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ISITC 2018

October 24-27, 2018

2018 INTERNATIONAL SYMPOSIUM ON INFORMATION TECHNOLOGY CONVERGENCE

Session FR1C : Signal Processing

09:00-10:40, Friday, October 26
Session Chair : **Seok-Hwan Park (Chonbuk National University, Korea)**
Session Co-Chair : **Saleem Ahmed (Dawood University, Pakistan)**

Session FR1D : Microwave

09:00-10:40, Friday, October 26
Session Chair : **Jongsik Lim (Soonchunhyang University, Korea)**
Session Co-Chair : **Joan Garcia (Universitat Autonoma de Barcelona, Spain)**

A Study Of Matching Network For X-band MMIC High Power Amplifier

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***Abstract*— In this paper, a study of matching network for X-band monolithic microwave integrated circuit (MMIC) high power amplifier (HPA) is presented. HPA die has multiple input/output pads on the gate and drain. If a matching circuit with uneven transmission characteristics is used, the output efficiency would be decreased due to the combine loss of output power at the final output stage. Therefore, individual transfer characteristics of pads to single input/output ends are important. By comparing tapper structure and signal line circuit (SLC) structure, SLC structure has more uniform transfer characteristics than tapper structure. To compare the characteristics, the HPA designed at 10 GHz based on the same input and output matching impedances using CGHV1J070D of Wolfspeed. HPA using SLC structures at input and output both sides, the output power and drain efficiency (DE) at saturation point are 48.62 dBm and 41.85%. In case of HPA with tapper structures, the output power and DE at saturation point are 48.35 dBm and 38.97%. Therefore, it can be seen that the SLC structure with more uniform transfer characteristics is more suitable for HPA design than the tapper structure.**

Keywords—high power amplifier, matching network, signal line circuit, tapper, X-band.

I. INTRODUCTION

The matching network is a very important factor in the power amplifier design. In particular, various methods have been studied to design high power and high efficiency characteristics of HPAs in x-band[1]-[4]. In [1] - [2], HPAs were designed using SiC substrate according to good heat dissipation characteristics. In [3] - [4], substrates with different dielectric constants were combined to miniaturize the circuit and improve electrical performances of HPAs. Previous studies suggest mainly the improvement of characteristics based on various materials. However, commonly used matching networks are not mainly studied. Even though HPA matching networks have been studied, research has been mainly focused on combining characteristics such as impedance matching and bandpass filters [5]-[6].

Fig. 1 shows CGHV1J070D transistor die of Wolfspeed, which is mainly used for HPA designs in the X-band. There are 12 pads in gate and drain, respectively. Therefore, the input and output matching networks must be connected to the entire pads

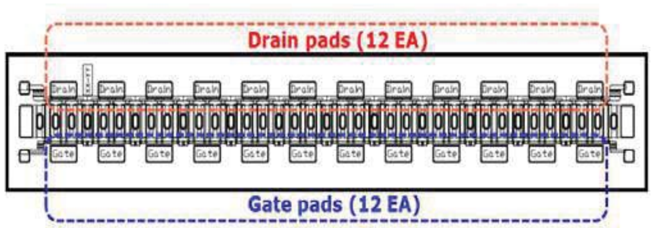


Fig. 1. Layout of CGHV1J070D.

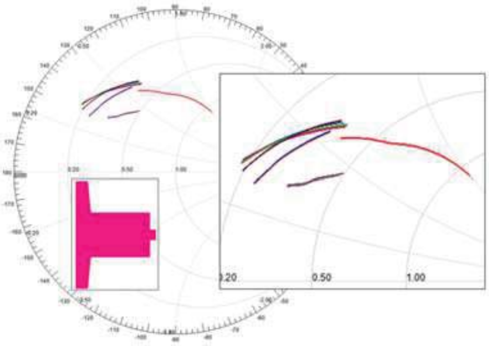
of TR and realized the desired impedance matching characteristics, simultaneously. In particular, the input matching network transmits signals from one input terminal to twelve gate pads. Similarly, the output matching network, signals are transmitted from one of the twelve drain pads to one output terminal. In this process, the differences among the transfer characteristics of each path cause output power and efficiency degradation due to the combining loss at the final single output terminal. Therefore, it is very important to design ~~a~~ matching networks with uniform transmission and impedance matching characteristics in the X-band HPA design.

