A 130-GHz 0.18-μm CMOS VCO with Enhanced Output Power

To-Po Wang, Yu-Zhang Nian

Abstract*— A 130-GHz cross-coupled push-push voltage-controlled oscillator (VCO) with enhanced output power is proposed in this paper. CMOS VCOs in millimeter-wave (mm-wave) frequency are typical with low output power due to the intrinsic characteristics of MOSFETs. In order to overcome the difficulty, the push-push signal (2fo) are extracted from the middle of inductors and combined with another extracted 2fo signal from the middle of varators. Therefore, the output power can be effectively increased. According to the proposed circuit topology, the 130-GHz VCO has been designed in 0.18-□m CMOS process. Simulated results confirm the 130-GHz VCO combing the proposed output power enhancement technique can effectively increase the output power up to 2.8 dB. Operating at 1-V supply voltage, the VCO core consumes 11.1-mW dc power. Moreover, the VCO's frequency ranges from 125 GHz to 130 GHz, leading to a 4% tuning range. Furthermore, the phase noise of the proposed VCO is -91.9 dBc/Hz at 1-MHz offsets from 130-GHz carrier.

***Index Terms*—phase noise, push-push, voltage-controlled oscillator (VCO).**

I. INTRODUCTION

Researches toward higher frequency bands ranging from millimeter-wave (mm-wave) band to Terahertz (THz) frequency are reported [1]-[16]. For wireless transceiver systems, the VCO is one of the most critical function blocks. It takes effects on system performance in terms of tuning range, phase noise, dc power consumption, signal-to-noise ratio (SNR), and sensitivity. Therefore, designing VCOs with wide tuning range, low phase noise, low voltage, low dc power dissipation, and high output power is a challenging task.

In [1]-[5], reports about noninvasive active and passive imaging, chemical and biological spectroscopy, and short-range radars are included. While operating in THz frequency range, considerations of tunable, high output power, and high energy efficiency for a signal source are required [6]-[8]. In [9]-[10], CMOS oscillators with fundamental frequencies up to the mm-wave range have been reported. However, they are with poor VCO phase noise and strict startup condition. To overcome the difficulties, injection-locking technique can be adopted to minimize VCO frequency and phase fluctuation [11]-[14]. However, additional high-quality signal sources are required for the injection-locking technique.

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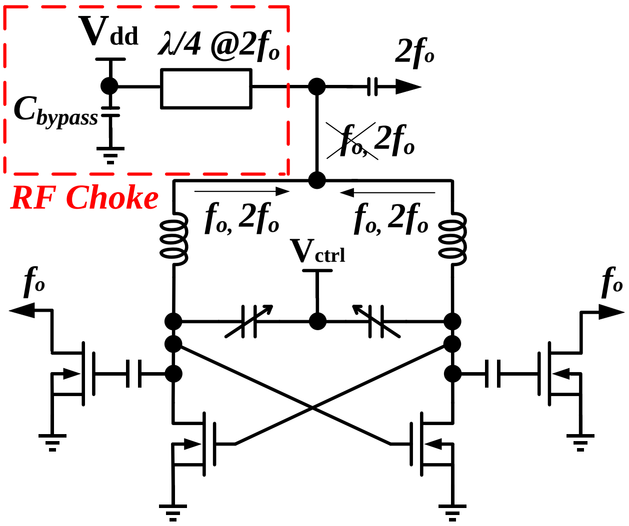

Fig. 1. Circuit topology of the regular push-push VCO.

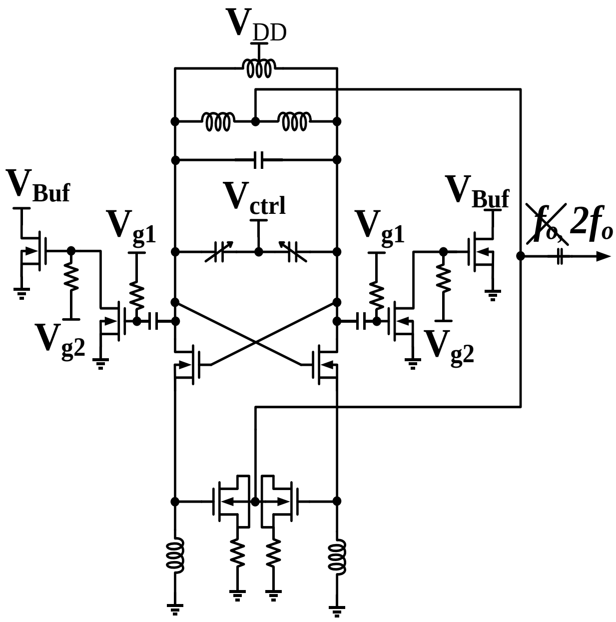

Fig. 2. Schematic of the proposed 130-GHz push-push VCO with enhanced output power.

