A Power Amplifier with Efficiency Improved Using Defected Ground Structure

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***Abstract*—This letter reports the effects of defected ground structure (DGS) on the output power and efficiency of a class A power amplifier. In order to evaluate the effects of DGS on the efficiency and output power, two class A GaAs FET amplifiers have been measured at 4.3∼4.7 GHz. One of them has a 50 Ω microstrip line with DGS at the output section, while the other has only 50 Ω straight line. It is shown that DGS rejects the second harmonic at the output and yields improved output power and power added efficiency by 1∼5%.**

***Index Terms*—Defected ground structure, harmonic tuned power amplifiers, harmonic tuning, power amplifiers.**

I. INTRODUCTION

THE MAIN design goals of a power amplifier are focused on output power and efficiency. The output power and efficiency depend on the active device, bias conditions according to the operating class, matching networks, and so on [1]. One of the methods to improve the output power and efficiency is to terminate the harmonics at the output [2], [3]. Among the harmonics, the second harmonic is especially in want of tuning, because its magnitude is relatively larger than the other harmonics. Many works have been reported for harmonic termination. The previous techniques include

1) adding a short-circuited stub or radial stub at the output [3], [4];
2) using a chip capacitor with a self-resonance near the second harmonic [5].

Recently, Radisic pointed out that the above techniques are narrowband and presented a new method for harmonic tuning by using photonic bandgap (PBG) structure at the output of the power amplifier [6]. Drilling for a lot of holes and adding copper tape onto the ground plane are required in realizing PBG after etching the amplifier circuit which includes a 50 Ω microstrip line at the output.

We propose a new technique for harmonic tuning using the microstrip line with defected ground structure (DGS) at the output. DGS also has a periodic structure, but it is easier to fabricate, because DGS patterns are realized when the PCB of the amplifier circuit is etched at the same time. Due to its effective additional L-C components [7], [8], DGS has a very wide stopband characteristics and does not show the periodic passband characteristics, thus allowing its use in the harmonic tuning of power amplifiers. We will compare two class A power amplifiers at C-band for showing the improvement in output power and efficiency by DGS. One amplifier is connected by DGS patterns at the output section, and the other one just by the 50 Ω straight line.

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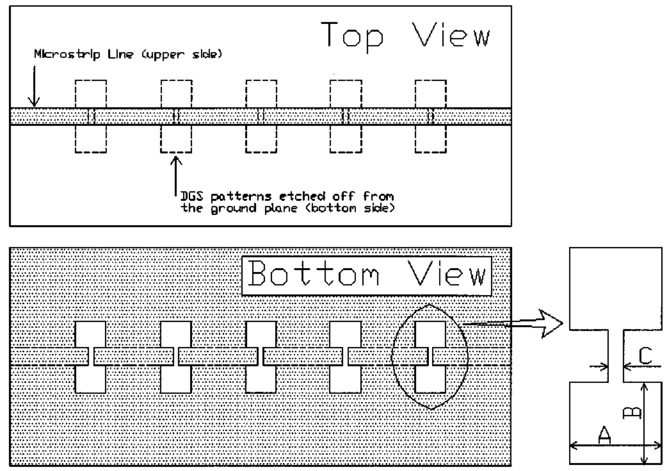


Fig. 1. Microstrip line with DGS patterns on the ground plane at the output of the power amplifier. ($A = 2.8$ mm, $B = 2.5$ mm, $C = 0.5$ mm).

