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Low Phase Noise and Low PowerSelf-Oscillating Mixer in 130-nm CMOS Technology for S-band Applications

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ABSTRACT: The design of a 2.7-3 GHz Self-oscillating mixer based on NMOS cross-coupled structure using TSMC 130nm CMOS technology is presented. The obtained phase noise of SOM is -112.28dBc/Hz at 1MHz offset which is lower than any of the previous work. The conversion gain obtained is -27.24dB for Vtune of 900mV. The total power consumption is only 3.73mW for 0.8V supply voltage. The frequency tuning range of the SOM is from 2.72 GHz to 3.38 GHz when the control voltage changes from 0 to 1.5V. The total chip area including the pads is 0.24mm^2. the proposed SOM meets all the requirement of low cost, low phase noise, low power consumption, high conversion gain and minimum hip area. This SOM can be used in any of the transceiver system.

KEYWORDS: injection locking, Self-oscillating mixer (SOM), voltage-controlled oscillator (VCO), low power, CMOS.

I. INTRODUCTION

Radio frequency identification (RFID) is used to uniquely identify person, animal or object. Millimeter Wave Identification (MMID) updates the RFID system to millimeter waves. The millimeter wave band can be used in various applications like security, medical imaging. These applications require small volume, low cost, very low power transceiver. Fig.1 shows simple block diagram of super-heterodyne receiver. In thisarchitecture the transmitter sends the modulated RF signal mixed with Local Oscillator(LO) and receiver down-converts RF signal by using receiver LO. The drawback of super-heterodyne receiver is that it requires high power and produces spurious signals. Fig. 2.shows the architecture of self-oscillating mixer (SOM) which generates the high power LO signal. The functionalities of oscillator and mixer are combined to form a single circuit under single bias current. The regenerated LO signal is used for the frequency down-conversion of the RF signal. As the mixing efficiency of a SOM depends only on self-generated LO power we can reduce the transmission LO power[1]. The transmitted LO power is used for the injection-locking of the SOM. It maintains the phase correlation between LO and RF signals for mixing process so that the down-converted IF signalhas low phase noise[1].

II. RELATED WORK

The injected RF signal accomplishes three key functions.Firstly, having the same frequency as the natural oscillation frequency of the SOM, injects an in-phase energy into the SOM, which relaxes thenegative resistance required to compensate the SOM losses, and therefore triggers and starts LO oscillation with lower power consumption[2]. Second, $f_{RF} = f_{LO}$,RF_{inj} locks the LO to its carrier frequency f_{RF}allowing a direct-conversion to baseband, given that the LO and RF_{inj} are self-mixed[2]. Third by injection-locking the LO, maintains a phase coherence between both signals, which enhances the SOM phase noise, as well as the phase noise of the down-converted baseband signal[2].The stacked configuration of three components, the oscillator, the mixer core, and the LNA transconductor stage make full use of dc current reuse from VCO to mixer to the LNA [3]. The voltage-controlled oscillator (VCO) is stacked on the

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top of switching transistors[3]. The VCO is located at the IF section of the mixer so this type of configuration facilitates the use of low noise amplifier (LNA) a transconductor stage at the RF input section of the mixer[3].

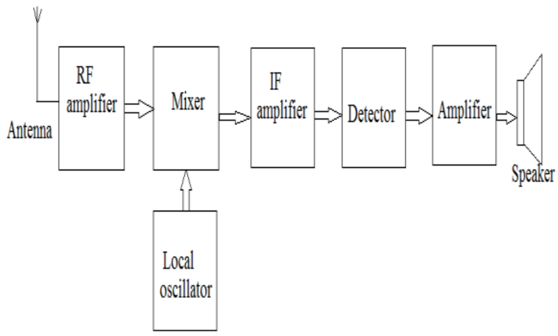

Fig. 1.A simple super-heterodyne receiver.

