

Phase-Noise Improvement and Harmonic Suppression of Microwave Feedback Oscillator

Muhyin Daud and Chao-Hsiung Tseng

Abstract— This paper presents a low phase-noise feedback oscillator using a harmonic suppressed ring resonator. The proposed resonator has harmonic suppression more than 41 dB at harmonic frequencies. Since the proposed resonator has the 2nd and 3rd harmonic suppression characteristics, the phase noise of the developed oscillator can be significantly improved about 10 dB at 100-kHz offset frequency as compared with that of the conventional one.

Index Terms—Harmonic suppression, microwave oscillator, ring resonator, shunt-stub-based resonator.

I. INTRODUCTION

Phase-noise is a critical performance parameter of a microwave oscillator. Referring to [1], the noise components located near the higher harmonic frequencies are transformed to low frequency noise sidebands, which then become a close-in phase-noise spectrum. Therefore, as the noise components contributed from higher harmonic frequencies can be effectively eliminated, one can achieve a better phase-noise performance. This approach can be realized by employing a harmonic-suppressed technique to design a low phase-noise oscillator, which has been demonstrated in [2]-[5].

In [2], [3], and [5], the authors use different type of resonators and open-stub structure to provide the harmonic suppressions. In [4], two parallel LC resonators are connected at the bilateral ends of the conventional tunable LC tank to form a harmonic tuned LC tank. However, this harmonic suppression will enlarge the circuit size. For published works, only authors in [2] and [4] demonstrate the phase noise improvement of less than 10.5 dB. Moreover, all of previous works lack a quantitative method to analyze and explain the phase-noise improvement.

In this paper, a shunt-stub-based (SSB) ring resonator is proposed to treat as a frequency selective element embedded into the feedback loop of the oscillator. The SSB ring resonator not only reduces a circuit size of 82 % as compared with the conventional one, but also provides the 2nd and 3rd harmonic suppressions more than 41 dB. The developed oscillator using the SSB ring resonator achieves better phase noise performance than [3]-[5] at 100-kHz offset frequency and improves about 10 dB as compared with that using the conventional ring structure. However, the complete work and

the quantitative analysis using impulse sensitivity function (ISF) of this phase noise improvement has been published in [6]. In [6], the author has explained that the ISF coefficients, c_2 and c_3 , of the proposed oscillator are smaller than the conventional one. This represents the harmonic noise of the proposed oscillator is effectively eliminated.

II. OSCILLATOR DESIGN USING SSB RING RESONATOR

The oscillator is developed based on the feedback circuit configuration and here, the SSB ring structure is composed of four 90° SSB artificial transmission lines which can be synthesized by the design equations in [7]. The calculated circuit parameters are determined as $Z_{se}=112 \Omega$, $Z_{sh1}=78.5 \Omega$, $Z_{sh2}=71.9 \Omega$, $\theta_{se}=24^\circ$, $\theta_{sh1}=10.4^\circ$, and $\theta_{sh2}=26.1^\circ$. At the design frequency, $f_0 = 2.5$ GHz, the SSB resonator only occupies a 28% circuit area of the conventional one.

Fig. 1 shows the transmission responses, $|S_{21}|$, of the conventional and SSB resonators simulated by Agilent Momentum. Compared with the conventional ring resonator, the SSB resonator provides 46-dB 2nd harmonic and 41-dB 3rd harmonic suppressions. Based on the phase-noise theory in [1], as a harmonic-suppressed resonator is employed to design an oscillator, one can achieve a better phase noise performance than that using a conventional resonator.

To obtain a stable oscillation, the feedback oscillator should be designed to satisfy the “Barkhausen oscillation criteria”, namely the loop gain of the oscillator must be greater than unity and the total loop phase should be 0° or multiple of 360°. The circuit photograph of the developed oscillator using the SSB ring resonator is shown in Fig. 2. As shown in Fig. 3, the measured phase noises are measured by Agilent Spectrum Analyzer N9010A. The oscillator using SSB resonator has the phase noises of -104.44 dBc/Hz and -128.68 dBc/Hz at 100-kHz and 1-MHz offset frequencies, respectively. For comparisons, the oscillator using conventional ring resonator has been fabricated and measured, which has phase noises -94.1 dBc/Hz and -120.1 dBc/Hz at 100-kHz and 1-MHz offset frequencies, respectively. It is obvious that a 10-dB phase-noise improvement can be achieved at 100-kHz offset frequency as compared with that of the oscillator using the conventional ring resonator. Moreover, two asymptotes with the slopes of -30 and -20 dB/decade are plotted to reveal the trend of the phase-noise curve. The proposed oscillator has an output power of 0.71 dBm at the oscillation frequency, 2.5

