International Journal of Research
International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 3, Issue 05, March 2016
Available at http://internationaljournalofresearch.org

Analysis of a dual mode wide-band switching reconfigurable oscillator for optimal frequency applications

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Abstract:

The voltage range of integrated oscillators will be excess than desired due to process and temperature variations, which will lead to phase-noise. In this paper a dual-mode LC-tank based VCO with active core reconfiguration is designed to allow two distinct modes of operation, with different oscillation frequencies which reduces phase noise with tuning ranges of 28% .The design is implemented in a 180nm CMOS technology and simulated using Advanced Design System tool, with measured tuning ranges of 56.9 GHz to 65.4 GHz, and 64.6 GHz to 75.3 GHz in the two modes respectively. This design ensures the overlapping of two oscillation mode frequency spans to reduce each frequency span phase noise problem. This design is very useful and recommended for radar applications.

Index Terms --- Dual-mode oscillator; phase noise; tuning range; varactor; VCO

I. INTRODUCTION

The voltage range of integrated oscillators should be more than desired due to system and temperature graduation. Whenever the voltage range will increase it will lead to phase-noise, so to enhance the voltage range. An unexceptional methodology for intensifying oscillator tuning-range involves the use of a bank of tunable capacitors within the tank of inductor based oscillator. However, phase-noise performance degrades as voltage range is increased, because of trade-off between switch on-state resistance and parasitic capacitance. A similar trade-off is observed when using varactors for frequency tuning. This work describes an oscillator that employs active core reconfiguration [1], [2] for mm-wave applications. The implementation of active core reconfiguration allows switching of oscillator operation, with different oscillation frequencies, by effectively modifying the inductance of an LC tank. As conferred below, the switches used for reconfiguration do not contribute to tank loss. Fine frequency tuning is implemented using varactors in each switching .The model pursues to fortify co-occurring frequency spans in the couple of oscillation modes, such that the upper end of the span of the low-frequency mode co-occurring with the lower end of the span of the high-frequency mode. This encompass the effective span of the oscillator .Since the frequency span required in each mode is compressed; the concession between voltage range and phase noise for varactor-based tuning is placid. Two or more distinct oscillators can also be used to alleviate this trade-off. However the use of active core reconfiguration is expected to reduce the potential for variations and mismatches that can arise from the use of two separate oscillators, since these would need individual LC tanks that are physically apart on the IC, and require distinct routing to the circuit driven by the oscillators. The architecture employed here is similar to [3]. However no implementation and measurements were included in [3]. This work also employs a customized spiral inductor or reducing die area. Unlike this work, the active core reconfiguration shown in [2] was employed to generate two widely separated frequencies. Switching that employ different architectures include [4] and [5], that effectively switch mutual inductance of multiple inductors to implement switching mode oscillators; a triple band oscillator with active core switching [6]; and a mode switching oscillator based on switching capacitance [7].The minimum size of the switches that is required to ensure transition from one mode to another is also analyzed. It is important to minimize switch size, since this helps to minimize the associated capacitive parasitic.

II. Switching mode VCO

The proposed switching mode VCO (Fig.1a) employs an NMOS cross-coupled core that is divided into two identical halves. The LC tank consists of an inductor composed of sections $L1$, $L2$ and $L3$. The mutual inductance in these inductors initially neglected. The oscillator is configured in one of two modes through the use of switches $SW1$ and $SW2$. In one of the switching $SW1$ is OFF and $SW2$ is ON (Fig. 1b). In this mode, the voltages at both sides are identical to each other so that $L1$ current will pass and

International Journal of Research

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avoids overall inductance. The contour can be represented by two identical *LC* based VCOs in parallel, with an effective tank inductance

$$L_L = L2 + L3.$$

If the capacitance within each half core is given by *C*, then the center frequency of oscillation will be

$$\omega_L = 1/2(L3 + L2)C$$

represented as common-mode (CM) configuration. In the second mode, *SW*1 is ON and *SW*2 is OFF (Fig.1c). The current flowing is180° out of phase with the same magnitudes, placing an ac ground in the middle of the *L*1 sections. The effective inductance in this mode will be

$$L_H = (L_1 - L_2) + L3$$

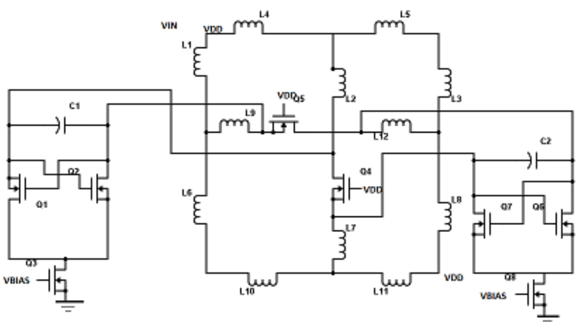

Fig.1.common mode operation of vco

With a corresponding oscillation frequency of

$$\omega_H = \frac{1}{2}\{(L_1 \_ L_2) + L_3\}C$$

represented as differential-mode (DM) configuration. The ratio of the oscillation frequencies in the two modes is given by

