Corrugated CPW EBG 구조를 이용한 낮은 위상잡음과 향상된 고조파 특성을 갖는 새로운 형태의 발진기

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A Novel Oscillator Utilizing Corrugated CPW EBG Structure with Reduced Phase Noise and Improved Harmonic Characteristics

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Abstract

This paper presents a new microwave oscillator incorporating a corrugated coplanar waveguide (CCPW) electromagnetic bandgap (EBG) structure as its terminating resonance component. The use of a compact CCPW EBG structure was effective in reducing the phase noise and improving the harmonic characteristics of the microwave oscillator circuit without additional backside processing and drastic size increment. The fully planar CCPW oscillator oscillating at the frequency of 5.41 GHz showed a phase noise characteristic of -90.7 dBc/Hz at 100kHz offset and a second harmonic suppression of 42.67 dB.

Key words : EBG, oscillator, corrugated CPW, harmonic suppression, phase noise

I. INTRODUCTION

In the last several yeas, the EBG structure, which has its origin in optics, has successfully applied to the various microwave components such as a power amplifier [1], a filter [2], and an antenna [3]. There also have been many interests in the microwave oscillator application of the structure, and several novel oscillator circuits utilizing the advantages of EBG structure were proposed where planar integration of the chip is primary concern. H.W. Liu *et al.* reported an efficiency improved VCO using defected ground structure (DGS) as a harmonic tuner of the oscillator circuit at the expense of additional chip area [4]. Y.T. Lee *et al.* showed the phase noise

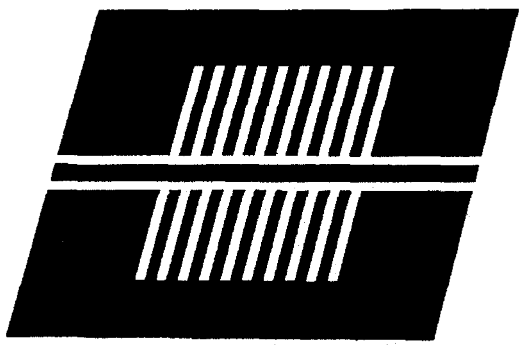


Fig. 1. Corrugated CPW EBG structure.

enhancement of an oscillator using a DGS structure as a resonator component of a conventional oscillator circuit [5]. In their work, they used a DGS as a harmonic suppressor or a novel phase noise reduction component of conventional oscillator circuit.

However, the DGS based oscillators inherently have disadvantages of the need for additional air gap between the perforated backside metal plane and the metallic shielding enclosure package [6],[7] that leads to the reliability problem and difficulty in miniaturization of the chip. Also, the inherently required five or six periods of the unit cell in the implementation of such a structure sometimes leads to the size problem. Additionally, the extra processing of backside metal plane causes the complexity in fully monolithic application of the chip.

In this paper, a novel compact EBG based oscillator based on the CCPW technology is presented for the first time. The CCPW, originally suggested as a harmonic tuning filter, is modified to the microwave resonator component of the oscillator circuit. The higher quality factor of the structure than that of the conventional CPW resonator plays a role of phase noise reduction of an oscillator circuit. And, the unique harmonic characteristic of the CCPW plays a role of harmonic suppression of the oscillator circuit that finally leads to enhancement in dc-ac power efficiency of the circuit.

II. DESIGN OF A CCPW RESONANT CELL

Recently, the one-quarter wavelength deep high impedance CCPW structure [8] was proposed as a planar version of Sievenpiper's high-impedance surface originally proposed in [9]. As can be seen in Figure 1, it consists of a center strip separated by a narrow gap from two ground planes and a lot of high impedance slots running down into the ground planes of the structure. The width of the slot is much shorter than the wavelength and the depth of the slot is one-quarter wavelength. This one-quarter wavelength of each slot transforms the zero impedance of the ground plane to the infinite, and finally forbid the propagation of transverse magnetic surface waves along the CPW line. Consequently, a deep stopband is generated that corresponds to the bandgap of any other EBG structures. Its uniplanar characteristic and compactness in size solved the inherent package problem of conventional DGS structure and showed more reasonable possibility of monolithic application of conventional EBG structures.

