Design of Gilbert Cell Mixer Using CMOS Technology

Bhoomi Patel [1], Amee Mankad [2]

P.G. Student, Department of Electronics and Communication Engineering, Shantilal Shah Engineering College, Bhavnagar, Gujarat, India[1]

bhoomipatel7960@gmail.com[1]

Assistant Professor, Department of Electronics and Communication Engineering, Shantilal Shah Engineering College, Bhavnagar, Gujarat, India[2]

ameechhaya@yahoo.in[2]

Abstract

An Up conversion mixer is proposed using 180 nm CMOS process. The study elaborates several types of mixer, mixer's performance parameters, the mixer's topologies and also the design technique to improve the mixer performance. The main aim is to improve the gain, increase the linearity and Noise Figure. Four metal layers are available to design. The previously published work has been compared and the best topology for low power mixer is suggested.

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Keywords: *Mixer, Noise figure, Conversion gain, CMOS*

1. Introduction

The Ultra Wideband (UWB) system is one of the major technology for wireless communication. Mixer is a key to translate RF signal to baseband signal. Mixer is one of the most important element in RF communication system. It is designed to yield both, a sum and a difference frequency at a single output port when two distinct input frequencies are inserted into the other two ports. The two signals inserted into the two input ports are usually the Local Oscillator signal, and the incoming (for a receiver) or outgoing (for a transmitter) signal. To produce a new frequency (or new frequencies) a nonlinear device is required. RF Mixer is fundamentally a device, which is shifting a signal from one frequency to another. Mixer produces harmonics of input frequency, LO frequency and their intermodulation products. These harmonics increase non-linearity of mixer. The basic aim while designing mixer is to suppress the harmonics. An ideal mixer is a multiplier circuit. An ideal mixer translates the modulation around one carrier frequency to another carrier frequency. As a mixer is a nonlinear device it cannot perform frequency translation.

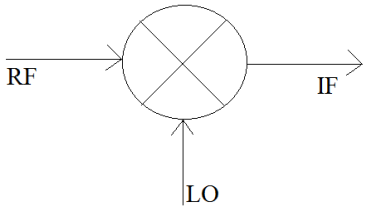

Fig.1 Ideal Mixer

A mixer is a 3 port device consisting of LO (local oscillator), RF radio frequency and IF (intermediate frequency) ports. LO port is a fixed amplitude large signal. When two signals at frequencies freq1 and freq2 are applied to a mixer; it produces new signals at the sum freq1+freq2 and difference freq1-freq2 of the original frequencies.

Mixer can be broadly classified as: Up-conversion mixer which is used to convert IF frequency (or baseband signal) to a higher IF or RF frequency for efficient transmission in transmitters .Down-conversion mixer is used to convert RF to a lower IF or baseband for easy signal processing in receivers. Up-conversion mixer in the transmitter chain converts incoming low frequency into a higher frequency by RF stage of the transmitter. Down-conversion mixer in the receiver chain converts incoming high frequency into a lower frequency by IF stage of the receiver. In this work a low voltage wideband Up-conversion mixer is design using CMOS process.

The proposed mixer is based on Gilbert-cell mixer which reduces DC power consumption and supply voltage. The proposed circuit is designed and simulated in RF CMOS process.In RFIC process four metal layers are available for interconnection.

Conversion gain

Conversion Gain or Loss of the RF Mixer is dependent by the type of the mixer (active or passive). It depends on the load input RF circuit as well the output impedance at the IF port. Conversion gain also depends on the level of LO.

Gain = $20 * \log_{10} V_{IF} / V_{RF}$

1-dB compression point

The point where the difference between the ideal linear curve and the actual output power curv is 1 dB is referred to as the 1 dB compression point.

