Highly Miniaturized 1-4 On-Chip Power Divider/Combiner Circuit on Silicon Substrate for Application to Long Distance Wireless Power Transmission

Jeong-Gab Ju, Jang-Hyeon Jeong, Young-Bae Park, Bo-Ra Jung, Eui-Hoon Jang, Suk-Youb Kang, and Young Yun

***Abstract*—In this paper, for application to a long distance wireless power transmission, a highly miniaturized 1-4 power divider/combiner employing periodic structure was fabricated on semiconducting silicon substrate. The 1-4 divider/combiner showed good RF performances from 1 to 25 GHz, and its size was 1.08 x 0.63 mm^2, which is 0.14 % of the size of the one fabricated on PCB.**

***Index Terms*—Coplanar waveguide, PAGS, Silicon, RFIC, AMP**

I. Introduction

Wireless energy or power transfer is the transmission of electrical energy from a power source to a power consumer without interconnecting wires [1]-[4]. Wireless transmission is useful in cases where interconnecting wires are inconvenient, hazardous, or impossible. The most common form of wireless power transmission is carried out using electromagnetic /inductive coupling followed by resonant inductive coupling. However, inductive/electromagnetic coupling method is near field over distances comparable to a few times the diameter of the device or devices approaching one quarter of the wavelength used [1]. For a long distance wireless power transmission, wireless power transmission employing microwave is a promising candidate. Experiments in the tens of kilowatts have been performed by several groups [1]-[4]. These methods achieve distances on the order of a kilometer. Main applications of wireless power transmission employing microwave are shown in Fig. 1.

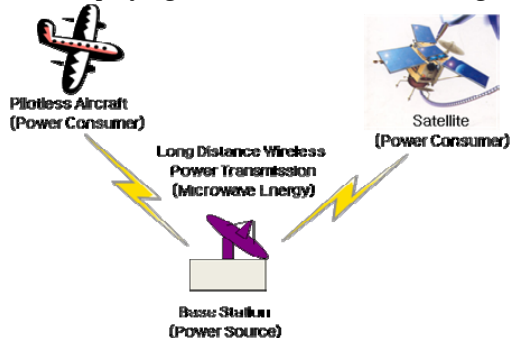

Fig. 1. Main applications of wireless power transmission employing microwave.

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Base station transmits the power needed for the operation of pilotless aircraft and satellite. In this case, a long distance wireless power transmission is required to provide the operation power for the aircraft and satellite. The long distance wireless power transmission system is shown in Fig. 2. Power source provide microwave power using oscillator for wireless transmission. The microwave power is amplified by power amplifier, and amplified microwave power is transmitted to the power consumer.

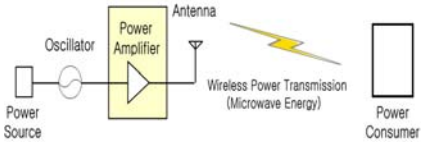

Fig. 2. The long distance wireless power transmission system.

In the above long distance wireless power transmission system, the power amplifier is a key device, because it amplifies the transmitted microwave power so that the power consumer operates well without additional power supply. Especially, a microwave power level of 1W – 1kW is required for application to the long distance wireless power transmission for aircraft and satellite. In this case, the size of power amplifier is highly increased, and it occupies most of the area of the system. Therefore, the main issue of the long distance wireless power transmission is to reduce the size of the power amplifier. Especially, the size of the power divider/combiner should be highly reduced for a miniaturization of power amplifier, because the power divider/combiner occupies most of the area of the power amplifier [5]-[13]. In conventional system, the power divider/combiner was fabricated outside of semiconducting IC (Integrated Circuit) due to its large size.

In this work, to reduce the size of the power amplifier, highly miniaturized 1-4 power divider/combiner employing periodic structure was fabricated on semiconducting silicon substrate. The 1-4 divider/combiner showed good RF performances from 1 to 25 GHz and its size was 1.08 x 0.63 mm^2, which is 0.14 % of the size of the one fabricated on PCB (Printed Circuit Board). This paper was selected from ICIIE (International Conference on Information and Industrial Electronics) 2011, and republished.

II. Structure of 1-4 Power Divider/Combiner

Fig. 3 shows a schematic diagram of the power amplifier for a long distance power transmission. As shown in this figure, several amplifiers are connected in parallel using power divider/combiner in order to extract a high microwave

power through power coupling. The size of the power combiner /divider should be highly reduced for a miniaturization of power amplifier, because the power divider/combiner occupies most of the area of the power amplifier [5]-[13]. In conventional system, the power divider/combiner was fabricated outside of semiconducting IC due to its large size. Fig. 4 shows the conventional X-band 1-4 divider/combiner fabricated on PCB. For, the power divider operation, the input microwave signal is applied to port 1, and it is split into four output signals from port 2 - 5. For the power combiner operation, the four input microwave signal are applied to port 2-5, and it is coupled at port 1. However, the power divider on PCB occupies a very large area. The size of the X-band power divider/combiner is 25 X 20 mm^2, which increases the module size of the power amplifier.

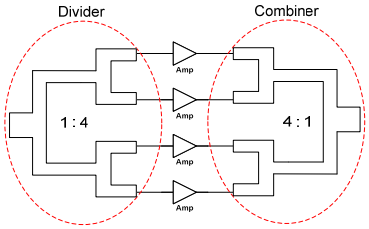

Fig. 3. The schematic diagram of power amplifier for a long distance power transmission.

