A highly miniaturized and low impedance on-chip Wilkinson power divider employing PGS on MMIC

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***Abstract*— In this work, we propose a low-impedance and highly miniaturized on-chip Wilkinson power divider on MMIC, which was fabricated by a microstrip line structure employing periodic ground structure (PGS) with single-sided via holes. Using the microstrip line with PGS, a miniaturized 13 Ω power divider was fabricated. The size of the power divider was 0.110 mm^2, which was 6 % of conventional one.**

Key words: Periodic ground structure (PGS), microstrip line, Wilkinson power divider.

I. Introduction

RF components dealing with high frequency signals are most important in wireless communication system and the performance of the system depends on them. In order to realize highly miniaturized and fully integrated MMICs, the development of miniaturized on-chip passive components is indispensable. The development of miniaturized on-chip passive components with low port impedances will especially greatly reduce the size of MMICs by removing bulky impedance transformation circuits between the passive components and low-impedance FETs; generally, the input and output impedances of the FETs are much lower than 50 Ω in the RF frequency.

Therefore, impedance transformation circuits should be employed for impedance matching between 50Ω - based passive components and low-impedance FETs [1].

However, in case of fabricating low impedance line using the conventional microstrip with ground metal on the backside of GaAs substrate, the width of the line becomes very large. For instance, when making 15 Ω line on the GaAs substrate with 100 μm height, the width of the line reaches 800 μm.

In this work, using Periodic Ground Structure (PGS) with single-sided via holes, we developed a low-impedance and highly miniaturized on-chip Wilkinson power divider on MMIC.

II. A Microstrip Line Employing PGS

In this work, we employed Periodic Ground Structure (PGS) with high capacitive element [2] in order to develop a low impedance on-chip Wilkinson power divider. Especially, the PGS structure with single-sided via holes was used for size reduction, which highly miniaturized the Wilkinson power divider.

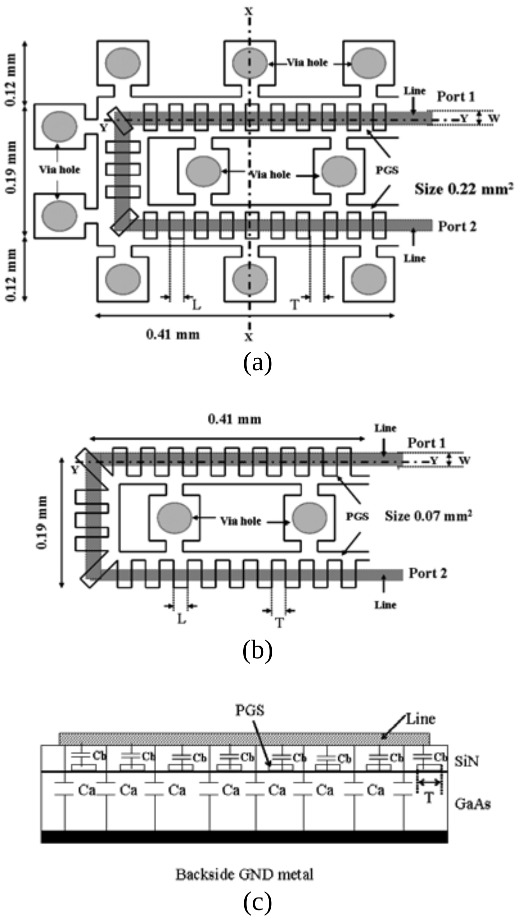

Fig. 1 (a) PGS bend structure with double-sided via holes. (b) PGS bend structure with single-sided via hole. (c) A cross-sectional view according to Y-Y direction of Fig. 1 (a) and (b)

Figure 1 (a) and (b) show a top view of the PGS bend structure with double-sided and single-sided via holes, respectively, and Fig. 1 (c) corresponds to a cross-sectional view according to Y-Y direction of Fig. 1 (a) and (b). As shown in Figure 1 (a)-(c), PGS was inserted at the interface between SiN film and GaAs substrate, and it was electrically connected to backside ground metal through the via-holes. As is well known, conventional microstrip line without PGS has only a periodical capacitance C_a (C_a is shown in Fig. 1 (c)) per a unit length, while the microstrip line employing PGS has additional capacitance C_b as well as C_a due to PGS. From this figure, we can see that the microstrip line with PGS exhibits much lower characteristic impedance (Z_0) and shorter guided-wavelength (λ_g) than conventional one, because Z_0 and λ_g are inversely proportional to the periodical capacitance, in other words, $Z_0 =(L/C)^{0.5}$ and $\lambda_g=1/[f\cdot(LC)^{0.5}]$.

TABLE I
THE SIZE COMPARISON FOR THE PGS AND THE CONVENTIONAL MICROSTRIP LINE (AT 5 GHZ)

	Width (mm)	**λ (mm)**
Conventional microstrip line	0.64	18.5
Periodic Ground Structure (PGS)	0.02	2.35

Table 1 shows the calculated wavelength for the conventional microstrip line and PGS. As shown in Table I, line width and wavelength of the PGS with a characteristic impedance of 13 Ω are 0.02 mm and 2.35 mm, while line width and wavelength of the conventional microstrip line with a characteristic impedance of 13 Ω are 0.64 mm and 18.5 mm. From the above results, we can conclude that low impedance and highly miniaturized passive components on MMIC can be realized by using the PGS.