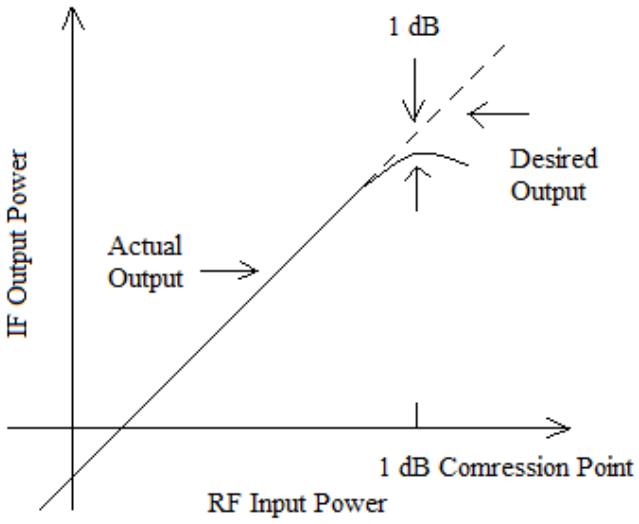

Fig.2 1-dB compression point [7]

Third order intercept point

The point at which the output level of third order intermodulation is equal to the desired output is called third order intercept point (IIP3).

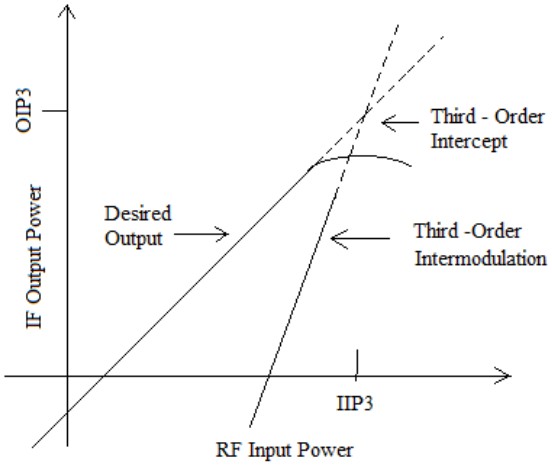

Fig.3 Third order intercept point [7]

2. Circuit Design

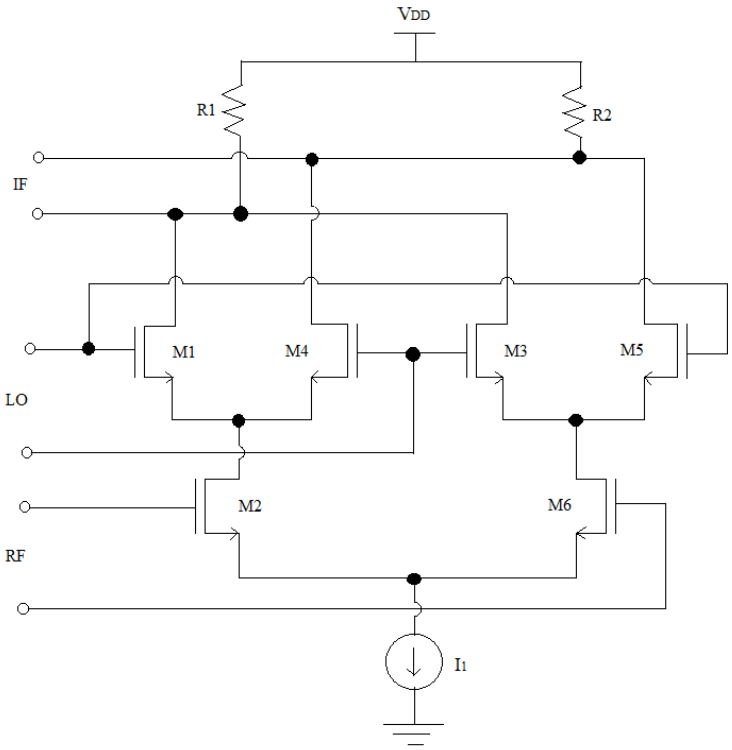

Fig.4 Double balance Gilbert Cell[8]

A double balance gilbert cell mixer is consists of six transistors. The transistors M2 and M6 form the differential pair transconductance that converts the RF input voltage into

current, the current is then commutated by the switching transistors M1-M4 and M3-M5. Each side of the IF output is connected with two transistors with 180º phase shifted LO signals so that the LO leakage signals from the two transistors cancels each other. The LO feed through from transistors M1 is canceled by M3 and M4 is canceled by M4. The mixed product of RF and LO is observed at the IF outputs.