$$\frac{W_L}{W_H} = \frac{(L_1 \; - L_2 \;) + L_3}{L_2 + L_3}$$

Through proper scaling of inductors, a rigorous ratio between ω_L and ω_H can be achieved. Since in either mode the voltage across the switch terminals is identical, the switches do not contribute to the tank loss [3]. Under the imagination that the impact of mutual inductance is ignored. The required tuning range around the formal frequency can be split into two overlapping halves. Then the tuning required per mode is also nearly divided, which relaxes the voltage-range vs. phase noise trade-off. It is also possible to employ a capacitor bank along with the varactor, in order to reduce the VCO gain (K_{VCO}), which helps to enhance the phase noise.

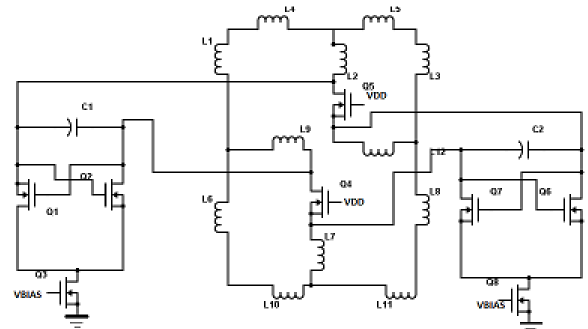

fig. 2.differential mode of vco

III.DESIGN CONSIDERATION

The low frequency flicker noise affects the phase noise because the flicker noise is heterodyned to the oscillator output frequency due to the active devices non-linear transfer function. The effect of flicker noise can be reduced with negative feedback that linearizes the transfer function is

$$H\,(f) = \frac{K}{C_{OX}\, W_L\, f}$$

Where *K* is the process-dependent constant, C_{ox} is the oxide capacitance in MOSFET devices, *W* and *L* are channel width and length respectively.

The instantaneous frequency of a switching VCO is often modelled as a linear relationship with its instantaneous control voltage

$$f(t) = f_{0} + K_0 \,.V_{in}\,(t)$$

$$\theta(t) = \int_{-\alpha}^{t} f(t)dt$$

f (t) is the instantaneous frequency of the oscillator at time t,f_0 is the quiescent frequency of the oscillator K_0 is called the oscillator sensitivity, or gain. Its units are hertz per volt. $f(t)$ is the VCO's frequency $\theta(t)$ is the VCO's output phase.

SWITCHING MODE ANALYSIS:

For analysing the resistor values designed in the circuit we have to calculate the approximate resistor values by

$$\frac{1}{R_L} = \frac{1}{R_{L,ind}} + \frac{1}{R_{L,cap}}$$

$$\frac{1}{R_H} = \frac{1}{R_{H,ind}} + \frac{1}{R_{H,cap}}$$

The switching analysis of VCO will form losses in inductors and capacitors which are represented by R_L, RH.

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Where R^1_H ,R^1_L are the losses of capacitors and resistors in differential switching

$$\frac{1}{R^1{}_L}=\frac{1}{R_{L,ind}}+\frac{1}{R_{L,cap}}+\frac{2}{R_d}$$

$$\frac{1}{R^1{}_H}=\frac{1}{R_{H,ind}}+\frac{1}{R_{H,cap}}+\frac{2}{R_c}$$

The current which will pass into inductor &voltage across capacitor in high frequency mode i,e differential switching is

$$\frac{d}{dt}(2c.v_L)= -i_L - F_L - \frac{V_L}{R_L}$$

$$L_L.\frac{d}{dt}i_L = V_L$$

$$\frac{d}{dt}(2c.v_H)= -i_H - F_H - \frac{V_H}{R_H}$$

$$L_H.\frac{d}{dt}\ i_H = V_H$$

By the Vander Val approximation the common mode and differential mode switching state equations of amplitude is measured as

$$\frac{d}{dt}A^2L=\frac{a_1-\left(\frac{1}{R_C}\right)}{2C}.A^2L - \frac{3}{8}\frac{a_3}{C}.A^4L-\frac{3}{4}\frac{a_3}{c}.A^2L.A^2H$$

$$\frac{d}{dt}A^2H=\frac{a_1-\left(\frac{1}{R_C}\right)}{2C}.A^2H - \frac{3}{8}\frac{a_3}{C}.A^4H-\frac{3}{4}\frac{a_3}{c}.A^2L.A^2H$$

