Oscillator with High Harmonic Suppression Using Split Quarterwave Microstrip Resonator

Hoyun Cho, Minho Go, Yunhyun Jo, and Hyodal Park

This letter presents a new type of resonator, namely, the split quarterwave microstrip resonator (SQMR), to improve the poor harmonic suppression and low Q-factors in conventional quarterwave microstrip resonators. An oscillator incorporating the proposed SQMR is designed, fabricated, and tested to demonstrate that, not only the second harmonic suppression, but also the phase noise of the oscillator can be improved. The oscillator with the SQMR shows improved second harmonic suppression of –74.59 dBc and phase noise figure of merit of –169.77 dBc/Hz at 1 MHz offset.

Keywords: Quarterwave microstrip resonator, oscillator, harmonic.

I. Introduction

To achieve communication and radar systems with excellent sensitivity and EMI/EMC characteristics, new oscillators having high harmonic suppression and low phase noise have been developed. An oscillator with a three-dimensional dielectric resonator has been widely used for these purposes, although it is expensive, large, and difficult to integrate. Many oscillators with a planar resonator have been proposed to improve the weak points of the dielectric resonator while achieving high Q-factors and superior harmonic suppression characteristics. However, these oscillators with planar structure, such as the split-ring resonator, the compact microstrip resonant cell, and the photonic bandgap, are complicated, bulky, and difficult to design [1]-[3].

This letter proposes a new resonator, namely, the split quarterwave microstrip resonator (SQMR), to improve the poor harmonic suppression performance and the low Q-factor of the quarterwave microstrip resonator (QMR). The new SQMR is simple, compact, and easy to design.

II. Split Quarterwave Microstrip Resonator

Figure 1 shows the resonant characteristics of the short-loaded QMR at the fundamental resonant frequency (f_0) as a function of operating frequency. Advanced Design System was used for the simulation.

Ideally, the QMR operates as a parallel resonant circuit at the desired fundamental resonant frequency (f_0, 5.04 GHz) as well as operating as a series resonant circuit at the second resonant frequency ($2f_0$, 10.08 GHz) by its regenerative properties. However, as shown in Fig. 1, the second resonant frequency occurs at 11.16 GHz, which is shifted about 1.08 GHz in

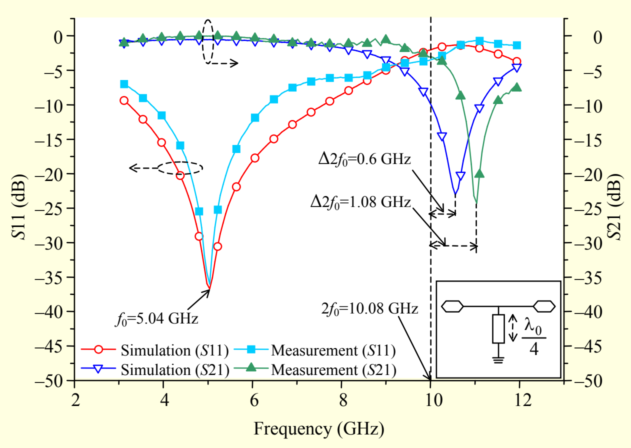

Fig. 1. Structure and resonance characteristics of QMR.

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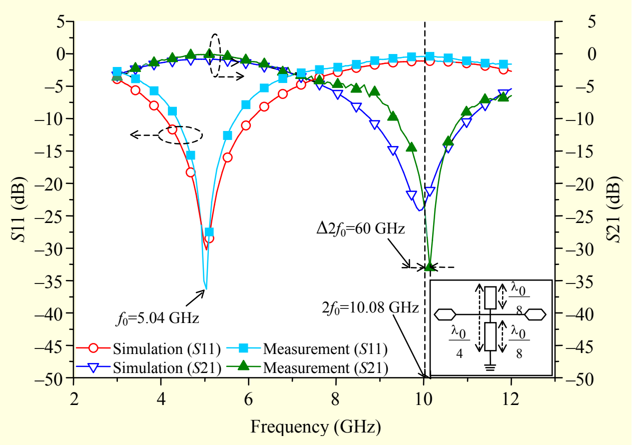


Fig. 2. Structure and resonance characteristics of SQMR.

comparison with the ideal second resonant frequency (2f_0, 10.08 GHz). The generation of the shifted-resonant frequency (Δ2f_0, 1.08 GHz) is caused by an effective dielectric constant, dependent upon the frequency. That is, as the frequency increases, the effective dielectric constant increases. So, the effective length of the microstrip line in the real case is shorter than in the ideal case [4]. As a result, an oscillator with the QMR that has a shifted-resonant frequency (Δ2f_0, 1.08 GHz) will represent a relatively limited harmonic suppression characteristic.

Figure 2 shows the simulation and measurement results of the proposed SQMR structure, which is composed of a parallel connection of a λ/8-open stub and λ/8-short stub. This circuit operates as a parallel resonant circuit at a fundamental frequency (f_0) because the whole length of the resonator is equal to a quarterwave (λ/4). This circuit also operates as a series resonant circuit at the second resonant frequency (2f_0) by the λ/8-open stub. Consequently, the SQMR can minimize a shifted-resonant frequency by adjusting the length of the λ/8-open and short stub (L_O, L_V). The resonant frequencies of parallel and series can be controlled by the length of L_O and L_V, respectively. As a result of the measurements shown in Fig. 2, parallel resonance occurs at the fundamental frequency (f_0, 5.04 GHz), and series resonance occurs at 10.14 GHz, which is shifted about 60 MHz from the ideal second resonant frequency (2f_0, 10.08 GHz). Therefore, an oscillator with the SQMR will have superior harmonic suppression characteristics to that of an oscillator with only QMR. Additionally, the phase noise of an oscillator with the SQMR will be improved because its loaded Q-factor of 31.25 is higher than the loaded Q-factor for the QMR of 20.83.

