A Novel Phase Noise Reduction Technique in Oscillators Using Defected Ground Structure

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***Abstract*—A new technique to reduce the phase noise in microwave oscillators is developed using the resonant characteristic of the defected ground structure (DGS). Two kinds of oscillators have been designed and measured for the examination of the reduction of phase noise by the DGS. The first adopts the DGS section under the microstrip line at the gate circuit, while the second has only the conventional microstrip line. Measurement shows reduced phase noise by 10–15 dB in the oscillator with the DGS compared to the conventional one.**

***Index Terms*—Defected ground structure (DGS), oscillator, phase noise.**

I. Introduction

SINCE phase noise is one of the most important parameters in the design of microwave oscillators, several methods have been proposed to reduce the phase noise. These methods have focused on improving the quality factor (Q) of resonators, which result in low phase noise oscillators. Dielectric resonators (DR) have been widely used for low phase noise in microwave oscillators due to their high quality factor. DRs however cannot be used in the monolithic microwave integrated circuits (MMIC) oscillators because they have a three-dimensional (3-D) structure [1]. To overcome this problem, a planar type microstrip line resonator has been suggested, but the measured phase noise has not been significantly improved because of the low quality factor of the microstrip line [2].

Recently, many papers have been reported to apply the microstrip line with the defected ground structure (DGS) in the design of microwave circuits such as filters, power dividers, and amplifiers and so on [3]–[6]. In particular, Lim *et al.* reported a power amplifier with efficiency improved using the DGS at the output. In their work, they employed the passband characteristic of the DGS at the fundamental frequency and the stopband characteristic of DGS at the harmonic frequencies to tune the harmonic components [6].

In this letter, a new technique is proposed that reduces phase noise using the resonant characteristic of the DGS. By fixing the resonant frequency to be the same as the oscillation frequency, a high input phase slope (in other words, a high quality factor) can be obtained. This technique guarantees two advantages: 1) Noticeable reduction of phase noise, which is difficult by using the conventional planar type resonators; 2) Simple fabrication, because this high Q resonator with DGS is planar structure. Hence, this structure can be realized in the MMIC, while it is extremely hard to apply the external high Q resonators in chip.

To confirm the validity of the proposed method, two kinds of oscillators are designed and the phase noise performances are measured. One is incorporated with a microstrip line with the DGS pattern at the gate terminal, and the other with the microstrip line only.

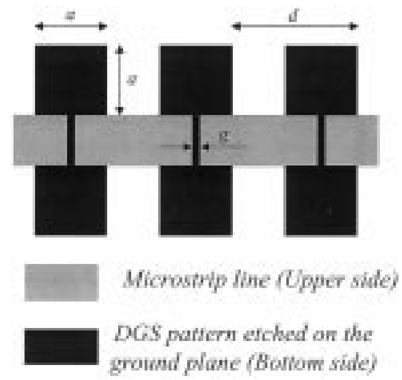

Fig. 1. Microstip line with DGS pattern on the ground plane.

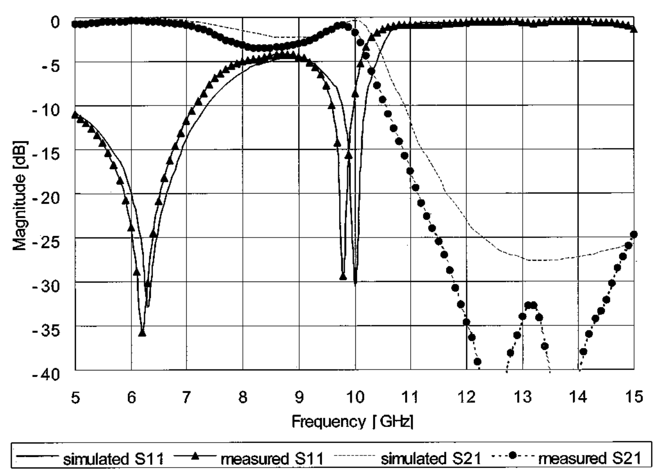

Fig. 2. Simulated and measured characteristics of the microstrip line with DGS.

