SIZE-REDUCTION AND HARMONIC-REJECTION OF MICROWAVE AMPLIFIERS USING SPIRAL-DEFECTED GROUND STRUCTURE

Jong-Sik Lim[1], Yong-Chae Jeong[2], Dal Ahn[3], Young-Taek Lee[1], Hyoungrae Cho[1], and Sangwook Nam[1]

[1] *School of Electrical Engineering and Computer Science, Seoul National University, Seoul, Rep. Of Korea*
Applied Electromagnetics Lab., Institute of New Media and Communications, Seoul National University, San 56-1, Shilim-Dong, Kwanak-Gu, Seoul, 151-742, Rep. Of Korea

[2] *Division of Information and Electronic Engineering, Chonbuk National Univ., Chonju, Rep. Of Korea*

[3] *Division of Information Technology Engineering, Soonchunhyang Univ., Chungnam, Rep. Of Korea*

Abstract **— A new method to reduce the size of amplifiers and reject harmonics using spiral-defected ground structure (Spiral-DGS) is presented. A microstrip transmission line having Spiral-DGS provides increased slow–wave factor (SWF) and excellent rejection characteristics for a specified harmonic frequency band as if it is a band rejection filter. Due to the increased SWF, the physical lengths of matching networks are shortened while the original matching and performances are preserved. The reduced lengths by Spiral-DGS are 39% and 44% of the original lengths in input and output matching networks, respectively. It is shown that the measured S-parameters of the reduced amplifier agree well with those of the original amplifier. The measured second harmonic of the reduced amplifier is much less than that of the original amplifier by at least 10dB.**

I. INTRODUCTION

In the design of microwave amplifiers, it is one of important goals to keep the circuit size as small as possible. One basic premise is that, if possible, size-reduction must not harm the amplifier performances. In other words, it is essential to preserve the original matching and performances even after the physical length has been reduced. Out of many choices, it is one way to accomplish this goal by using the increased slow-wave effect of the transmission lines in matching networks by giving disturbances like periodic structures.

Planar transmission lines combined by periodic structures such as photonic bandgap (PBG) and defected ground structures (DGS) are known to have larger slow-wave factor (SWF) than standard transmission lines [1]-[3]. In addition, Spiral-DGS for transmission lines has been proposed in [4] and [5].

It is attractive that "the transmission line with spiral-shaped DGS" ("Spiral-DGS line") has higher SWF than the transmission lines with dumbbell-shape DGS or standard transmission lines. So, if Spiral-DGS patterns are used in amplifier matching networks, it is expected that the circuit size would be quite reduced. In addition, because a Spiral-DGS line has a band rejection characteristic, it is relatively easy to reject harmonic components of amplifiers.

II. SLOW-WAVE EFFECT OF MICROSTRIP LINE WITH SPIRAL-DGS

The previously proposed dumbbell-DGS (DB-DGS) is consisted of two large rectangular defected areas and one connecting slot on the ground plane [1]. Other geometries rather than rectangles can be adopted for defected ground area. It has been reported that Spiral-DGS line has greater SWF than DB-DGS line and the existing PBG line for the same defected area [4, 5]. In addition, Spiral-DGS line has a specified rejection band like band rejection filters. This property is very useful in amplifiers because the harmonic components are rejected inherently.

Fig. 1 shows a standard microstrip line, a DB-DGS line, and a Spiral-DGS line. Although physical lengths are the same as “L”, the electrical length of Fig. 1(b) is longer than that of Fig. 1(a), i.e. θ < θ’ because of the additional circuit elements of DGS. The same situation goes for Fig. 1(c) and Fig. 1(b), and θ’ < θ”. This means the SWF of Fig. 1(c) is the greatest.