III. Oscillator with SQMR Design and Measurements

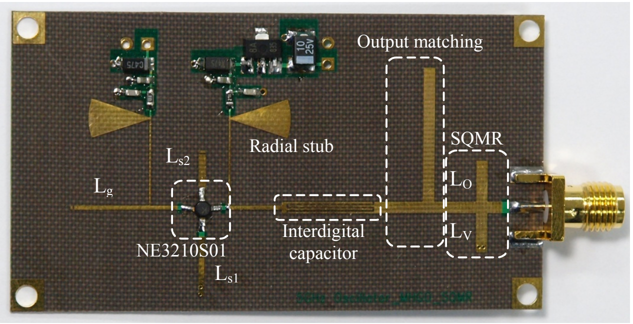
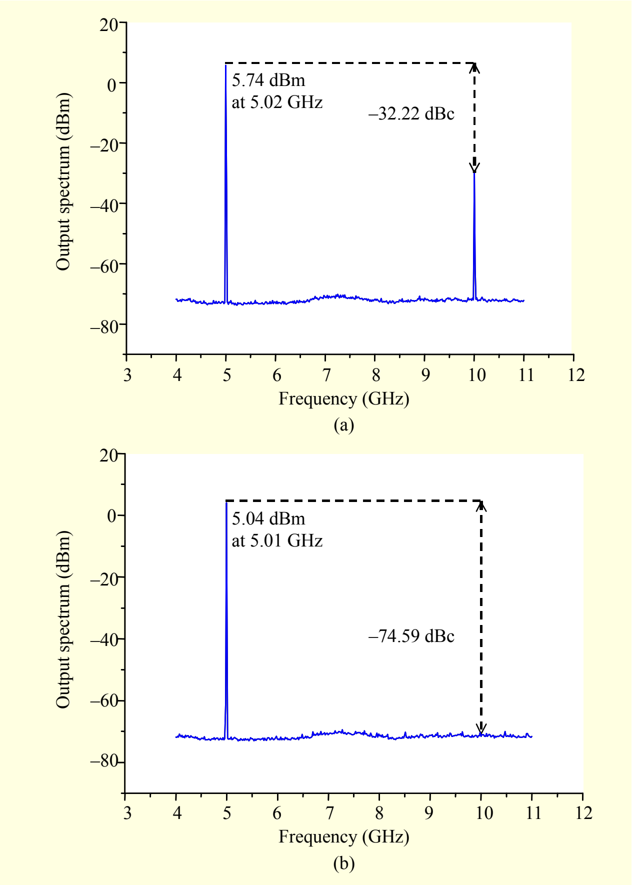


Fig. 3. Photograph of oscillator with SQMR.



(a)

(b)

Fig. 4. Output spectrum characteristics of an oscillator: (a) oscillator with the QMR and (b) oscillator with the SQMR.

Figure 3 shows a photograph of the oscillator with the SQMR. The active device is NE3210S01 (NEC Co., Ltd.), and the bias is determined as drain voltage of 2 V, gate voltage of –0.5 V, and drain current of 11 mA. The microstrip lines at the gate and source ports (L_g, L_{s1}, and L_{s2}) are used to generate a negative resistance, and the lengths of microstrip lines are 13.2 mm of L_g, 8.6 mm of L_{s1}, and 4.8 mm of L_{s2}. The radial stubs at the gate and drain are used for bypassing, and an interdigital capacitor is applied for the DC block. The two-port type resonator, namely, the SQMR, is located after the matching circuit [5]. The dimensions of SQMR are 5.0 mm of L_O and 4.8 mm of L_V.

The oscillator is fabricated on a Teflon substrate with a relative dielectric constant of 2.5, a dielectric substance thickness of 0.5 mm, and a loss tangent of 0.0017. An E4405B spectrum analyzer is used for the measurements.

Figure 4(a) shows the output spectrum of an oscillator with the QMR, with an output power of 5.74 dBm at the fundamental frequency of 5.02 GHz, the second harmonic suppression of –32.22 dBc, a phase noise, and figure of merit (FOM) of –166.06 dBc/Hz at 1 MHz offset. Alternatively, an oscillator with the SQMR, as shown in Fig. 4(b), represents an output power of 5.04 dBm at the fundamental frequency of 5.01 GHz, the second harmonic suppression of –74.59 dBc, and phase noise FOM of –169.77 dBc/Hz at 1 MHz offset.

IV. Conclusion

This letter has proposed the SQMR structure to improve the second harmonic suppression characteristics and the phase noise of an oscillator. Its performance has been verified by application to an oscillator. The proposed SQMR shows a loaded Q-factor of 31.25 at the fundamental resonant frequency (f_0). The SQMR also minimizes the shifted-resonant frequency about 60 MHz at the second resonant frequency ($2f_0$) by proper tuning. An oscillator with the SQMR achieves higher second harmonic suppression and lower phase noise than an oscillator with the QMR. In conclusion, the proposed SQMR can be adapted by systems that require minimum spurious emission and have low-phase noise.

References

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