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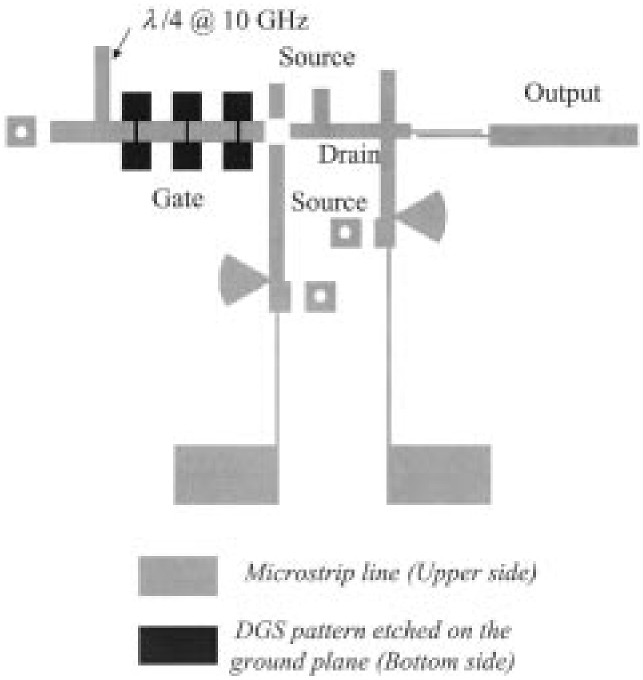
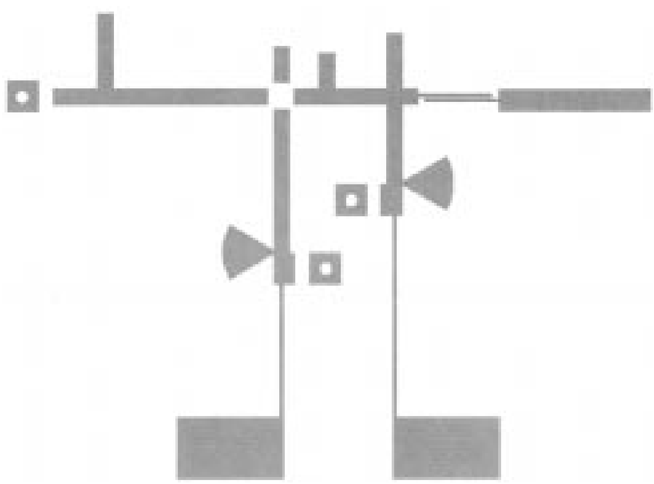


(a)



(b)

Fig. 3. (a) Layout of the oscillator with DGS. (b) Layout of the oscillator without DGS.

II. DGS Design and Its Application to Oscillators

Fig. 1 shows the DGS section etched on the ground plane under the 50 Ω microstrip line. It is fabricated using a Teflon substrate of 0.504 mm thickness and a dielectric constant of 2.52. The length of the rectangle, a, is 1.95 mm and the etched gap, g, is 0.2 mm and the period, d, is 3.44 mm. By adjusting the period of these cells, the resonant frequency near the cutoff frequency—in this work, 10 GHz—can be easily obtained as shown in Fig. 2. The simulated results indicate that input characteristic impedance of the DGS section is nearly 50 Ω at the resonant frequency. However, as the frequency deviates from the resonant frequency, the values of input resistance and reactance of the DGS section vary rapidly from 50 Ω and 0 Ω, respectively. This implies that the gate circuit with this DGS section has a higher input phase slope than that of the gate circuit without the DGS section. A higher quality factor can therefore be obtained [7]. This is the key point of this work.

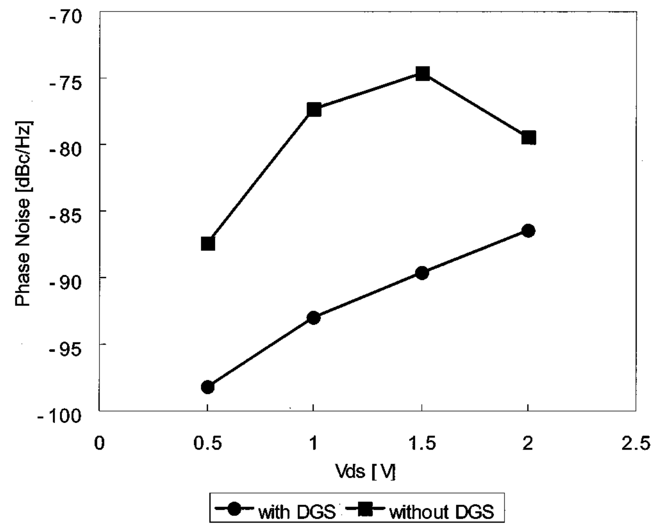


Fig. 4. Measured phase noise performances of two oscillators at 100 KHz offset ($V_{gs} = -0.3$ V).