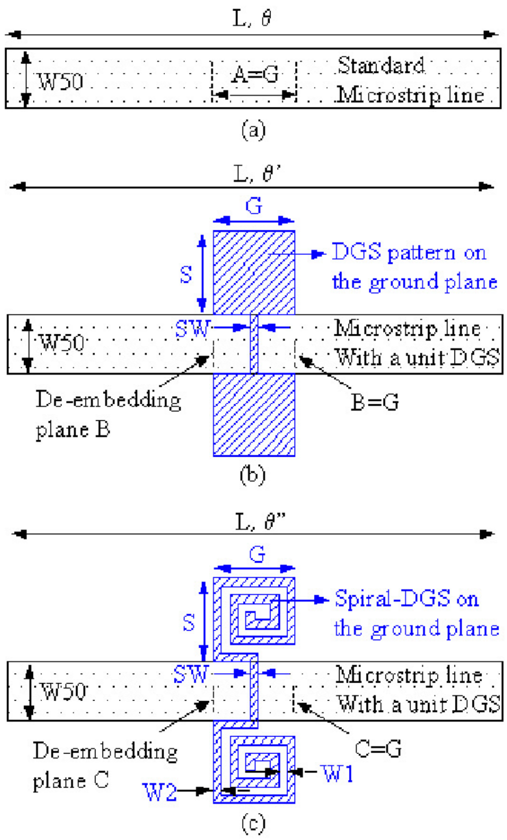


Fig. 1. (a) A standard microstrip line (b) A microstrip line with unit DB-DGS (c) A microstrip line with unit Spiral-DGS (W50=1.4mm,G=S=A=B=C=2mm,SW=W1=W2=0.2mm, ε_r=2.6, Substrate thickness=20mils)

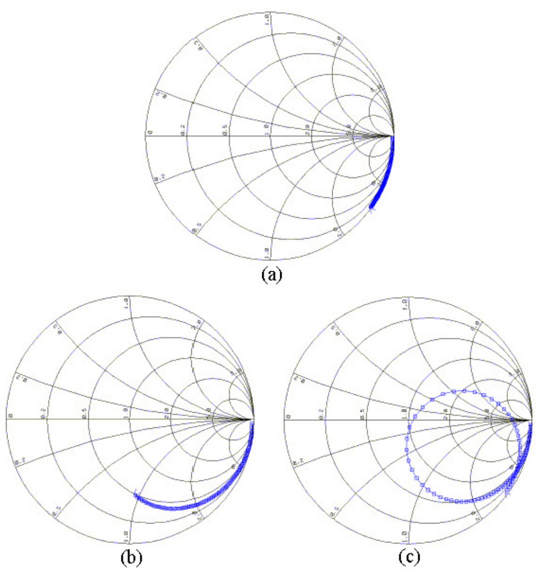


Fig. 2. Electrical lengths (S21 phases) of three microstrip lines up to 10GHz over (a) the de-embedded plane “A” (b) the de-embedded plane “B” (c) the de-embedded plane “C”.

Fig. 2 shows the S21 phases of three microstrip lines with the length of 2mm at the de-embedded planes “A”, “B”, and “C” up to 10GHz. It is observed that the electrical length of Fig. 1(c) is the longest one. Provided that the standard microstrip line in Fig. 1(a) is a part of the matching network of an amplifier, it is possible to reduce the physical length by combining Spiral-DGS on the ground plane. Of course, the available frequency band for applying the Spiral-DGS must be much lower than the resonant frequency so that the loss problem may not be serious.

Fig. 3 shows the SWFs of three microstrip lines at their de-embedded planes. It is illustrated that the SWF of the Spiral-DGS line is the highest one. It is expected that a shorter Spiral-DGS line can replace the longer standard microstrip line with the same electrical length preserved.

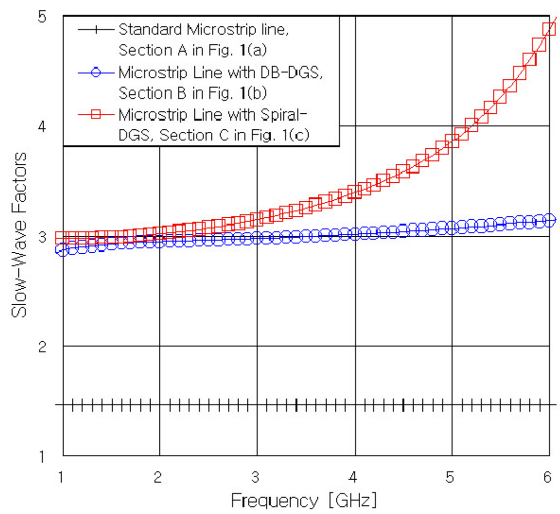
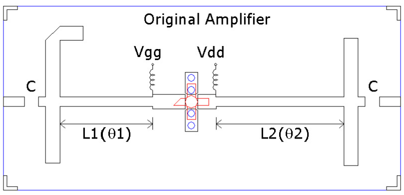


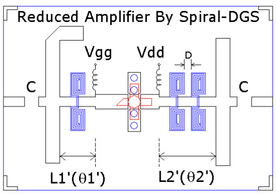
Fig. 3. Slow-wave factors of three microstrip lines