COMMON-MODE TO DIFFERENTIAL-MODE SWITCHING:

In steady-state CM operation, with *SW*1 OFF and *SW*2ON, the LHS of (9) is zero and *AH* = 0. Thus

$$0=\frac{a1-(1\div RH).A^2H}{2c}-\frac{3}{8}.\frac{a3}{c}.A^4H-\frac{3}{4}.\frac{a3}{c}.AL^2.AH^2$$

$$=4\left(a1-\frac{1}{RH}\right)-3a3.A^2H-6a3.AL^2 \qquad (12)$$

$$\left(a1-\frac{1}{RH}\right)-\frac{3}{4}.a_3.AH^2-\frac{3}{2}a_3.A^2L>0$$

$$R_d < \frac{4}{a_1+\frac{1}{R_H}-\frac{2}{R_L}}$$

Where Rd is the on-resistance of the differential switching

DIFFERENTIAL-MODE TO COMMON-MODE SWITCHING:

$$0=\frac{a1-(1\div RL).A^2L}{2c}-\frac{3}{8}.\frac{a3}{c}.A^4L-\frac{3}{4}.\frac{a3}{c}.AL^2.AH^2$$

$$= 4\big(a1-(1\div RL)\big)AL^2-3(a3)AL^4$$

$$=4a1AL^2-4(1\div RL)AL^2-3a3AL^4$$

$$=4a1-4(1\div RL)=3a3AL^2$$

$$=4\big(a1-(1\div RL)\big)=3a3AL^2$$

$$= a1-(1\div RL)=\frac{3}{4}\ a3.AL^2$$

$$= a1-\frac{1}{RH}-\frac{3}{4}a3.AH^2-\frac{3}{2}a3.AL^2>0$$

$$R_C < \frac{4}{a_1+\frac{1}{R_H}-\frac{2}{R_L}}$$

Where AL= Amplitude of the low frequency mode
AH=Amplitude of the high frequency mode
RL=Total shunt losses of the low frequency mode
RH=Total shunt losses of the high frequency mode
Rd=on resistance of the differential mode
Rc= on resistance of the common mode

SCHEMATIC TOPOLOGY OF SWITCHING VCO:

Novelty in this design is shown as the switching mode vco which is operated in two different modes where the frequency balancing is done using this unique kind of vco, As one mode will give high frequency up to 75.3GHz and the former one will give the low frequency starting with 64.3GHz which will made the design flexible to all robust conditions the execution of common mode configuration is shown in fig (3), as the schematic is modelled using ADS simulation The measured tuning range in the two modes is 56.9-65.4 GHz and 64.6-75.3 GHz

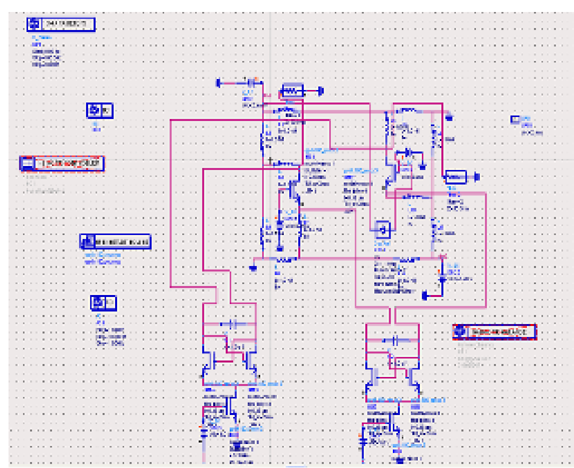

Fig .3. Common mode switching of vco

The differential pair of transistors which is attached to the bulk of paired inductors with couple of capacitors is configured into common mode switching which is operated in low frequency i.e. from ,The oscillations with measured tuning range from 64.3 to75.6GHz

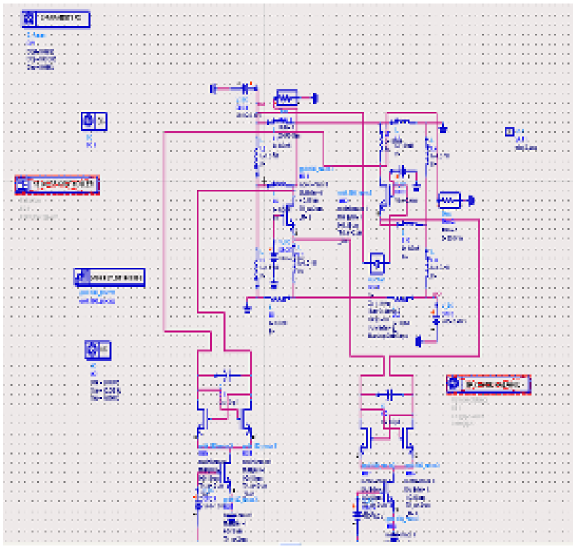

Fig.4. Differential mode switching VCO

Oscillation ports are placed at the two voltage biasing to measure the transient analysis of the schematic and also to evaluate the frequency variations, eliminating the phase noise by developing the immune noise figure which will avoid uncertain disturbances.