In this paper, a study of matching network for X-band monolithic microwave integrated circuit (MMIC) high power amplifier (HPA) is presented. The characteristics of signal line circuit (SLC) structure and tapper structure, which are generally used, are compared through EM simulation. For a validation, the design procedure and simulation results of HPAs with SLC and tapper matching networks are provided.

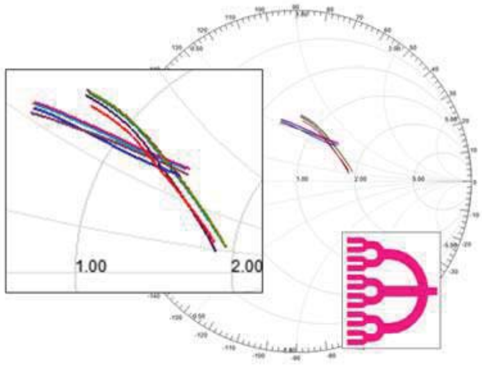
II. ANALYSIS OF MATCHING NETWORK

In this section, the transmission characteristics are compared using the most widely used SLC and tapper circuits among various matching networks. Each matching network is designed using numbers of gate and drain pads of CGHV1J070D and silicon substrate with 100um height and 10 um metal thickness at 10 GHz.

Fig. 2 shows the transmission characteristics of the SLC and tapper matching networks designed with 0.27 + j0.3 Ω impedance matching. In case of tapper matching network shown in Fig. 2 (a), the transfer characteristics from 12 pads to single terminal are dispersed. Although the transfer characteristics are relatively uniform at the inner pad, but the

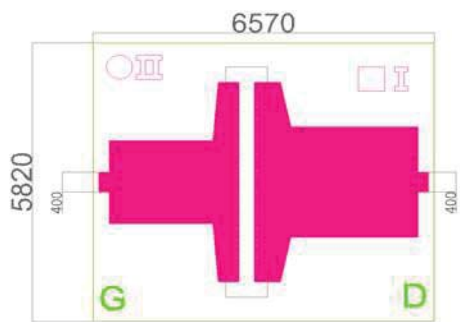


(a)

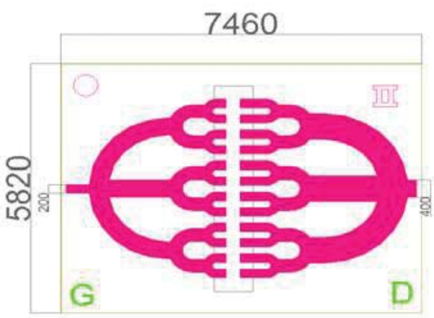


(b)

Fig. 2. Transfer characterisitics and photograph of (a) tapper and (b) signal line circuit.



(a)



(b)

Fig. 3. Layouts of simulated X-band high power amplifier with (a) tapper (5.82×6.57 mm^2) structure and (b) signal line circuit (5.82×7.46 mm^2).

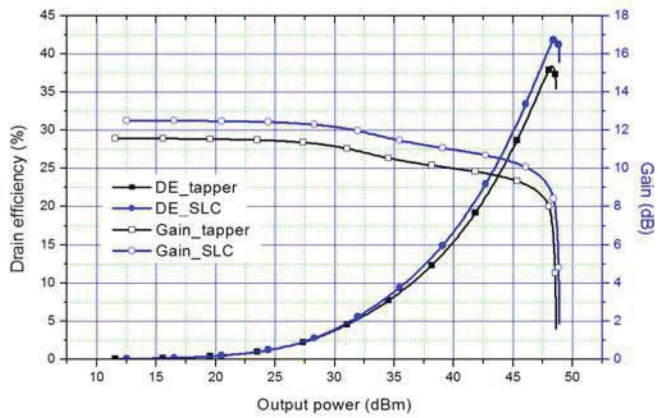


Fig. 4. Simulation results of X-band high power amplifier with signal line circuit and tapper matching networks.