The measured results shown in Fig. 2 are very close to the predicted ones.

III. Design of Oscillators

Two oscillators are designed and fabricated at 10 GHz using NE32484 HEMTs devices. One has DGS section, the other does not. Fig. 3(a) and (b) shows the layouts of oscillators with and without the DGS section, respectively. In order to demonstrate the effect of the DGS section on phase noise, the source and drain circuits of the two oscillators are to be identical, respectively. Furthermore, the embedding impedance of the gate circuit of the oscillator with the DGS was made to equal that of the oscillator without DGS by adjusting the length of the microstrip line connected to the gate terminal [8]. The oscillator circuit and DGS pattern can be realized simultaneously by a simple etching process.

IV. Measurements and Results

Figure 4 shows the measured phase noise performances of the two oscillators. It should be noted that the phase noise of the oscillator with the DGS section is reduced by 10–15 dB at 100 KHz offset compared to that of the oscillator without the DGS section. This is a remarkable reduction of phase noise even the resonator is entirely planar type. It is understood that the Q factor of an oscillator is estimated as the slope of the reactance versus frequency, or pulling figure—the maximum oscillation frequency change for a load mismatch of all phases [9]. It has been found from the circuit simulation that the slope of reactance of the oscillator with the DGS is 6 times that of the oscillator without the DGS. This provides about 15 dB reduction of phase noise, which shows good agreement with the measured results. The pulling figures of these two oscillators were also measured for the constant load VSWR of 1.55. The ratio of the measured pulling figures of these two oscillators with and without the DGS is 4.35, which implies 12.78 dB improvement in phase

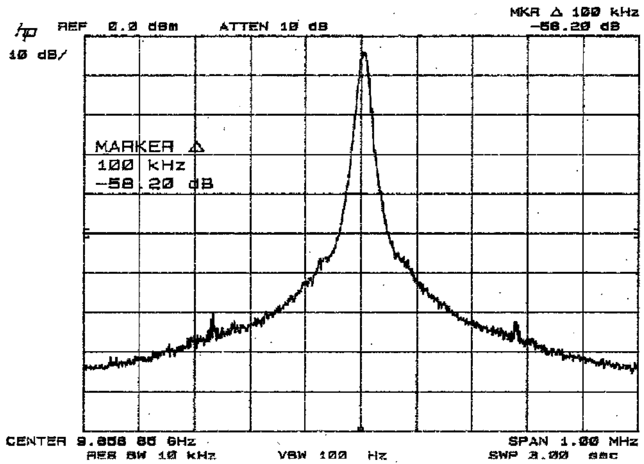


Fig. 5. Output spectrum of the oscillator with DGS ($V_{\rm ds} = 0.5$ V, $V_{\rm gs} = -0.3$ V).

noise. This result agrees well with the measured improvement in phase noise performance, too. The measured pushing factor of the oscillator with DGS is 6 MHz/V, while that of the oscillator without DGS is 110 MHz/V. Also, the oscillation frequency of the oscillator with the DGS is 9.86 GHz, which is almost equal to the resonant frequency of the DGS section. The output powers of the oscillators with and without the DGS are 7.4 dBm and 7.5 dBm respectively at $V_{\rm ds} = 2$ V and $V_{\rm gs} = -0.3$ V. Therefore, no significant cost of output power can be observed. The measured output spectrum of the oscillator with the DGS is illustrated in Fig. 5.

V. Conclusion

A new design technique to reduce the phase noise has been presented using the resonant characteristic of the DGS. The oscillator with the DGS shows reduction of phase noise by 10–15 dB compared to the other one without the DGS. Low phase noise performance can be achieved while a planar type of resonator is used (-98.2 dBc/Hz at 100 KHz offset). Due to its simple fabrication process and planar type, it is expected that this technique can be widely used for low phase noise oscillators for both MIC and MMIC applications.

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