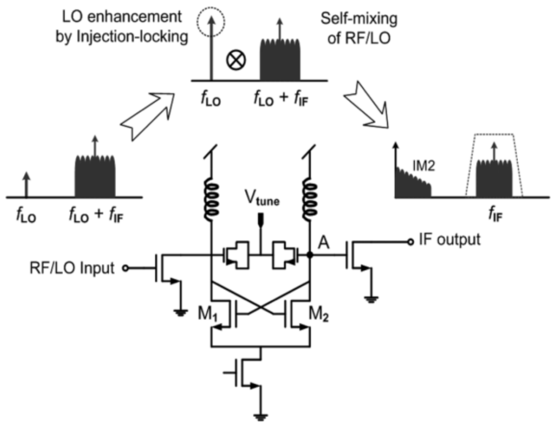

Fig.2. Operating principle of Self-oscillating mixer[1].

IV. SYSTEM THEORY

Negative resistance oscillator do not obey Ohm's law. negative resistance devices are suitable in the design of microwave oscillators to compensate for the resonator losses thereby sustaining the oscillations. Examples of devices that exhibit this property include tunnel diodes, gunn diodes and gas discharge tubes. A negative resistance oscillator can be viewed basically as an amplifier that produces an output when there is no input. A block diagram of the general negative resistance oscillator is as shown in fig. 3. The negative resistance can be calculated as,

$$I_x = I_{d1} = -I_{d2} \quad (1)$$

$$V_x = V_{gs2} = -V_{gs1} \quad (2)$$

$$I_x = -G_m V_x \quad (3)$$

$$R_{in} = -2/g_m \quad (4)$$

The negative transconductance provides negative resistance to compensate the tank losses and therefore allows a sustained oscillation[3]. g_m is transconductance. With an appropriate device size and biasing, the value of negative resistance required to compensate tank losses can be determined. The capacitor in the LC circuit of the oscillator is a varactor diode which when tuned by a DC voltage varies the capacitance of the diode thereby achieving a mechanically tuned frequency of oscillation. This is highly desirable since we can tune the frequency of the LO thus increasing the range of frequencies of the RF that can be "mixed" by the circuit.

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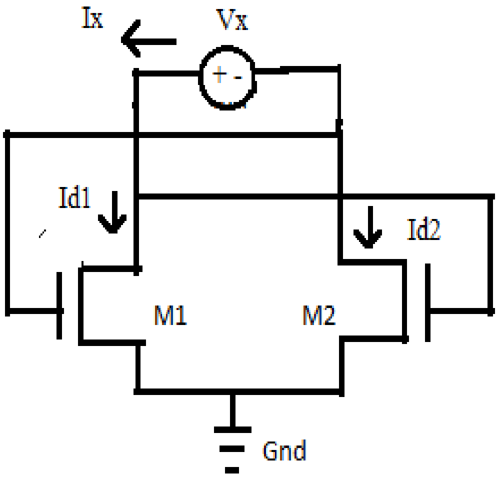

Fig. 3. Negative reistance.

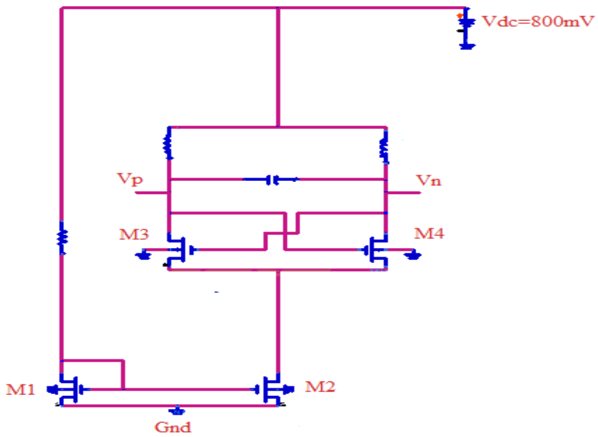

Fig.4. Implementation of oscillator circuit in ADS 2009.