To improve the quality factor of passive components and eliminate additional signal sources, micromachined inductors can be used [15]. Due to the high-quality passives, the VCO phase noise can be improved. However, this solution requires additional post-CMOS processes, resulting in challenges for predicting the circuit performance and product yields.

In this work, a 130-GHz VCO with enhanced output power has been designed in 0.18-μm CMOS. The push-push signal ($2f_o$) are extracted from the middle of inductors and combined with another extracted $2f_o$ signal from the middle of varators. Therefore, the output power can be effectively increased.

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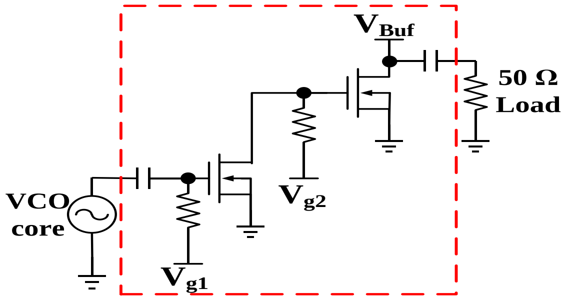

Fig. 3. Proposed VCO buffer.

II. PROPOSED VCO

Push-push technique can be used to mm-wave VCO designs due to the advantage of the enhanced 2nd harmonic signals. Fig. 1 shows a regular push-push VCO. The VCO core consists of a cross-coupled pair and an LC tank. The push-push signal ($2f_o$) is extracted from the middle of the circuit structure, while the fundamental signal (f_o) is cancelled at the common node. However, an RF choke, consists of a bypass capacitor and a one-quarter wavelength ($\lambda/4$) microstrip or coplanar waveguide (CPW) line, is required to provide high impedance and a dc current path at the frequency of $2f_o$. However, it takes a large chip area of several hundreds of micrometers in length to implement the $\lambda/4$ microstrip or coplanar waveguide (CPW) line in a silicon process [16].

To overcome the difficulties, a 130-GHz VCO with enhanced output power is proposed, as shown in Fig. 2. The push-push signal ($2f_o$) are extracted from the middle of inductors and combined with another extracted $2f_o$ signal from the middle of varators. Therefore, the magnitude of the push-push signal ($2f_o$) can be effectively improved. In order to minimize VCO load effects, two-stage common-source MOSFETs are proposed as VCO buffer, as shown in Fig. 3. The device size of the first stage is minimized to reduce the VCO loading effect on the LC tank. In addition, the device size of the second stage is enlarged to increase VCO the output voltage swing and output power.

III. SIMULATION RESULTS

The proposed 130-GHz VCO with enhanced output power has been designed in 0.18-µm RF CMOS process. The supply voltage of the VCO is 1 V, and the dc power consumption of the VCO core is 11.1 mW. The simulation is performed by using circuit simulator Agilent's Advanced Design System (ADS). Moreover, passive components including the inductors, capacitors, and interconnections are considered by adopting the full-wave electronic-magnetic (EM) simulation tools, Sonnet and HFSS.

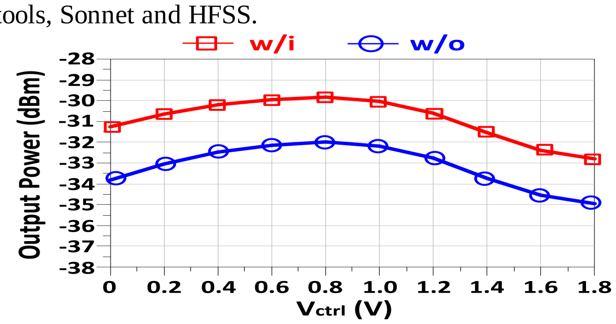

Fig. 4. Simulated VCO output power with and without the proposed output power enhancement technique.