TABLE I

PARAMETER	VALUE
NF	0.05dB
S_{11}	<-10dB
TECHNOLOGY	0.18µm

Fig.5. Tabular form of simulated results

5. SIMULATION RESULTS

The oscillating frequency of the common mode and differential mode switching will varies according to the given Vdc where the voltage controlled oscillator will generate noise free sine wave transient analysis

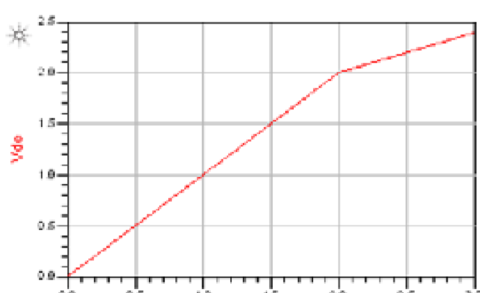

Fig.6. variations of frequency vs bias voltage

Transient analysis will show the oscillations of the switching mode vco

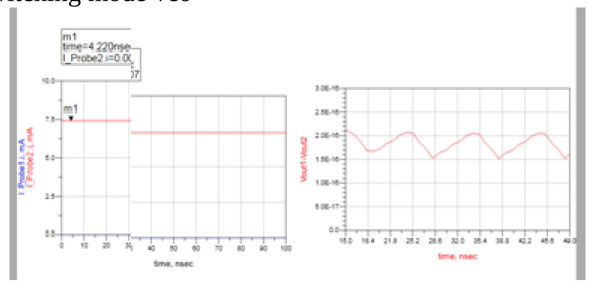

Fig.7.Transient analysis of VCO

The noise factor is the ratio of actual output noise to that which would remain if the device itself did not introduce noise, or the ratio of input SNR to output SNR.

The s-paramters obtained using the proposed oscillator have matching between S(1,2),S(2,1) and the S(1,1) should be more than -10 dB

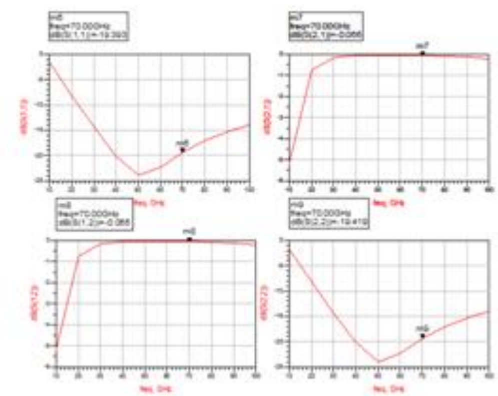

fig.8. S-parameter calculation of proposed vco

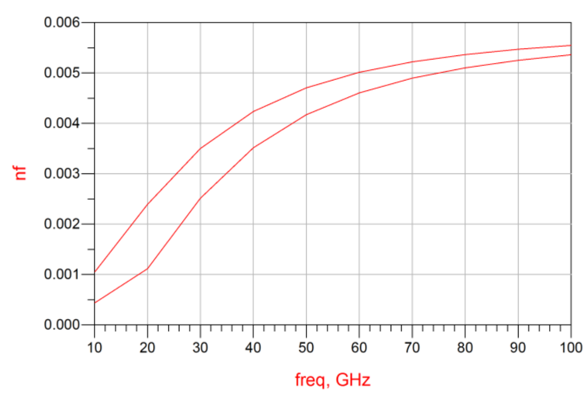

Fig.9.Noise figure of vco

The noise figure of the switching proposed VCO is 0.05dB shown in fig (9) at the measured frequency of 67.8GHz where the noise is eliminated from the oscillator.

The measured DC power of the VCO core excluding output buffers was 13 mW from a 2.5V supply, which is comparable to the state-of-the-art performance

6. CONCLUSION

A switching mode reconfigurable VCO is demonstrated here using 0.18um technology in ADS simulation, the large frequency span helps to mitigate the impact of variability, which can pose a significant challenge in mm-wave designs. The phase noise is compressed even though at high frequency operation and a less distortion oscillations are generated.

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