3. Proposed Mixer Design

The proposed mixer design consists of two parts: Input stage and Switch stage. Input stage is also called transconductance stage which consist of M4 and M5 which converts IF voltage signal to current signal.

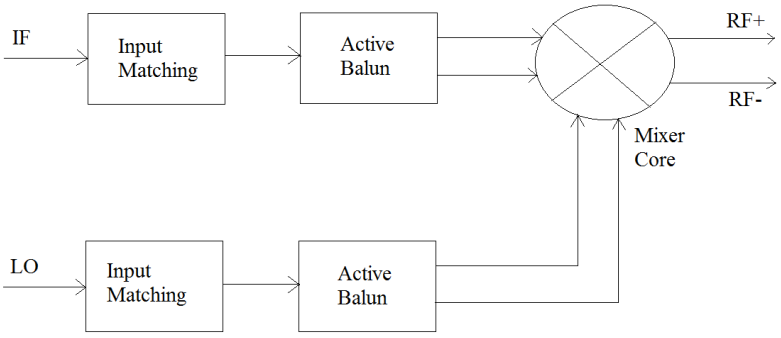

Fig.5 Block diagram of mixer

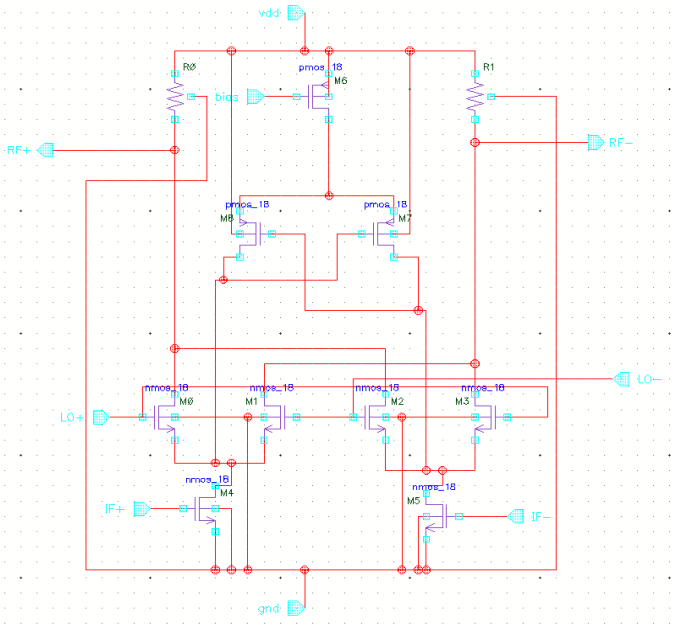

Fig.6 Proposed Up conversion mixer

The switch stage consists of M0, M1, M2 and M3 which is driven by LO signal. IF signal is applied to the transistors M4 and M5. The LO signal is applied to M0 and M2, and 180º phased LO signal is applied to M1 and M3. The PMOS M7, M8 forms RF output stage. PMOS with moderate W/L are sufficiently fast to completely steer the current from transconductance stage to the switching stage with reasonable LO amplitudes. IF transistors are biased in saturation region to provide higher gain for IF input signal. The LO transistors are biased at near pinch off region to act as switches.

4. Comparison Summary

Parameter	[1]	[2]	[3]	[4]	Proposed work
Process	1P8M 130 nm	TRPC 130 nm	180 nm	1P6M 130 nm	180nm
RF	40 GHz	40 GHz	3.5–10 GHz	40 GHz	5 GHz
LO	39.99 GHz	39.99 GHz	–	39.99 GHz	4.5 GHz
IF	100M	100M	–	100M	500M
Conversion gain/loss	–	–	5 dB	8.1 dB	~10 –12 dB
Chip size	0.98 × 1 mm^2	1.25×0.78 mm^2	–	0.9 ×1 mm^2	2×2 mm^2

5. Conclusion

The proposed up conversion Gilbert cell mixer has been designed using 180nm CMOS technology. The active balun is designed for single ended to differential signals. Inductor is not used in mixer so chip size should be compact. The proposed design can achieve 10-12 dB conversion gain.

6. References

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