

Study on Improving the Phase Noise of Broadband Voltage-Controlled Oscillator

Min-Ho Go* · Hyoung-Joo Kim

Abstract

This paper proposes a voltage-controlled oscillator (VCO) that has broadband tuning and low-level of phase noise characteristics. Due to the micro-strip line resonant circuit with a low Q value, which is applied to the broadband tuning range, the depreciated phase noise performance is compensated by restraining the harmonics of the oscillating frequency. The VCO was designed according to the proposed structure as well as the conventional structure, and the superiority of the proposed structure was verified through its simulation, fabrication, and measurement.

Key Words: Broadband, Harmonic Suppression, Phase Noise, VCO.

I. INTRODUCTION

Designing a voltage-controlled oscillator (VCO) with a broadband tuning bandwidth is very important for many communication and radar systems. There have been many studies promoting a VCO with broadband and low phase noise characteristics [1]. To realize the low phase noise characteristic, the resonant circuit with a high Q value has to be used; however, this method decreases tuning bandwidth. If a special high Q resonant circuit, such as the Yttrium Iron Garnet (YIG), is applied, it is possible to achieve a VCO with low phase noise and a broad tuning bandwidth. Such a VCO type is difficult to integrate with other circuits and needs large-scale power consumption.

Therefore, this paper proposes the use of a VCO-applied coupling structure resonant circuit to realize broadband and low phase noise characteristics. It is verified by comparing its characteristics with general structures of VCOs.

II. DESIGN AND MEASUREMENT

This study applied a low micro-strip line resonant circuit with a low Q value to satisfy the broadband tuning characteristic. However, the resonant circuit decreases the phase noise characteristic [2, 3]. Due to its nonlinear characteristic, the phase noise of the actual oscillator is the sum of $1/f$ noise of the active element and the downward transformation of white noise in all the harmonic bands of the frequency [4].

In other words, the phase noise characteristic can be improved by restraining the harmonics signal generated by the oscillator. Fig. 1(a) shows the VCO structure proposed in this study. To restrain the harmonics component of the active element, it produces the oscillating signal from the coupling structured resonant circuit. Compared with the conventional case, where the oscillating signal is generated from the nonlinear active element (as in Fig. 1(b)), the proposed structure has a superior harmonics suppression performance, resulting in

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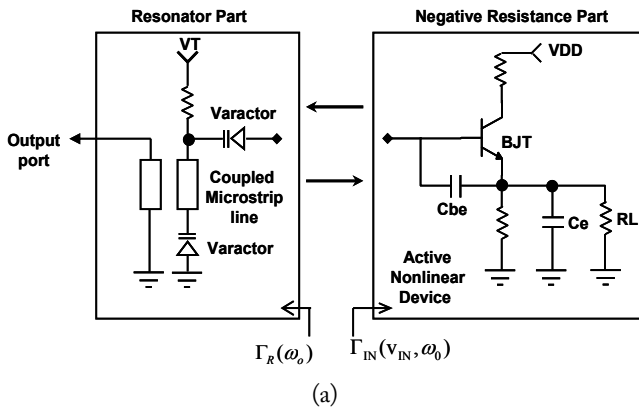


Fig. 1. VCO configuration: (a) proposed, (b) conventional.

a relatively improved phase noise performance.

To compare the restraint of the harmonics and the improvement of the phase noise characteristic of the proposed structure, the circuit composition was fabricated to be the same as the conventional structure except for the resonant circuit structure. Both structures were also designed the same way. They have a negative resistance and a resonant circuit to satisfy the oscillating conditions. This makes the reflection coefficient of the negative resistance at $1/\Gamma_{IN}(V_{IN}, \omega_0)$, and the reflection coefficient of the resonant circuit at $\Gamma_R(\omega_0)$, orthogonal with the optimal phase noise characteristic [5]. Since the proposed structure has its output in the coupling structure, its output level is lower than the conventional structure. It generates the nonlinear difference from the active element. The load impedance (Γ_{LOAD}) of the proposed structure is determined by the load-pull analysis so that the output power is to be a similar to that of the conventional structure.

Fig. 2 shows a diagram of the proposed VCO's entire structure. For the design and circuit simulation, Agilent Technologies ADS 2014 was used. The BFP405 of infineon was utilized for the active element in the negative resistance, and Infineon's BB837 was used for the varactor diode.

To produce the conventional and proposed structures, an

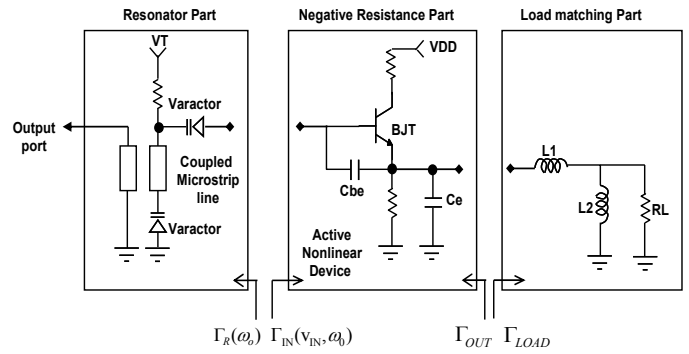


Fig. 2. Diagram of the proposed VCO structure.

