30 dBm, and LO power of -5 dBm. The conversion gain is 3.3 ± 1.5dB with a bandwidth of 2.4 to 10.7 GHz, The measured RF return loss is better than 10 dB as shown in Fig. 7. The measured RF-to-IF, LO-to-IF and RF-to-LO isolation shown in Fig. 8. are better than 20 dB. Fig. 9 shows the linearity of the mixer as a function of frequency. The measured IIP3 is 4 ~ 6.9 dBm and P1dB is -2.8 ~ -5.8 dBm in the bandwidth of 2.4 to 10.7 GHz.

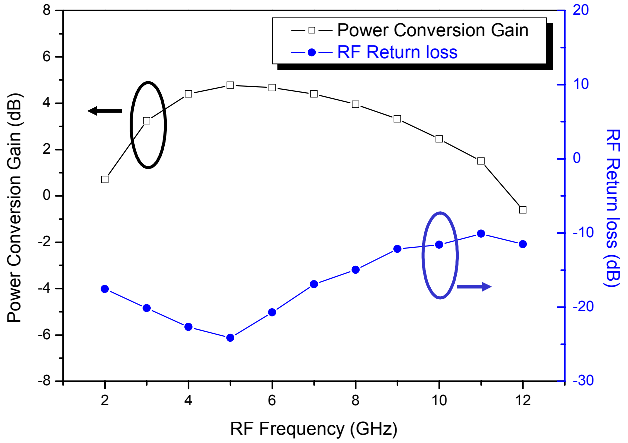

Fig. 7. Measured power conversion gain and RF return loss versus RF frequency with the IF frequency is 50MHz, RF power is -30dBm, and LO power is -5 dBm

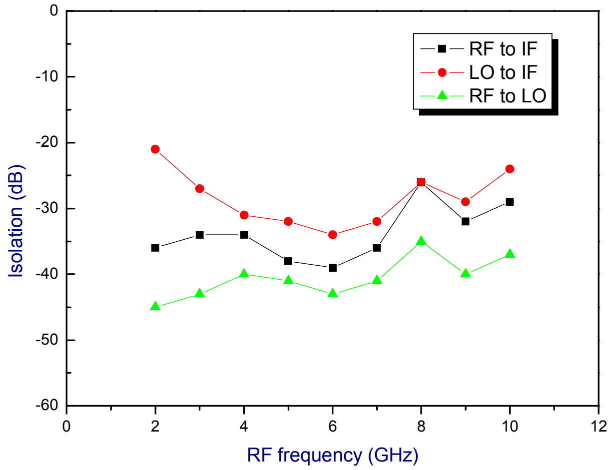

Fig. 8. Measured Isolation versus RF frequency

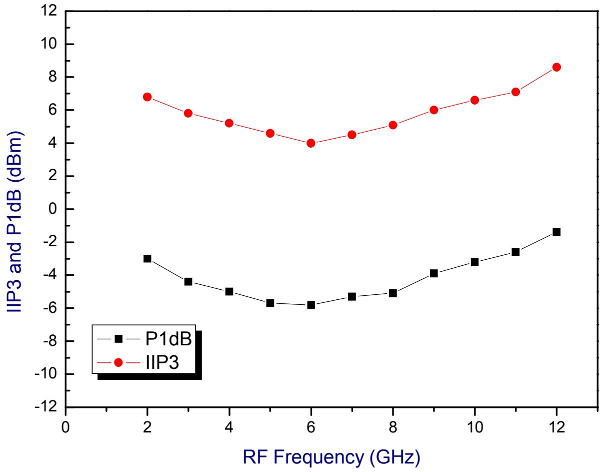

Fig. 9. Measured IIP3 and P1dB versus RF frequency

Finally, the comparison of the proposed mixer against recently reported CMOS mixer is shown in Table I, it indicates that the proposed mixer provides better linearity, more compact chip size, and acceptable conversion gain and power consumption.

TABLE I
PERFORMANCE COMPARISON BETWEEN PREVIOUSLY PUBLISHED WORKS ON WIDEBAND CMOS MIXERS

Ref.	[14]	[15]	this work
Technology	0.18um CMOS	0.18um CMOS	0.18um CMOS
IF frequency (MHz)	10	528	50
Frequency (GHz)	0.3～25	3.1～8.72	2.4 ～ 10.7
CG (dB)	11+/- 1.5	3.75 +/- 1.25	3.3 +/- 1.5
IIP3 (dBm)	---	5	6.9
P1dB (dBm)	-5	---	-2.8
LO Power (dBm)	-1	9	-5
Pdis (mW)	71 (mixer core)	10.4	14.4
Supply voltae (V)	5	1.8	1.8
Die area (mm2)	0.8X1	1.4X1.16	0.70X0.58

IV.CONCLUSION

In this paper, a wideband mixer using LC folded cascode mixer topology and a modified feedforward compensated differential transconductor in TSMC 0.18μm CMOS technology is presented. The LC folded cascode method is used to get enough voltage headroom to work with, and the modified feedforward compensated differential transconductor is adopted to achieve broadband impedance matching and lower the overall distortion. The designed mixer is suitable for MB-OFDM UWB receivers.

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