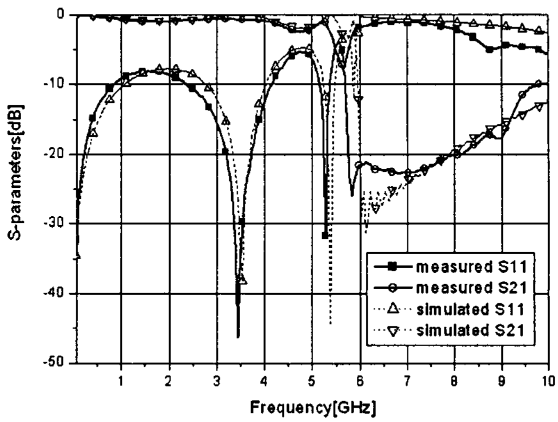


Fig. 2. Simulated and measured S-parameter of the CCPW EBG resonant cell.

Figure 2 shows the simulated and measured S-parameter of the CCPW structure fabricated on RT/Duroid 6010 substrate of dielectric constant of 10.2 and thickness of 25mil. The widths of the line and the gap of the 50 ohm CPW transmission line were calculated as 0.9 mm and 0.55 mm, respectively. And, the depth of the slot was set to 5mm which corresponds to one quarter wavelength at the offset frequency of 6GHz. The stopband in forward transmission, beginning from 6GHz, can be seen as anticipated

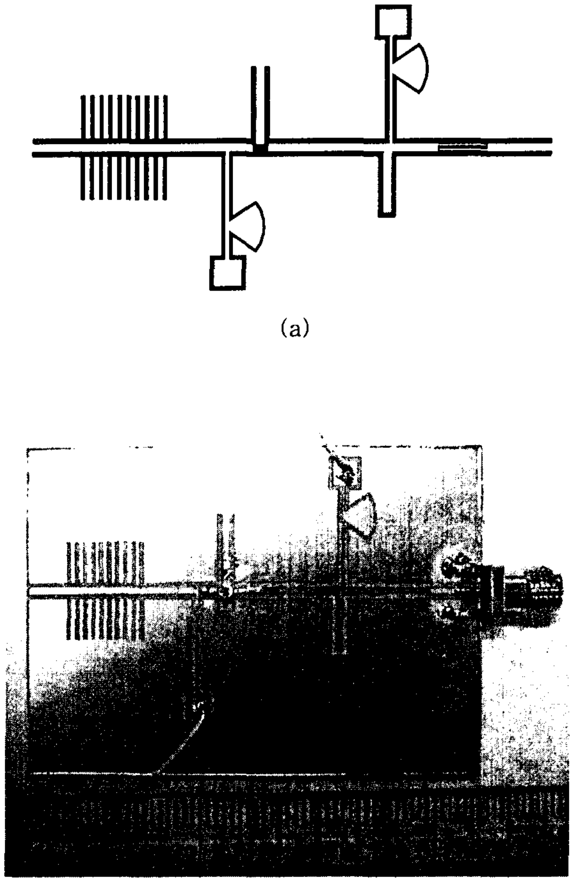
The cutoff frequency of 6GHz near the resonance frequency varies rapidly the input impedance of the CCPW structure from 50 ohm to 0 ohm, and contributes to the higher input phase slope at the gate circuit. From this, we can achieve higher quality factor than that of the circuit without the CCPW [5],[10]. Therefore, an oscillator with reduced phase noise could be achieved utilizing the deep attenuation in S11 at 5.5 GHz as a resonance frequency of the circuit. The resonance frequency and subsequent oscillation frequency can be easily tuned by changing the depth of the CCPW structure.

Another advantage of the CCPW resonator is its harmonic tuning characteristic. The harmonics of the circuit can be suppressed by controlling the reflection phase of terminating resonance as suggested in [11]. The length between the CCPW structure and the transistor was tuned to 9.09 mm in order to negatively feedback the second harmonic component signal of the oscillator circuit. In addition to this methodology, we used the inherent absence of any nth-harmonic in S11 characteristic of 5.5GHz CCPW resonator to reduce the harmonics of the final oscillator circuit. From this suppression of harmonics, increase in fundamental output power and dc-ac power efficiency could be achieved.