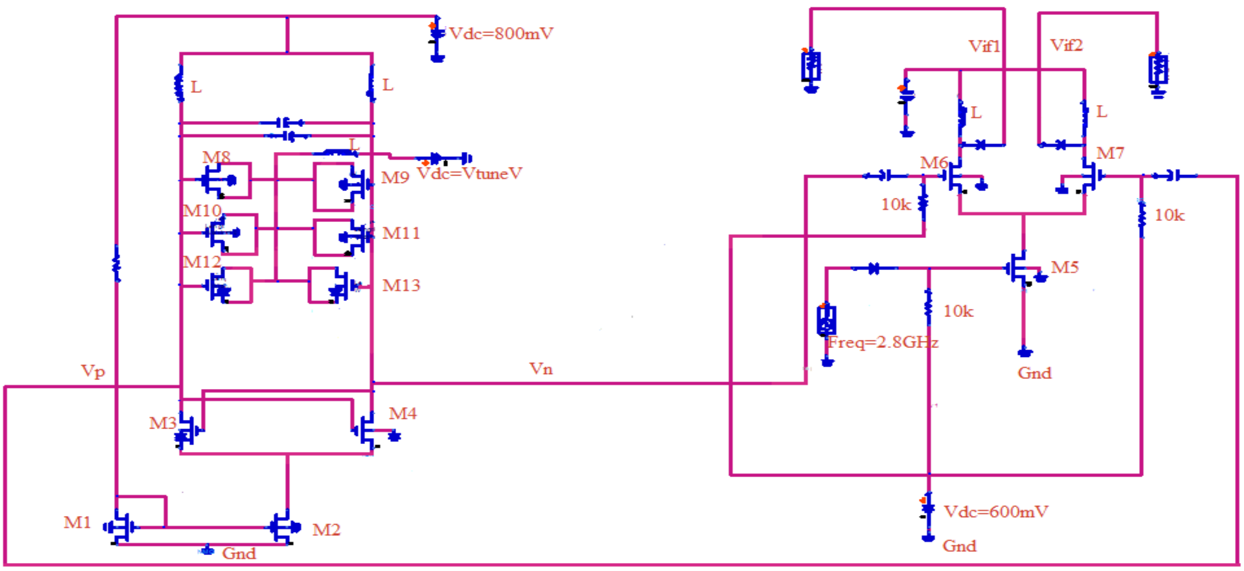

Fig. 5. Schematic circuit of self-oscillating mixer(SOM) in ADS 2009.

Vif1 and Vif2 are the terminals at which IF frequency is obtained. Fig. 5 shows SOM in which MOSFETs M8-M13 are used for getting wide range.For wideband application MOS as a capacitor circuit is designed. Drain and source terminals are connected together and Vtune voltage is applied to it.

V. SIMULATION RESULT

The MOSFET is of gate length 130-nm. Voltage of gate is varied from 0 to 800mV for biasing of NMOS of 130-nm. The current values obtained at the drain are in μA. As the channel length decreases the drain current increases. We can not change the gate length of MOSFET which is 130-nm CMOS technology. For an oscillator to be stable S_{11}

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which is input reflection coefficient should be greater than 1.Fig. 6 shows input reflection value for different frequnecy range. Fig. 6 shows at the frequncy 3GHz S_{11} is 1.390 dB.

Fig. 7 shows the greater voltage swing. The transient analysis is measured by transient analysis tool in ADS. Conversion gain is shown in fig. 9 which is 2.591 at Vtune=900mV. Conversion gain should be greater than 1. We want conversion gain as high as possible. The conversion gain of an oscillator obtained is -24.54dB.

A mixer is a non-linear circuit. Mixer produces the noisy signal. The degree at which mixers noise degrades the signal-to-noise ratio (SNR) of a signal is termed as a noise figure(NF)[1]. The value of noise figure should be more negative.The simulated value obtained in our work is -112.28dBc/Hz at 1MHz offset.