III. Size-Reduction Using Spiral-DGS and Measured S-Parameters

Fig. 4(a) shows an original amplifier designed using standard microstrip lines. L1 (=13mm) and L2 (=18mm) are to be shortened by inserting Spiral-DGS so that the matching performances are kept to be the same. Fig. 4(b) shows the layout of the size-reduced amplifier with Spiral-DGS patterns inserted in matching networks. The dimension “S” of the Spiral-DGS pattern shown in Fig. 1(c) has been modified from 2mm to 3.4mm for much higher SWF. It should be noted that only the original lengths, L1 and L2, are reduced and all the other parts remain untouched. The resultant lengths, L1’ and L2’ are 5mm and 8mm, respectively. The ratios of the reduced lengths to the original ones are only 39% (=5mm/13mm) and 44% (=8mm/18mm). Fig. 4(c) shows the reduced amplifier using DB-DGS, which has been proposed in [6]. Two lengths, L1" and L2", are 7mm and 10mm, respectively.

It is the most important to preserve the original amplifier performances even after the size has been lessened. This is proved by the comparison of the measured S-parameters. Fig. 5 (a) and (b) depict the measured S-parameters of two amplifiers agree well with each other. This means the matching is still being preserved after size-reduction.

(a) 

(b) 

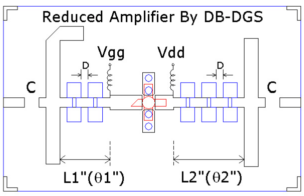
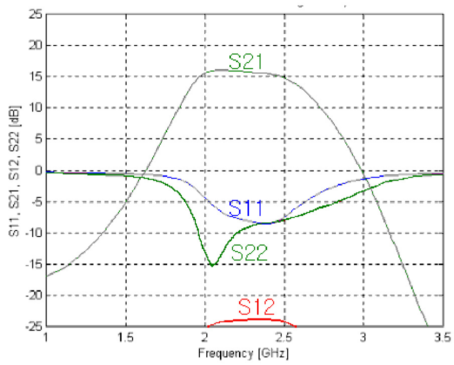
(c) 

Fig. 4. Layout of the (a) original amplifier (b) reduced amplifier by Spiral-DGS and (c) reduced amplifier by DB-DGS (D=1mm)

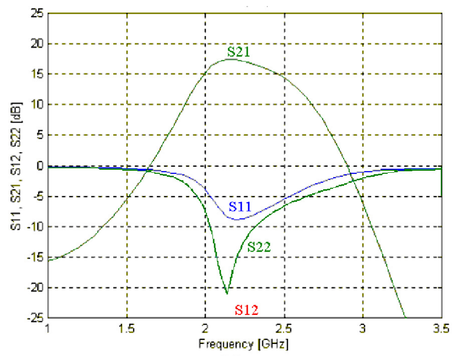
IV. Harmonic Rejection by Spiral-DGS

The standard microstrip line in the output matching network of the original amplifier, which is designated as L2, has only all pass characteristics as shown in Fig. 6(a). However, the Spiral-DGS line designated as L2' has a band rejection characteristics at the second harmonic band. Fig. 6(b) illustrates that the second harmonic will be rejected inherently by the output matching network. This is a remarkable advantage of the proposed size-reduction method.

Fig. 7 shows the measured suppression of the second harmonic component to the fundamental output power. There is a meaningful difference in the ratios between Fo and 2Fo (Fo-2Fo [dBc]). It is definite that the magnitude of the second harmonic power of the size-reduced amplifier is quite smaller than that of the original amplifier. It should be emphasized that there is no other try to reject the harmonic except the inserted Spiral-DGS.

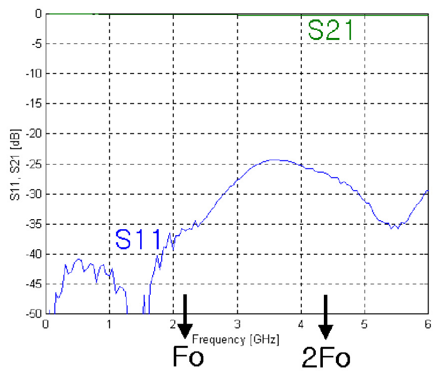


(a)

