A Method to Shorten the Size of Amplifiers Using Vertically Periodic Defected Ground Structure

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This paper presents a method to reduce the size of amplifiers using a vertically periodic defected ground structure (VPDGS). The microstrip line combined by VPDGS provides 3 times higher slow–wave factor than standard microstrip line. Due to the increased slow-wave effect, the electrical length of the microstrip line with VPDGS is longer than that of the standard microstrip line for the same physical length. Using this property, the physical lengths of microstrip lines in the matching networks of an amplifier are reduced by inserting VPDGS in order to preserve the same electrical length, matching, and, ultimately, performances. The resultant lengths of the microstrip lines with VPDGS in input and output matching networks are only 38.5% and 44.4% of the original microstrip lines, respectively. It is shown that the measured performances of the reduced amplifier are maintained even after the lengths of microstrip lines in matching networks have been shortened by VPDGS.

INTRODUCTION

It is well known that planar transmission lines combined by periodic structures have typical low-pass properties [1-5]. Another representative features of the periodic structures are the increased slow-wave factor (SWF) and the existence of the cut-off and resonant frequencies, while an ultra broad passband exists only in standard transmission lines.

Defected ground structure (DGS) is one of periodic structures. It is suitable for planar transmission lines such as microstrip and coplanar waveguide. It is realized by etching off defected patterns from the ground plane. The basic shape of DGS is dumb-bell, which is composed of two large defected areas and narrow connecting slot [5]. They are the source of the equivalent L-C components.

It has been known that the microstrip line with DGS has much higher SWF, i.e. longer electrical length than standard microstrip line for the same physical length. Hence the length of microstrip line can be reduced using this principle [6]. Additionally, it is one of the important merits of dumb-bell shaped DGS to form a vertically periodic DGS (VPDGS), while the conventional PBGs and DGS have the horizontally periodic (HP) structure, i.e. serially cascading structure along the transmission direction. It is possible to get much more increased SWF and electrical length if a microstrip line is combined by VPDGS. Therefore, the size of amplifiers can be much more reduced if VPDGS is inserted into the matching networks. Of course the performances of the reduced amplifier are well maintained even after the size has been reduced by DGS.

MICROSTRIP LINES WITH VPDGS

Fig. 1 shows a standard microstrip line and two microstrip lines combined by a unit DGS and VPDGS pattern. The shape of defect can be circle or octagon. It is easily thought that there exist the equivalent L-C elements because of a resonant and 3-dB cut-off frequencies. The electrical lengths of three microstrip lines illustrated in Fig. 1 are not equal, but θ < θ' < θ''. This means the SWF of Fig. 1(c) is the greatest one for the same physical length, L.

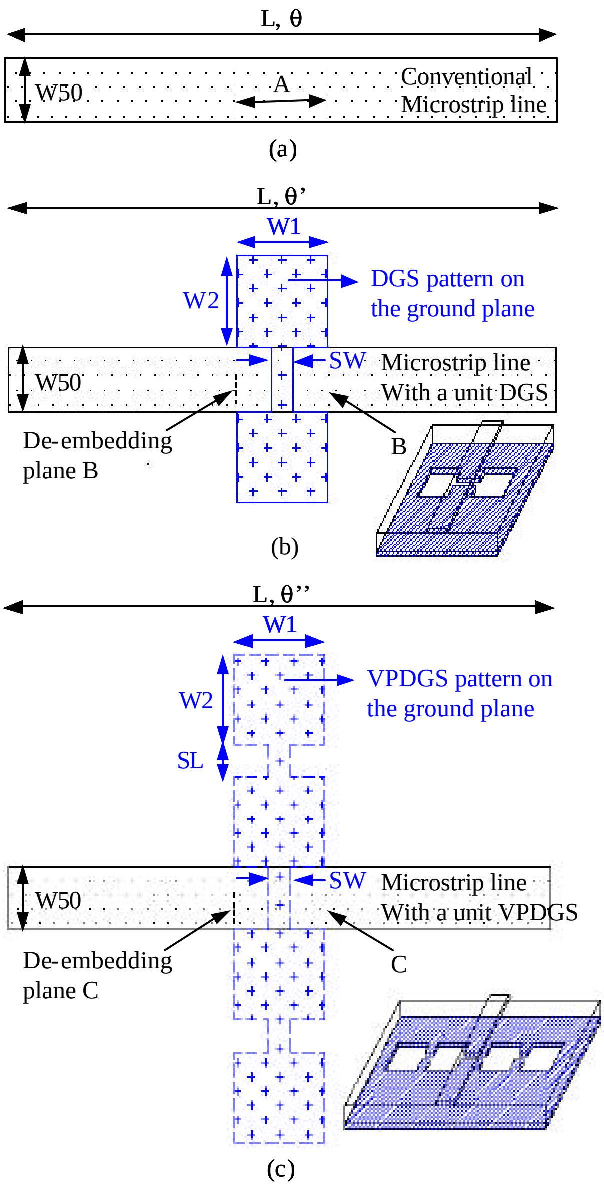


Fig. 1 (a) A conventional microstrip line. (b) A microstrip line with a unit DGS pattern. (c) A microstrip line with a unit VPDGS pattern (W50=1.4mm, SW=0.5mm, W1=W2=2mm, SL=W50/2. ε_r=2.6, Substrate thickness=20mils)