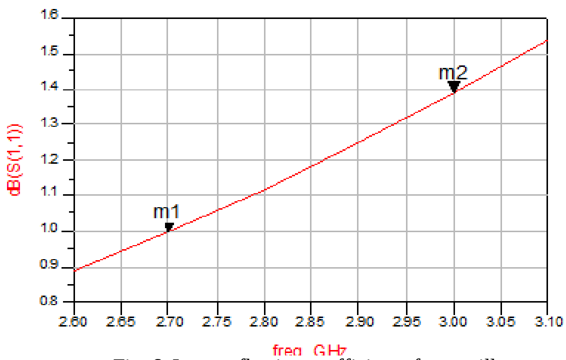

Fig. 6. Input reflection coefficient of an oscillator.

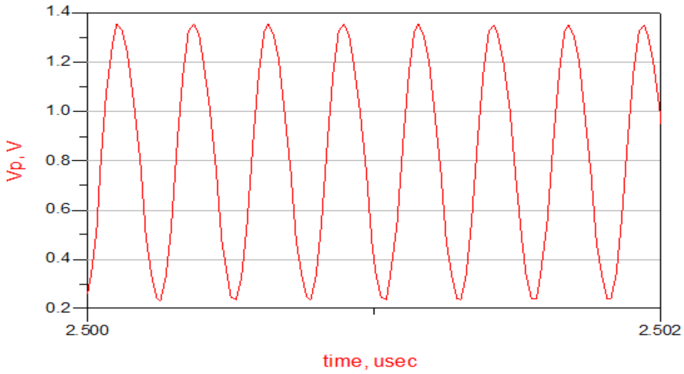

Fig. 7.Simulated result of a VCO circuit.

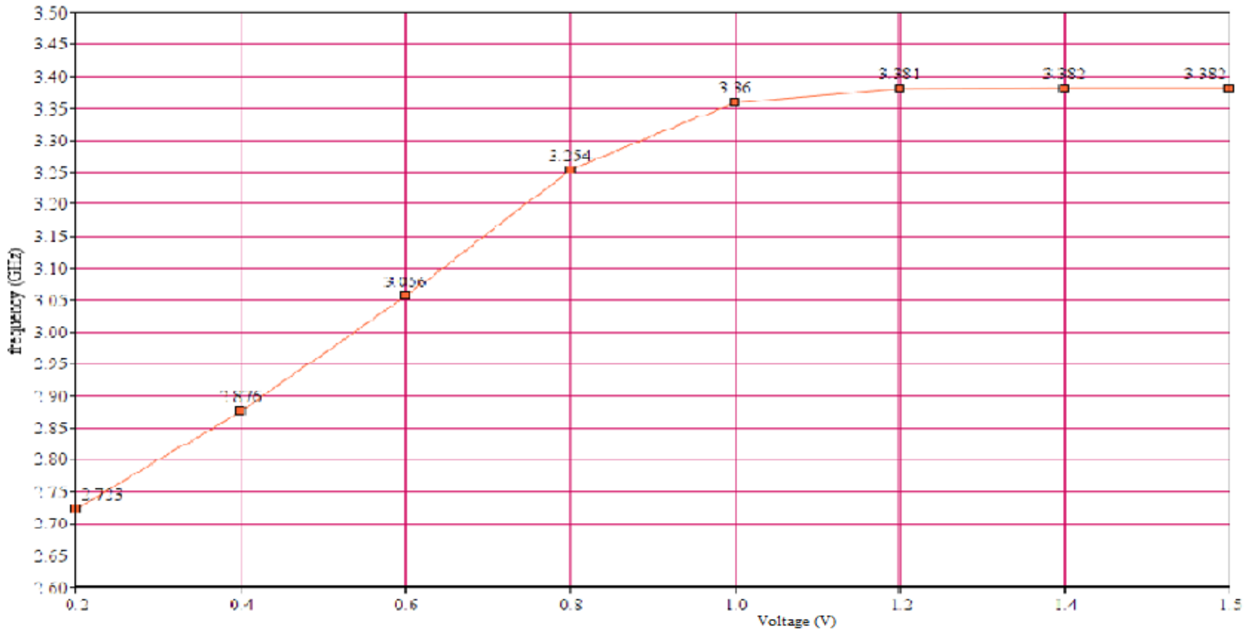

Fig. 8. Wide tuning range when Vtune is changed from 0 to 1.5V.