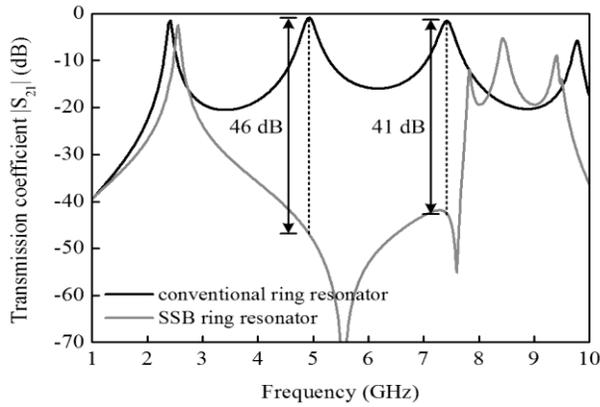


Fig. 1. Simulated transmission responses, $|S_{21}|$, of the conventional and SSB ring resonators.

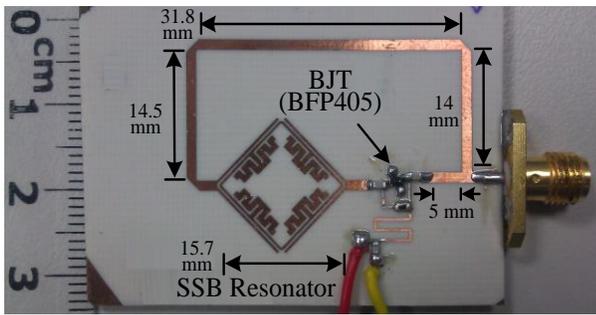


Fig. 2. The circuit photograph of the developed oscillator using the SSB ring resonator

GHz, and consumes a DC power of 20 mW. The figure of merit (FOM) [8] of an oscillator can be calculated by

$$\text{FOM} = L(\Delta f) - 20 \log \left(\frac{f_0}{\Delta f} \right) + 10 \log \left(\frac{P_{dc}}{1 \text{ mW}} \right) \quad (1)$$

where $L(\Delta f)$ is the phase noise at the offset frequency Δf , f_0 is the oscillation frequency, and P_{dc} is the dc power consumption (mW). The FOM of the oscillators using the conventional and SSB resonators at 1-MHz offset frequency are -174.39 dBc/Hz and -183.67 dBc/Hz, respectively.

III. CONCLUSION

In this paper, the SSB ring resonator is proposed to develop a microwave feedback loop oscillator. Since it has the 2nd and 3rd harmonic suppressions, the phase-noise performance of the oscillator has been improved about 10 dB as compared with that using a conventional ring resonator.

IV. NEXT CAREER PLAN

As MTT-S scholarship awardee, I am so motivated to learn microwave related subject. After I graduate from National Taiwan University of Science and Technology, Taiwan in July 2013 for my Master degree in Electronic Engineering, I will

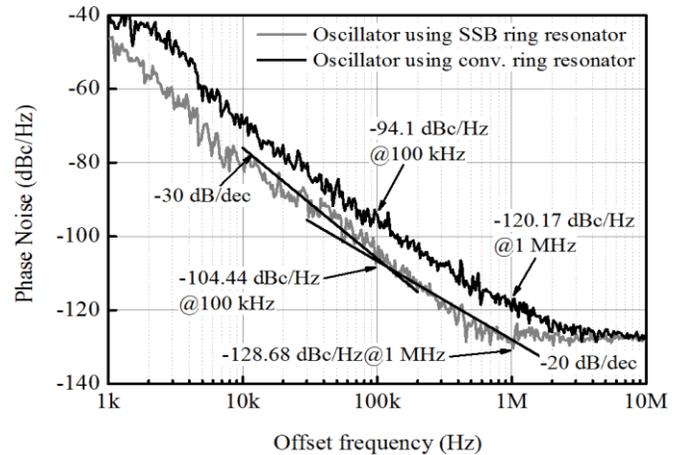


Fig. 3. Measured phase noises of oscillators using conventional and SSB ring resonators.

dedicate my knowledge and my experience into the development of Telecommunication and Electronic industry in my home country, Indonesia. I want to enhance my skill in the area of microwave active and passive components, i.e. oscillator, low noise amplifier, power amplifier, passive isolation component, and antenna. Then, by being an RF engineer for PT. Dua Empat Tujuh (247), Indonesia that develops radar system, I believe that I can learn more and strengthen my skills.

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