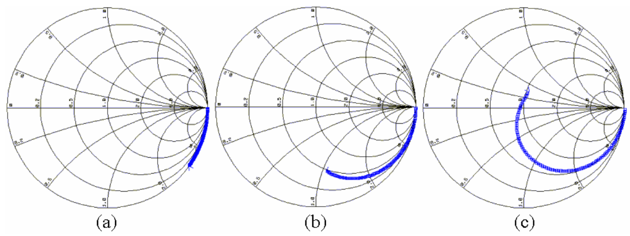


Fig. 2. Electrical lengths (S21 phases) of three micro strip lines up to 10GHz.
(a) Plane "A" in Fig. 1(a) (b) Plane "B" in Fig. 1(b) (c) Plane "C" in Fig. 1(c)

Fig. 2 shows the S21 phases of three microstrip lines up to 10GHz at the de-embedded planes. The de-embedded planes, "A", "B", and "C" have the same physical length, the dimension of W1. The simulations were performed using MicroWave Studio V3.0. The electrical length indicated by S21 phase of "the microstrip line with VPDGS" (hereinafter, "the VPDGS line") is the longest one. So, if the electrical length of the VPDGS line shown in Fig 1(c) is to be the same as that of Fig 1(a), the length of the microstrip line both of the VPDGS pattern should be shortened. Additionally, if Fig. 1(a) is a part of the matching network of an amplifier, it is able to reduce the physical length by inserting the VPDGS to make the original electrical length and matching of the amplifier preserved.

Fig. 3 shows the SWFs of three microstrip lines at their de-embedded planes. As has been expected through Fig. 2, SWF increase due to DGS and VPDGS. The SWF of the microstrip line with VPDGS is three times higher than that of the standard microstrip. Therefore, the reduced microstrip line with VPDGS can replace the original standard microstrip line.

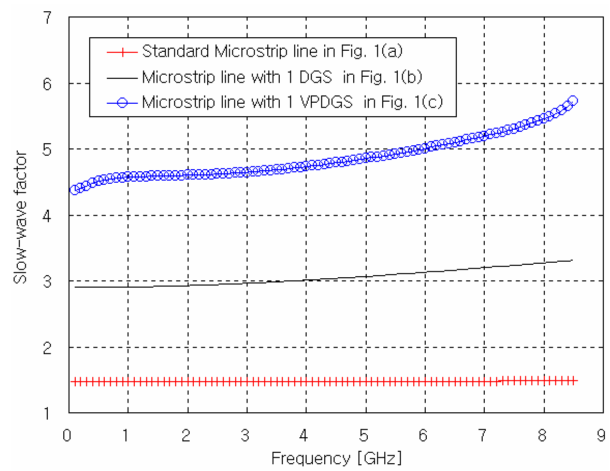


Fig. 3. Slow-wave factors of three microstrip lines. (At the de-embedded plane "A", "B", and "C").

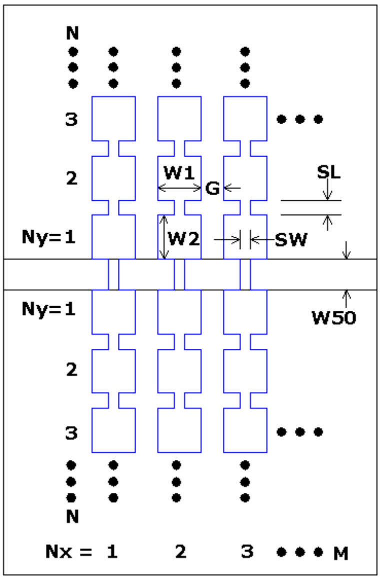


Fig. 4. General structure of the microstrip line with VPDGS.

Fig. 4 shows the general structure of VPDGS on the ground plane of microstrip line. N_x and N_y mean the number of periodicity along the horizontal and vertical direction, respectively. VPDGS is the extended DGS along the vertical direction from the basic structure, which was introduced in [5] for the first time. The unit element of basic DGS can be expressed as $(N_x,N_y)=(1,1)$ if the position and the number of DGS elements are expressed as matrices for convenience.

SIZE-REDUCED AMPLIFIER USING VPDGS

First of all, a 2GHz amplifier, called as the "original amplifier", has been designed using standard microstrip line and measured in order to be compared to the "reduced amplifier". The layouts shown in Fig. 5 have been simplified so that the size-reduction of matching networks is emphasized for convenience comparison.