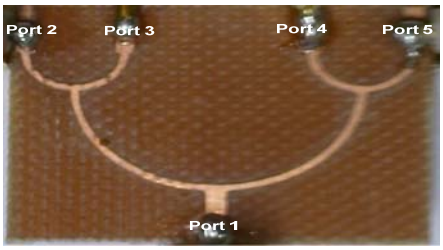

Fig. 4. Conventional 1-4 divider/combiner on PCB

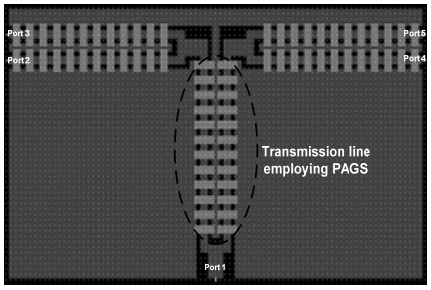

Fig. 5. A layout of the fabricated 1-4 power divider/combiner employing PAGS on silicon substrate

In this work, to reduce the size of the power amplifier, highly miniaturized 1-4 power divider/combiner employing periodic structure was fabricated on semiconducting silicon substrate. Fig. 5 shows a structure of the 1 to 4 power divider/combiner employing PAGS (Periodically Arrayed Ground Strip) structure [14], [15] on silicon substrate. As shown in this figure, the power divider/combiner consists of the transmission line employing PAGS. Fig. 6 shows the PAGS structure [14], [15]. According to our previous report [14], [15], the transmission line employing PAGS showed slow-wave characteristics, and the wavelength of the transmission line employing PAGS was reduced to 60~65% of conventional one, which enables a miniaturization. Its size was 1.08 X 0.63 mm^2, which is 0.14% of the size of the conventional power divider/combiner fabricated on PCB (The size of the conventional power divider/combiner fabricated on PCB is 25 X 20 mm^2.)

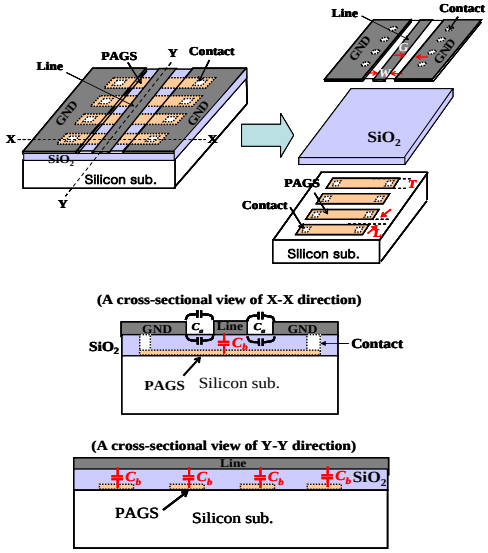

Fig. 6. Structure of the transmission line employing PAGS structure [14]

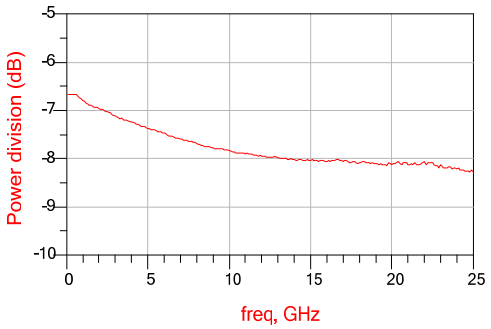

Fig. 7. Measured Measured power division characteristics of the 1-4 power divider/combiner employing PAGS

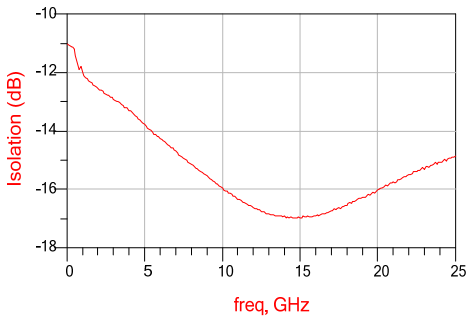

Fig. 8. Measured isolation characteristics of the 1-4 power divider/combiner employing PAGS

III. Performance of 1-4 Power Divider/Combiner

Actually, we fabricated 1-2 power divider/combiner on silicon substrate, and measured its RF characteristics. We extracted the RF performances of the 1-4 power divider /combiner from the above measured data. Fig. 7 and 8 show measured power division and isolation characteristics of the 1-4 power divider/combiner employing PAGS. We can observe good power division characteristic from 1 to 25 GHz. Concretely, power division exhibits a value of -7.5 dB at 10 GHz. In a frequency range of 1 to 25 GHz, show a value of -7.5 ± 1.0 dB, which is comparable to conventional power divider/combiner on PCB. Isolation characteristic shows a value of -16 dB at 10 GHz, and we can observe isolation characteristics higher than -11 dB in the range of 1 to 25 GHz, which is sufficient for a dividing/combining of power.

IV. Conclusions

In this work, for application to a long distance wireless power transmission, we fabricated a highly miniaturized 1-4 power divider/combiner employing periodic structure on semiconducting silicon substrate. The 1-4 divider/combiner showed good RF performances from 1 to 25 GHz, and its size was 1.08 x 0.63 mm^2, which is 0.14 % of the size of the one fabricated on PCB.

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