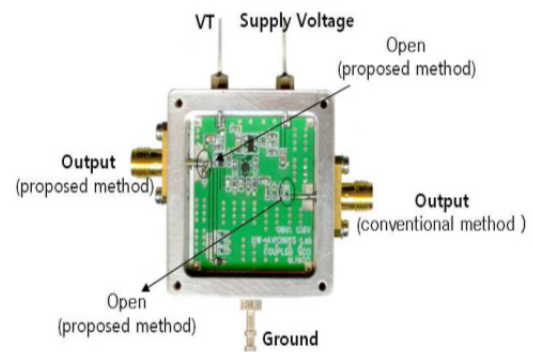
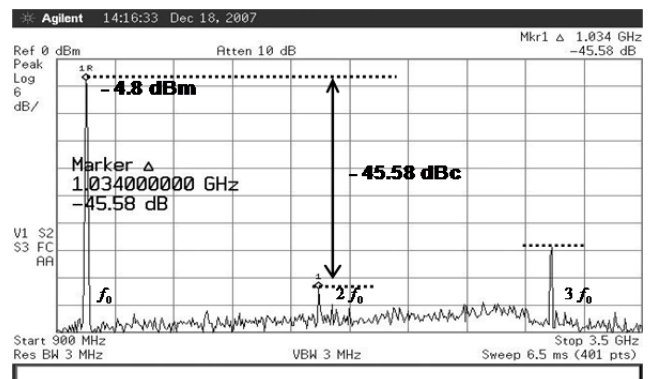
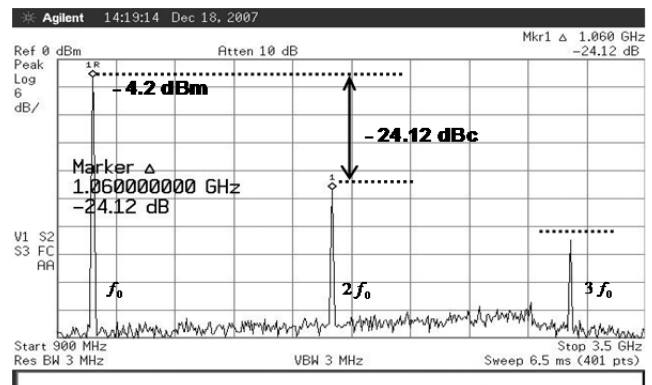


Fig. 3. Photograph of the proposed VCO.



(a)



(b)

Fig. 4. The harmonics suppression performance: (a) proposed, (b) conventional.

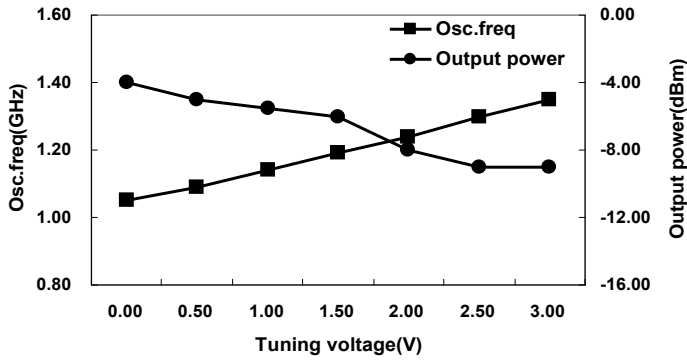


Fig. 5. Tuning range and output power of the proposed VCO.

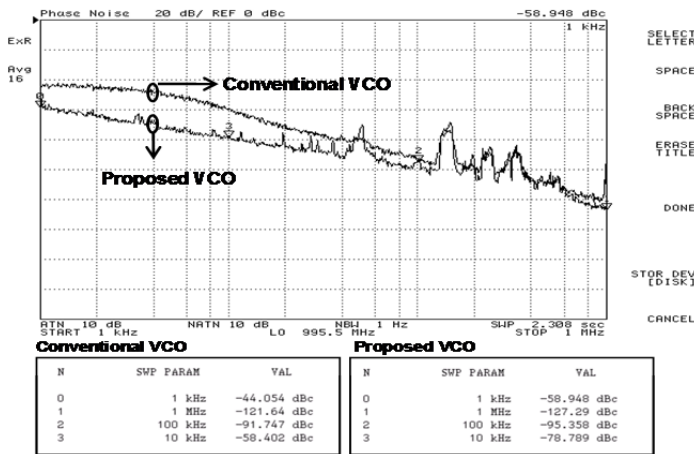


Fig. 6. The measured phase noise performance.

FR4 plate with a relative dielectric constant of 4.6 and thickness of 1.0 was used. Fig. 3 shows a real picture of the proposed structure that was manufactured for the experiment.

Fig. 4 shows the harmonics restraint characteristic of the VCO. Fig. 4(a) shows the harmonics restraint characteristic of the proposed structure; and Fig. 4(a) shows a -45 dBc of the second harmonics restraint characteristic and a -38 dBc of the third harmonics restraint characteristic. On the other hand, the conventional structure in Fig. 4(b) shows a -24 dBc of the second restraint characteristic and a -35 dBc of the third harmonics restraint.

Fig. 5 shows the oscillating frequency according to the tun-

ing voltage of the proposed structure and the output power performance of the proposed structure. It shows 100 MHz/V of the broadband tuning characteristic. The change of output power shows a change of about -6 dB. This is seen as a difference according to the coupling characteristic by the frequency of the coupling structure resonant circuit.

Fig. 6 shows the phase noise characteristic measured by the 4352B (Agilent) VCO/PLL analyzer. The proposed structure shows more than 15 dB of phase noise improvement than the conventional structure on the offset frequency close to the carrier.

III. CONCLUSION

To improve the phase noise characteristics by reducing the harmonic component, this paper proposed a structure that enables the elimination of the harmonic component. Through the design, fabrication, and measurement of this VCO that has a broadband tuning range and a low-level phase noise, its superiority was proven.

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