The total size of the CCPW EBG structure was only 12 mm × 9.5 mm which corresponds to 0.57 λg × 0.45λg, where λg is the wavelength of resonance frequency.

III. DESIGN OF OSCILLATORS

Figure 3 shows the layout and fabricated result of 5.5 GHz oscillator circuit. Negative resistance to compensate for the loss in resonator was generated using the short stub in source terminal of the transistor which can be easily fabricated in CPW technology. Output matching stubs were tuned to meet the small signal oscillation condition, and the designed CCPW cell was implemented as a fundamental frequency selection component of an oscillator circuit. For comparative purpose, conventional CPW oscillator without CCPW resonator structure was also designed and fabricated. The other components except the CCPW structure were set identical including used transistor of Agilent ATF-36077 pHEMT. The fabrication processes of oscillators were extremely simple without any via-hole process, pattern on backside metal layer, or any lumped element soldering process.



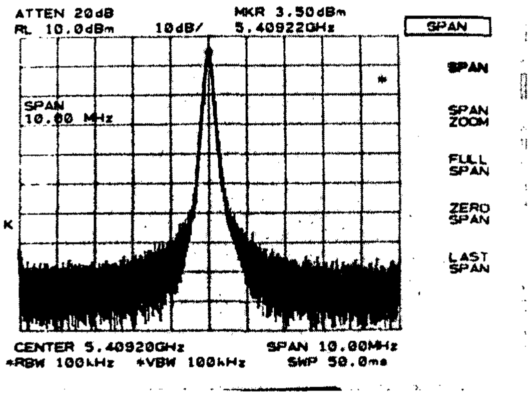
(a)

(b)

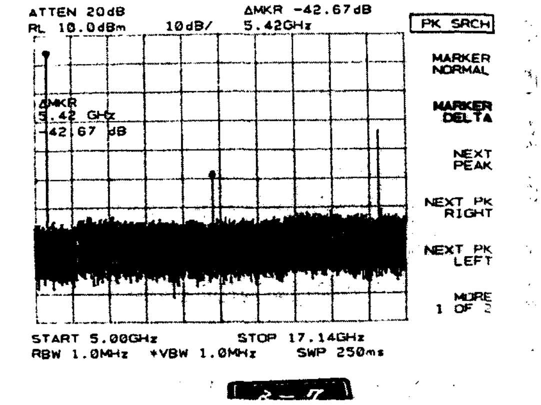
Fig. 3. (a) Layout and (b) photograph of the oscillator with CCPW resonant cell.

IV. MEASUREMENT RESULTS

Figure 4 shows the photograph of the measured fundamental output spectrum and harmonic performance of the fabricated CCPW oscillator. The oscillator exhibits a measured oscillation frequency of 5.41 GHz with the measured peak output of 3.50 dBm at the bias condition of Vds=1.5V and Vgs=-0.2V. Phase noise is measured as -90.7 dBc/Hz and -115.3 dBc/Hz at offsets of 100 kHz and 1 MHz, respectively. The second and third harmonic suppressions were



(a)



(b)

Fig. 4. Measured output spectrums. (a) Fundamental output power spectrum.(b) Harmonic characteristic.

measured as 42.67 dB, and 27.00dB, respectively. Even more harmonic suppression is expected if we add another CCPW harmonic tuner at the output stage of the circuit.

These results are over 10dB improvement in phase noise performance and over 20 dB improvement in second harmonic suppression when compared to those of conventional CPW oscillator without CCPW structure.

V. CONCLUSION

In this paper, a novel oscillator that incorporates a uniplanar CCPW EBG structure as a resonator component of the conventional CPW oscillator circuit was presented. The introduction of the CCPW EBG structure was proved to be effective in reducing the phase noise and enhancing the harmonic performance and dc-ac power efficiency of an oscillator circuit in very little chip size increment. The small size and uniplanar structure characteristic of the circuit can be easily applied to the MMIC application of the circuit without suffering from the drawbacks of the conventional DGS based EBG oscillators.

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