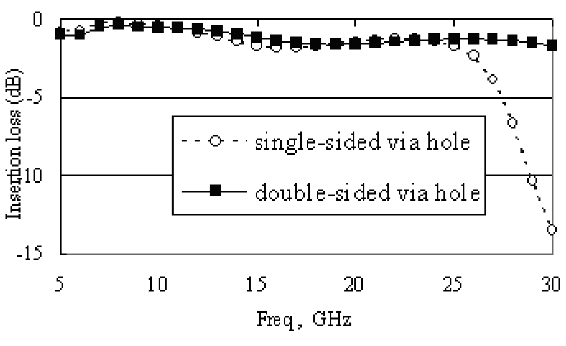

Fig. 2 Insertion loss of PGS bend structure with single-sided and double-sided via holes.

A number of via holes are required for perfect ground condition of the PGS. In this work, however, the number of via holes was minimized in order to reduce the component size as much as possible, and the PGS bend structure with single-sided via holes shown in Fig. 1 (b) was used for further reduction of the power divider. Figure 2 shows the insertion loss of the PGS bend structures with double- and single-sided via holes shown in Fig.1 (a) and (b). As shown in this figure, a significant difference between the two structures is not observed up to 25 GHz, and the PGS bend structure with single-sided via holes was employed for MMIC applications in lower frequencies than K band.

III. A MINIATURIZED AND LOW IMPEDANCE ON-CHIP WILLKINSON POWER DIVIDER EMPLOYING PGS WITH SINGLE-SIDED VIA HOLE

In this work, using the PGS with single-sided via holes, a highly miniaturized on-chip Wilkinson power divider with a low port impedance of 13 Ω was developed. The photograph for the power divide is shown in Fig. 3. Real size of the power divider corresponds to the part surrounded by dotted line because GSG pad was connected for on-wafer measurement, and its size is 0.11 mm^2, which is 6 % of the size of the one fabricated by conventional microstrip line (the size of the power divider employing conventional microstrip line is 1.82 mm^2 at a 5 GHz [3]).

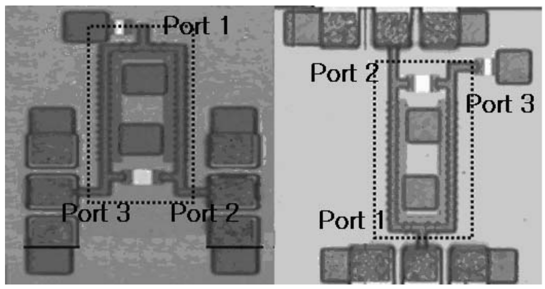

Fig. 3 A photograph of Wilkinson power divider employing PGS bend structure with single sided via holes.

Figure 4 (a) and (b) shows measured power division (S_{12} and S_{13}) and isolation characteristics (S_{23}) for the Wilkinson power divider employing PGS respectively. As shown in Fig. 4 (a), we can observe equal power division characteristics due to its symmetrical structure. From Fig. 4 (a) and (b), we can observe insertion loss values lower than 5.5 dB, and isolations values higher than 7.5 dB from 4.5 to 6 GHz. Isolation characteristics can be improved by increasing the number of via holes for the PGS, however, the PGS bend structures with only two via holes (see Fig. 3) was employed for size reduction.

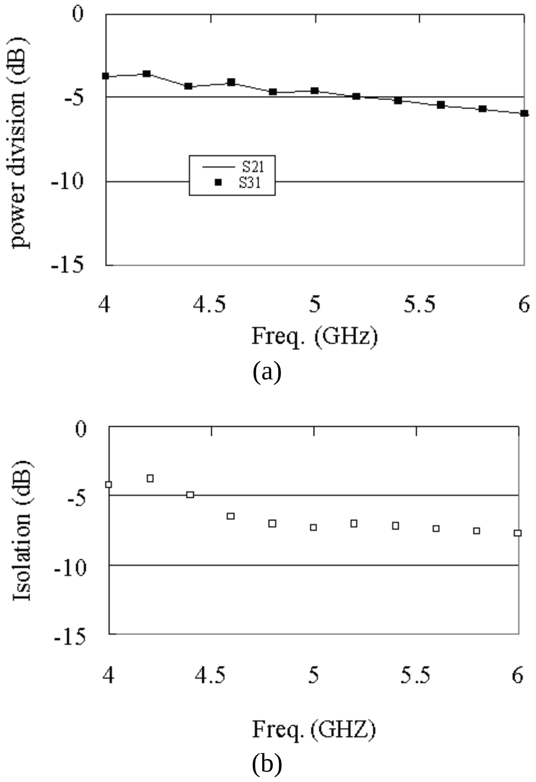

Fig. 4 (a) Measured power division characteristic for the Wilkinson power divider. (b) Measured isolation characteristic for the Wilkinson power divider.

IV. Conclusion

In this work, highly miniaturized and low impedance on-chip Wilkinson power divider employing PGS structure with single-sided via holes was fabricated on GaAs MMIC. Its size was 0.117 mm^2, which was 6% of the conventional one. Equal power division characteristics were observed from the power divider. The power divider showed insertion loss values lower than 5.5 dB and isolations values higher than 7.5 dB from 4.5 to 6 GHz.

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