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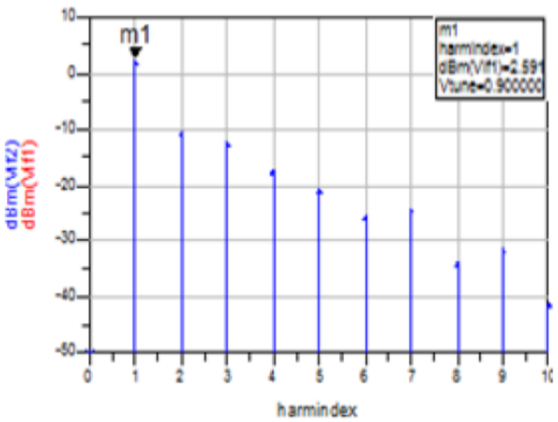

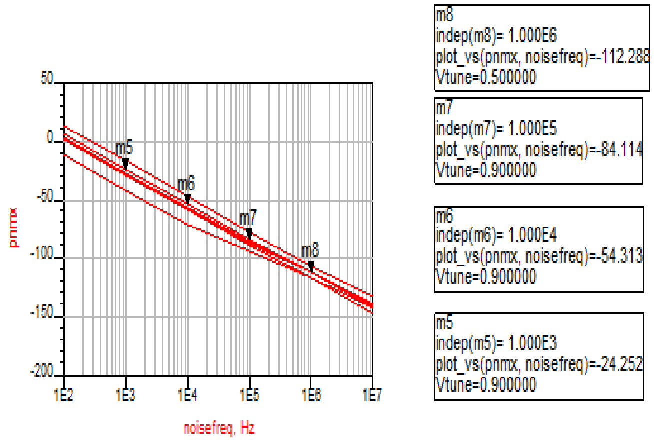

Fig. 9. Conversion gain of SOM at Vtune=900mV.

Fig. 10. Phase noise by changing Vtune

We have used MOS as a capacitor. Vtune in fig. 5 is used for changing the volage from 100mV to 1.5V. conversion gain at haromics is caluted by changing the voltage. Fig. 8 shows the conversion gain at the fundamental frequency. Fig. 8.conversion gain of SOM at a fundamental frequency when voltage is varied from 0.100V to 1.5V.As shown in fig. 5 Vtune is varied from 100mV to 1.5V. The conversion gain at these voltages is shown in fig.9. The conversion bandwidth obtained is 659MHz which was not obtained in any previous work.

We choose differential circuit differential oscillators are used to provide higher frequencies in very high performance systems where single- ended clocks do not perform very well. Typically, they are used because the rise times of differential clocks are usually much faster and can support high frequencies. Differential oscillators offer more against power supply noise (and therefore a higher PSRR) and reduce common mode noise coupling in the system. This is especially crucial for high speed circuits The design procedure of making the differential self oscillating mixer is fairly straightforward as compared to VCO design

Six pin IC is designed in ADS 2009 of the proposed self-oscillating mixer. The advantage of this IC is that all the components are internal. As we have combined oscillator and mixer into single device size of circuit is reduced. The cost of implementation is also reduced.

