Design of a Low-Phase-Noise 70-/105-GHz Dual-Band VCO With Common Mode Resonance Expansion

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December 23, 2024

Abstract

This article presents the design of a CMOS-based voltage-controlled oscillator (VCO) operating in both V- and W-bands by fully utilizing the harmonics in Class-F23 tank. An auxiliary common mode (CM) resonance is introduced to Class-F23 structure via a transformer for CM resonance expansion. This transformer serves dual functions, also generating the second harmonic output, thereby enhancing the area efficiency. The proposed CM resonance expansion suppresses the flicker noise upconversion in a wideband without manual harmonic tuning. A Class-F23 VCO without CM expansion is designed and fabricated for comparison. Besides, the challenges in high-frequency harmonic extraction are highlighted and addressed. The proposed VCO is fabricated using 40-nm CMOS technology.

1 Introduction

Development of high-performance millimeter-wave voltage-controlled oscillators (VCOs) is important for future radar and communication systems. Short-range, highspeed communication systems operate within the V-band, while long-range radar systems typically utilize the W-band. Recently, multi-band VCOs have demonstrated considerable potential for future multifunctional transceiver systems, effectively harnessing spectrum resources. For example, a 28-/39-GHz dual-band transceiver has been proposed [1], which required a VCO operating at both 28 and 39 GHz. In comparison to design an ultra-wideband VCO, our proposed dual-band VCO exhibits better power consumption, phase noise (PN) performance, and area efficiency.

The most common way to design a dual-band VCO is to switch different oscillation cores [2], [3], [4], [5], [6], [7], [8], [9], [10]. This method demands two pairs of transistors and inductors, along with a switch to toggle between high- and low-frequency bands. However, when it comes to high-frequency dual-band VCO design, this method poses challenges. First, the switch significantly deteriorates the quality (Q) factor of resonators and PN. Second, multiple oscillation cores consume a large area, and the coupling effect between multiple resonators is not negligible. In addition, the PN analysis of dual-band VCOs often focuses on the Q factor improvement and lacks numerical analysis of flicker noise.

2 PROPOSED CM EXPANSION

2.1 Limitations on Class-F23 VCO

A conventional Class-F23 tank is shown in the red dotted box of Fig. 1(a). The transformer demonstrates an implicit CM resonance at 2 $f0$ and a differential mode resonance at both $f0$ and 3 $f0$, as shown in Fig. 1(b). These resonant frequencies are determined by two ratios, denoted as $X1$ (= $(CP + Ct)/CS)$ and $X2$ (= $Ct\ /Cp)$ [12]. However, to meet the two specified ratios for $X1$ and $X2$, Ct , Cp, and Cs all must be adjustable. This introduces significant challenges in harmonic tuning and constrains the tuning range.

2.2 Implementation of Wideband CM Expansion

Use the table and tabular environments for basic tables — see Table **??**, for example.

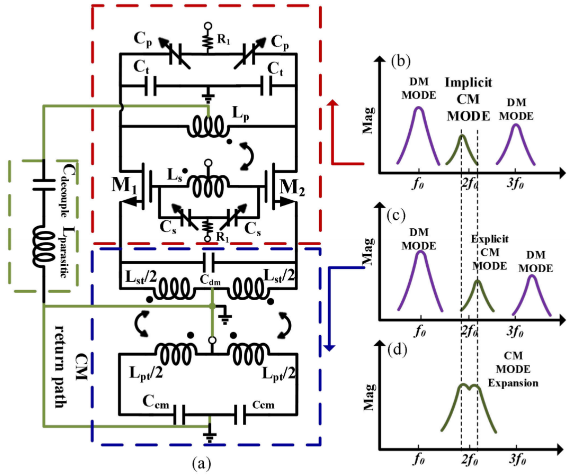

Figure 1: (a) Schematic of the proposed CM expansion. (b) Magnitude of $Z11$ of the Class-F23 transformer. (c) Magnitude of $Z11$ of the CM expansion transformer. (d) Magnitude of $Z11$ of the expanded CM resonance.

CM Resonant Frequency(GHz)		58	71	75
With CM Expansion				
Without CM Expansion				

Table 1: SIMULATED AND CALCULATED PN

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2. and like this.

. . . or bullet points . . .

- Like this,
- and like this.

2.5 How to write Mathematics

LaTeX is great at typesetting mathematics. Let $X_1, X_2, \ldots, X_n$ be a sequence of independent and identically distributed random variables with $\mathrm{E}[X_i] = \mu$ and $\mathrm{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \cdots + X_n}{n} = \frac{1}{n}\sum_{i}^{n} X_i$$

denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.

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We hope you find Overleaf useful!

References

[Gre93] George D. Greenwade. The Comprehensive Tex Archive Network (CTAN). *TUGBoat*, 14(3):342–351, 1993.