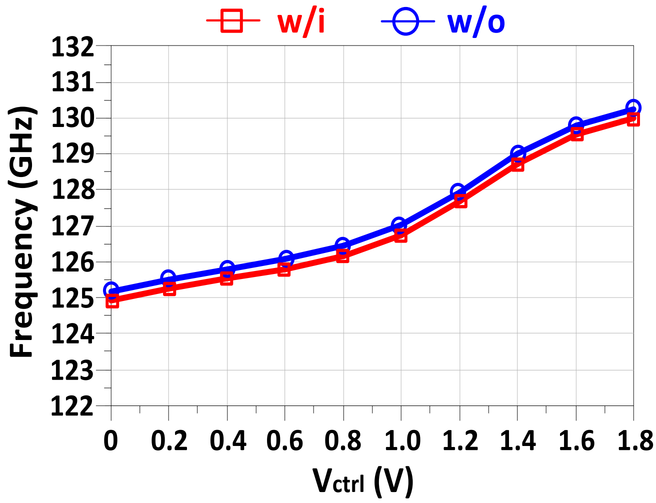

Fig. 5. Simulated VCO frequency with and without the proposed output power enhancement technique.

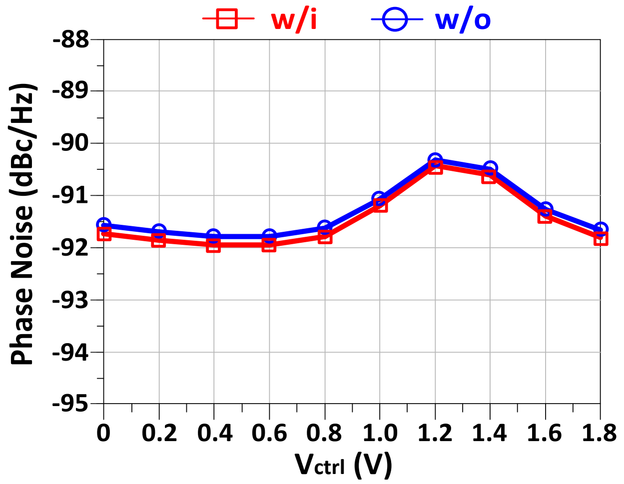

Fig. 6. Simulated VCO phase noise with and without the proposed output power enhancement technique.

Fig. 4 shows the simulated VCO output power with and without the proposed output power enhancement technique. From this figure, it is observed that the improvement of the VCO output power can be improved about 2.8 dB. Moreover, the simulated VCO frequency with and without the proposed output power enhancement technique is depicted in Fig. 5. From this figure, it is indicated that the tuning frequency is from 125 to 130 GHz, leading to a 4% tuning range. Fig. 6 illustrates the simulated VCO phase noise with and without the proposed output power enhancement technique. From this figure, it is observed that the phase noise of the proposed VCO is -91.9 dBc/Hz at 1-MHz offsets from 130-GHz carrier.

To characterize the VCO performance, the widely used figure of merit (FOM) and figure of merit including the tuning range (FOM_T) [16] are adopted in this work. The FOM and FOM_T are written as

$$FOM = L(\Delta f) - 20\log_{10}\left(\frac{f_o}{\Delta f}\right) + 10\log_{10}\left(\frac{P_{DC}}{1mW}\right) \quad (1)$$

$$FOM_T = L(\Delta f) - 20\log_{10}\left(\frac{f_o}{\Delta f}\cdot\frac{Tuning\ Range}{10}\right) + 10\log_{10}\left(\frac{P_{DC}}{1mW}\right) \quad (2)$$

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where $L(\Delta f)$ is the VCO phase noise, Δf is the offset frequency, f_o is the carrier frequency, and P_{DC} is the dc power consumption. From (1) and (2), the proposed 130-GHz is with FOM and FOMT of -183.7 dBc/Hz and -175.7 dBc/Hz, respectively.

IV. CONCLUSION

The 130-GHz VCO with enhanced output power is proposed in this paper. The push-push signal ($2f_o$) are extracted from the middle of inductors and combined with another extracted $2f_o$ signal from the middle of varators. Therefore, the output power can be effectively increased. In addition, two-stage common-source MOSFETs are proposed as VCO buffer. The device size of the first stage is minimized to reduce the VCO loading effect on the LC tank. In addition, the device size of the second stage is enlarged to increase VCO the output voltage swing and output power. According to the proposed circuit topology, the 130-GHz VCO has been designed in 0.18-μm CMOS process. Simulated results confirm the 130-GHz VCO combing the proposed output power enhancement technique can effectively increase the output power up to 2.8 dB.

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