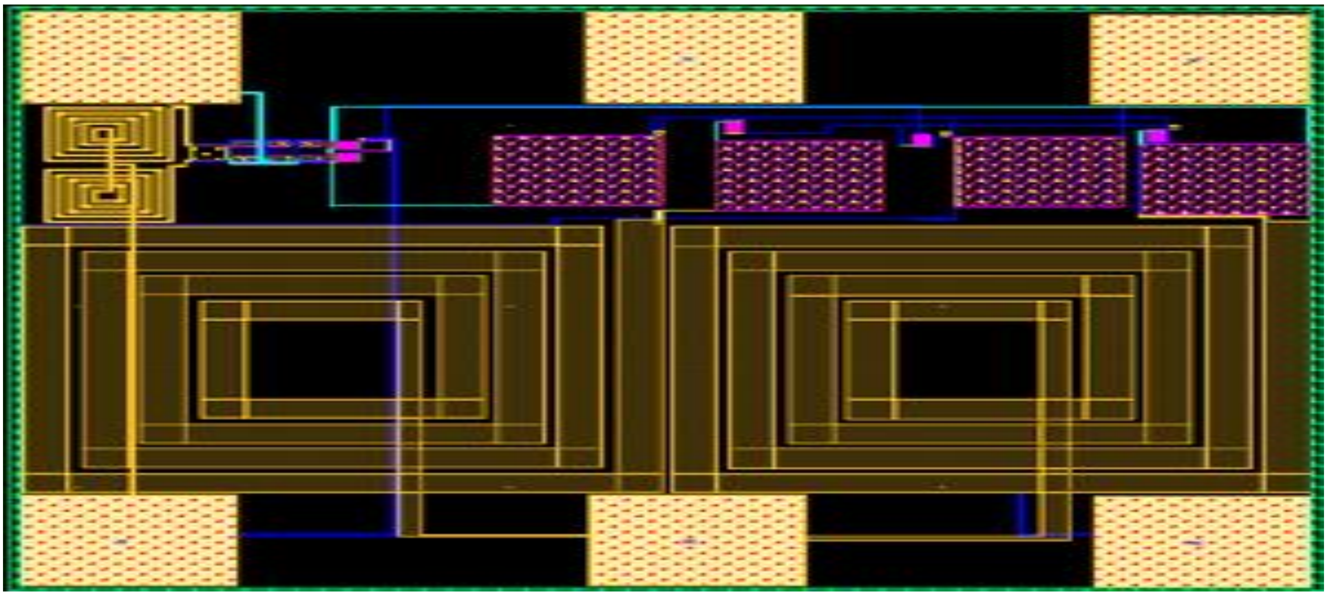

Fig. 11. Range of IF conversion (660MHz) at fundamentalfrequency when Vtune is changed from 100mV to 1.5000V. Fig. 13. Layout of Self-oscillating mixer implemented in ADS 2009.

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TABLE IPERFORMANCE SUMMARY AND COMPARISON OF SOMs

parameters	[5]	[4]	[3]	[1]	[2]	This work
Supply voltage (V)	1.5	1.5	1.2	1.2	0.8	0.8
Frequency (GHz)	5-11.8	7.8-8.8	1.56	30	40	2.7-3
Technology	130-nm	130-nm	130-nm	130-nm	65-nm	130-nm
Conversion gain (dB)	5-12	11.6	36	-30	-30	-27.35
Phase noise (dBc)	N/A	N/A	N/A	-105	-95	-109.8
Chip size(mm2)	0.53	0.53	1.5	N/A	0.24	0.37
Range of IF Frequency(MHz)	N/A	N/A	N/A	N/A	N/A	660

VI. CONCLUSION AND FUTURE WORK

A low-power self-oscillating mixer is proposed. Power consumed is 3.73mW which is very low. The designed circuit requires very low supply voltage which is 800mV. The noise figure value obtained at 900mV is -112.28dBc/Hz at 1MHz offset which is significantly low than any of the previous work. Conversion gain obtained is -27.24 which is high. Tuning range of an oscillator is obtained. Chip size is 0.24mm^2 which is minimum.The designed SOM can be used in any transceiver circuit.

VII. ACKNOWLEDGEMENT

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BIOGRAPHY

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