II. DGS DESIGN AND ITS CHARACTERISTICS

Fig. 1 shows the DGS section etched on the ground plane under the 50 Ω microstrip line. The unit DGS pattern looks like a dumb-bell and is composed of two 2.8 mm × 2.5 mm rectangles and a connecting slot with a gap of 0.5 mm. The length of the connecting slot is the same as the width of the microstrip line on the upper plane, and the period is 7.8 mm. We analyzed and measured the microstrip line with DGS shown in Fig. 1 using the RT/Duroid 5880 with 2.2 of dielectric constant and 31 mils of thickness. The simulated results are very similar to the measured ones shown in Fig. 2. From the measured results, it is found that the performance of the power amplifier is not degraded by DGS because of excellent S_{11} and S_{21} at the operating frequency band, 4.3∼4.7 GHz. It should be noted that the stopband begins abruptly from 7.7 GHz and the frequency band of the second harmonic to be tuned is 8.6∼9.4 GHz. In particular, the stopband shown in Fig. 2 is an ultra wideband, which makes it possible to tune all harmonics, while the PBG structure in [6] tunes only the second harmonic because of its periodic passband characteristics.

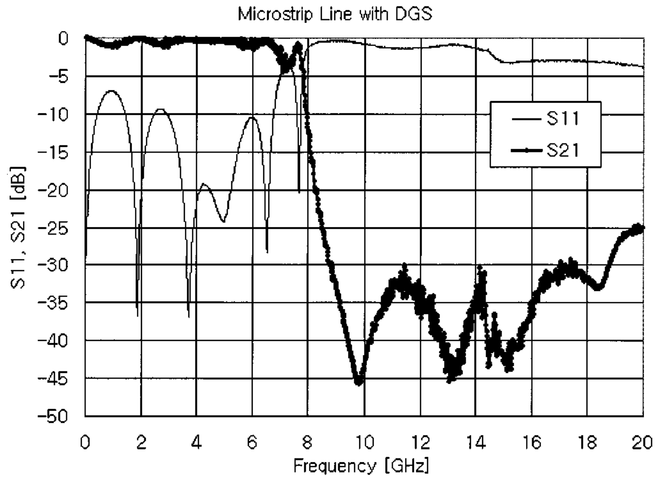
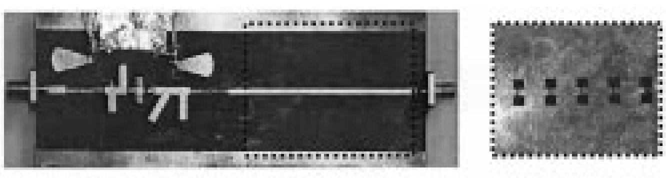


Fig. 2. Measured characteristics of the microstrip line with DGS. The characteristics simulated by FEM and MOM, which are not shown here, are so similar to the measured results.



(a) (b)

Fig. 3. (a) Photograph of the power amplifier with DGS (b) DGS pattern on the ground plane at the output.

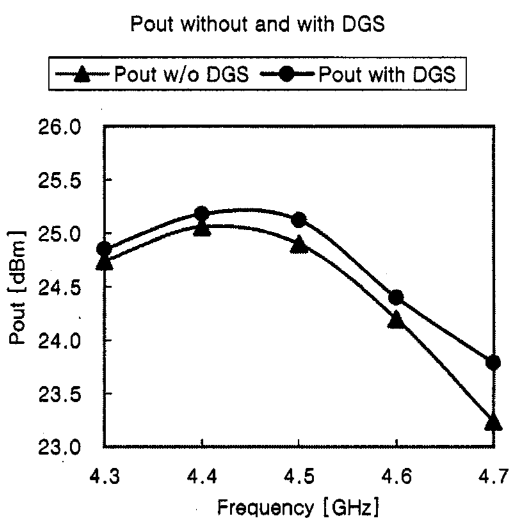


Fig. 4. Measured output power of the power amplifiers.