The lengths of the standard microstrip lines in the original amplifier illustrated in Fig. 5(a), L1 and L2, are the targets for the size-reduction. Of course L1 and L2 can be shortened using the HPDGS as mentioned in [6]. However, in this work, L1 and L2 are reduced using (1,2) and (2,2) VPDGS as shown in Fig. 5(b). The lengths of L1' and L2' are only 5mm and 8mm, while L1 and L2 are 13mm and 18mm, respectively. The reduction ratios by VPDGS are 38.5% (L1'/L1 = 5mm/13mm) and 44.4% (L2'/L2 = 8mm/18mm).

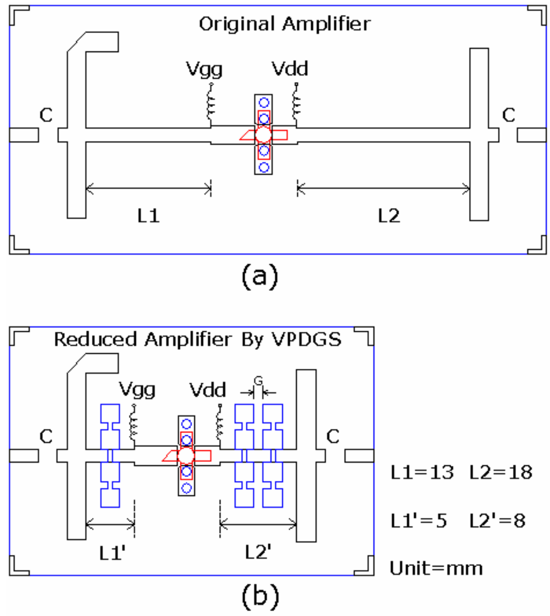
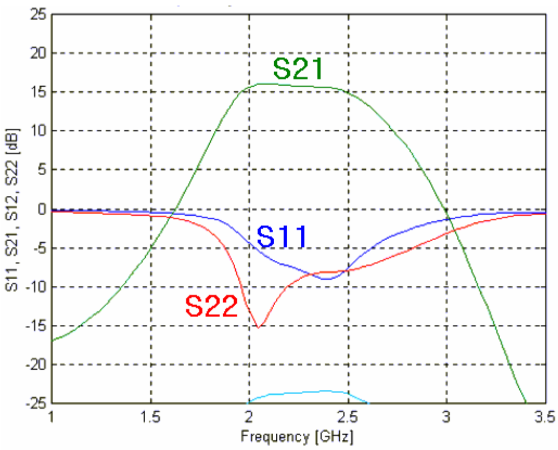


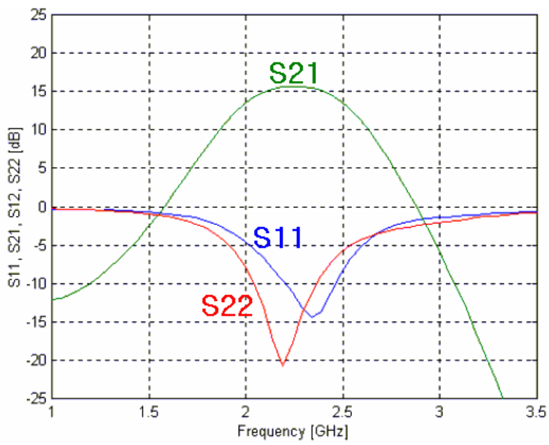
Fig. 5. Simplified layouts of the (a) original amplifier and (b) reduced amplifier by VPDGS (G=1mm).

MEASURED PERFORMANCES

It is important that there should not exist any critical damage at least in the original amplifier performances. This proposition is confirmed by the measured S-parameters of the original and reduced amplifiers. Fig. 6 illustrates the measured S-parameters of two amplifiers. Although there are some minor differences, the measured performances of the reduced amplifiers are quite similar to the ones of the original amplifier. The similar responses show that the matching of the reduced amplifier is being preserved even after L1 and L2 have been reduced to L1' and L2' by VPDGS. It can thus be insisted that the proposed size-reduction technique using VPDGS is an effective method in reducing the size of amplifiers without critical cost of performances.



(a)



(b)

Fig. 6. Measured Performances of the (a) original amplifier and (b) reduced amplifier by VPDGS

CONCLUSIONS

A new method to shorten the size of amplifiers using VPDGS has been discussed. Owing to the increased electrical length of the microstrip with VPDGS, the physical size of the original amplifier was reduced, while the amplifier performances were maintained. The resultant lengths of the microstrip lines with VPDGS were only 38.5% and 44.4% of the original ones in input and output matching networks, respectively.

The good agreement between the measured performances of the original and reduced amplifiers proves the slow-wave effects of the VPDGS line are very effective in reducing the size. Even when a matching network has been designed to have the shortest locus on smith chart, the proposed method can be attempted again as the second try for size-reduction. Additionally, it is expected that the proposed method can be applied to other circuits for reducing the size.

ACKNOWLEDGEMENT

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