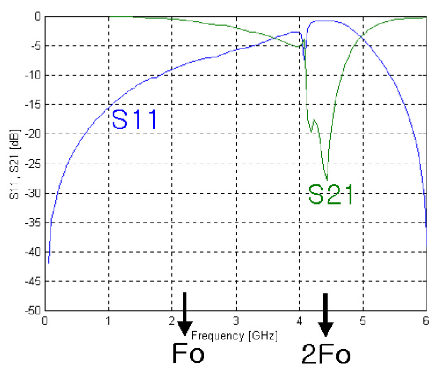


(b)

Fig. 5. Measured performances of the (a) original amplifier and (b) size-reduced amplifier by Spiral-DGS



(a)



(b)

Fig. 6. Measured characteristics of the (a) standard microstrip line designated as L2 and (b) Spiral-DGS line designated as L2'

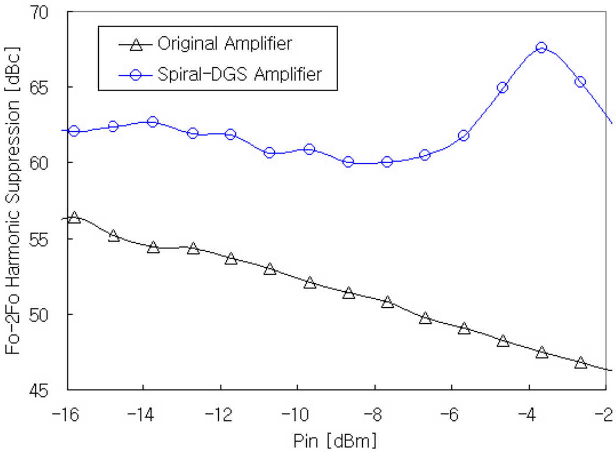


Fig. 7. Measured suppression ratios of the second harmonic to the fundamental out power of two amplifiers (Fo-2Fo).

V. CONCLUSION

A method to reduce the size of amplifiers using Spiral-DGS has been proposed. Due to the increased SWF and electrical length of the microstrip line with Spiral-DGS, the size of the original amplifier has been reduced successfully without any critical degradation in gain and matching performances. In additional, because the Spiral-DGS line has a rejection band, the second harmonic power is rejected inherently by the output matching network without needing any other efforts. The measured second harmonic rejection to the fundamental power of the reduced amplifier was better than that of the original amplifier by more than 10dB.

It is expected that other related power performances of the size-reduced amplifier would improved by the inserted Spiral-DGS. Although the used device in this work is not a high power device of Watt-level, the same technique can be applied to other power amplifiers.

ACKNOWLEDGEMENT

This work was supported by the Brain Korea 21 Project.

REFERENCES

[1] C. S. Kim, J. S. Park, D. Ahn, and J. B. Lim, "A Novel 1-D Periodic Defected Ground Structure for Planar Circuits," *IEEE Microwave Guide Wave Lett.* vol. 10, No. 4, pp.131-133, Apr. 2000.

[2] F. R. Yang, K. P. Ma, Y. Qian, and T. Itoh, "A Uniplanar Compact Photonic-Bandgap (UC-PBG) Structure and its Applications for Microwave Circuits," *IEEE Trans. Microwave Theory Tech.*, vol. 47, No. 8, pp. 1509-1514, Aug. 1999.

[3] T. Y. Yun and K. Chang, "Uniplanar One-Dimensional Photonic-Bandgap Structures and Resonators," *IEEE Trans. Microwave Theory Tech.*, vol. 49, no. 3, pp. 549-553, Mar. 2001.

[4] C. S. Kim, J. S. Lim, S. Nam, K. Y. Kang, J. I. Park, G. Y. Kim, and D. Ahn, "The Equivalent Circuit Modeling of Defected Ground Structure with Spiral Shape," *2002 IEEE MTT-S Digest*, vol. 3, pp. 2125-2128.

[5] J. S. Lim, C. S. Kim, Y. T. Lee, D. Ahn, and S. Nam, "A Spiral-Shaped Defected Ground Structure for Coplanar Waveguide," *IEEE Microwave and Wireless Components Letters*, vol. 12, no. 9, pp. 330~332, Sep. 2002.

[6] J. S. Lim, J. S. Park, Y. T. Lee, D. Ahn, and S. Nam, "Application of Defected Ground Structure in Reducing the Size of Amplifiers," *IEEE Microwave and Wireless Component Letters*, vol. 12, no. 7, pp. 261-263, Jul. 2002.