III. Class A Power Amplifiers

We designed and fabricated two power amplifiers using Fujitsu FLK022WG GaAs FET's for the comparison of output power and efficiency for two cases; with and without DGS. Fig. 3(a) and (b) show the fabricated power amplifier with DGS and the etched patterns on the ground plane under the microstrip line. The recommended bias conditions for class A operation of this device are $Vds = 10$ V and $Ids = 0.6$ Idss from its data sheets. Two stubs are used for matching networks and coupled

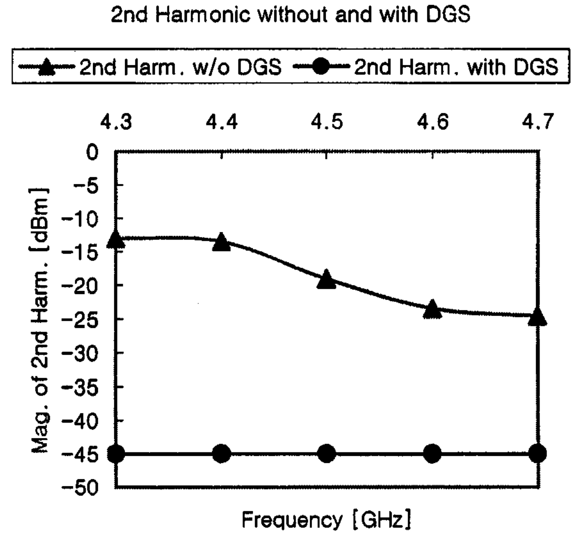


Fig. 5. Measured second harmonics of power amplifiers. (Second harmonic was not found by the -45 dBm detection level at the output of power amplifier with DGS).

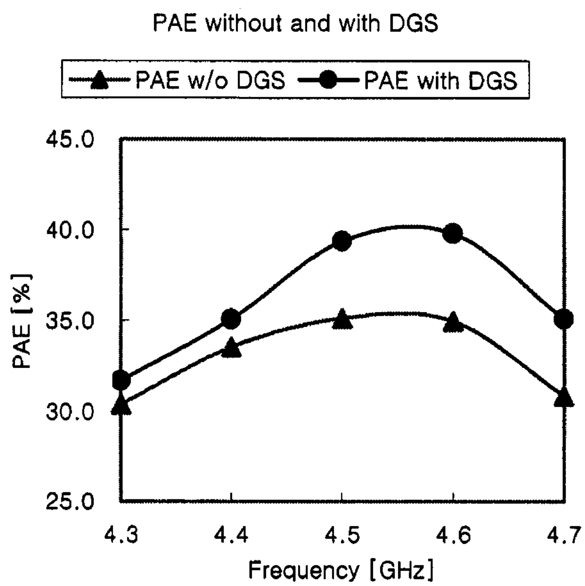


Fig. 6. Measured power added efficiency of power amplifiers.

microstrip lines are inserted for DC block. Quarter wavelength lines with high impedance and radial stubs are adopted for the bias circuit. The amplifier circuit and DGS patterns are realized at the same time by a simple etching process.

IV. Effects of DGS on the Power Amplifiers

Fig. 4 shows the measured output powers for the two cases. The improvement in output power is 0.11~0.55 dBm and is not noticeable because the magnitude of the second harmonic is absolutely and relatively small. The magnitude of the second harmonic was measured using a Spectrum Analyzer at the saturation output power and is shown in Fig. 5. The second harmonic of the power amplifier without DGS is $-13 \sim -23$ dBm, while it was not detected up to -45 dBm level for the power amplifier with DGS. This means that DGS terminates the second harmonic perfectly including all the other harmonics. Even though the improvement in output power is small, power added efficiency has been improved by $1\sim5\%$ in the case of "with DGS." This is caused by the less current flow into the device for the similar output power when the harmonics are tuned by DGS. It is clear, from the measured results, that DGS has improved output power and efficiency of the power amplifier (see Fig. 6).

V. Conclusion

It was verified that a microstrip line with DGS on the ground plane has a very wide stopband and can be used for tuning all harmonics in power amplifiers. The class A power amplifier with DGS showed improved output power and power added efficiency by $1\sim5\%$ compared to the other power amplifier without DGS. For the amplifier with DGS, second harmonic was not detected up to -45 dBm level at the output, while $-13\sim-23$ dBm of second harmonic was measured for the amplifier without DGS. It is expected that DGS can be applied to other types of power amplifier for tuning harmonics and performance improvement by its very wide stopband and simplicity in realization.

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