TABLE. I PEERFORMANCES OF HPAS AT SATURATION POINT

	P_{out} (dBm/W)	Gain (dB)	DE (%)
SLC	48.62/72.8	7.42	41.85
Tapper	48.35/68.4	6.55	38.97

maximum phase difference from the pad of outer is 42° compared with inner pads. In addition, magnitudes transferred from each pad are not uniform.

Fig. 2 (b) shows the simulation results of the SLC structure. Compared to the tapper structure, it shows more uniform transmission characteristics. The maximum phase difference among transmission characteristics of the SLC is 21°. Thus, when the transmission characteristics of each path have a magnitude and a phase differences, a loss occurs when signals are combined at the output terminal. To avoid this loss, the SLC structure and other type matching networks are should be used.

III. HPAS USING SLC AND TAPPER MATCHING NETWORK

In this section, HPAs were designed and compared using SLC and tapper structures at the input and output stages. CGHV1J070D of 70 W pulse mode GaN HEMT transistor was simulated. Selected bias condition was V_{DD} = 40 V, V_{GS} = -2.6 V, and I_{DQ} = 537 mA. As load-pull and source-pull simulations, the optimum load and source impedance are 1.27 + j2.6 Ω and 0.27 + j0.3 Ω, respectively. Fig. 3 shows the layouts of the simulated HPAs. Fig. 3(a) implements matching circuits using a tapper structure at the input/output stages. Fig. 3(b) shows the HPA design using SLC. The sizes of the two HPAs are 5.82 × 6.57 mm^2 and 5.82 × 7.46 mm^2, respectively, and the SLC structure occupies a larger area than tapper structure.

Figure 4 compares the gain and drain efficiency (DE) characteristics of two HPAs according to the output power. As can be seen in the figure, the HPA using SLC shows higher gain and DE than HPA using tapper in the overall output power range. Table 1 compares the characteristics of the two HPAs in the saturation region. The output power, gain, and DE of the

HPA using SLC structure are higher about 4.4 W, 0.87 dB, and 2.88% than HPA using tapper, respectively. Because, in case of the tapper structure, both the input and the output matching networks generate a difference of signal transmission and it caused a combine loss at the final output. In the case of the SLC structure, it is possible to realize better characteristics under the same conditions because relatively uniform characteristics.

IV. Conclusion

In this paper, a study of matching network for X-band monolithic microwave integrated circuit (MMIC) high power amplifier (HPA) is described. It analyzes the matching circuits used in the X-band HPA design and the factors of performance degradation. Especially, HPA performance according to the transmission characteristics distribution of the signal line circuit and tapper matching network are reviewed. It has been presented that matching circuits with uniform transmission characteristics are suitable for improving HPA performances.

Acknowledgment

Research reported in this work has been supported by ICMTC (Institute of Civil-Military Technology Cooperation) of Korea under an ICMTC program (16-CM-SS-16).

References

[1] H. I. Tao, W. Hong, B. Zhang, and X. Yu, "A compact 60W X-band GaN HEMT power amplifier MMIC," *IEEE Microwave Wireless Component Letter*, vol. 27, no. 1, pp. 73-75, Jan. 2017.

[2] F. Van Raay, R. Quay, R. Kiefer, F. Benkhelifa, B. Raynor, W. Pletschen, M. Kuri, H. Massler, S. Müller, M. Dammann, M. Mikulla, M. Schlechtweg, and G. Weimann, "A coplanar X-band AlGaN/GaN power amplifier MMIC on s.i. SiC Substrate," *IEEE Microwave Wireless Component Letter*, vol. 15, no. 7, pp. 460-462, Jul. 2005.

[3] Y. Kawamura, M. Hangai, T. Mizutani, K. Tomiyama, and K. Yamanaka, "30W output / 60% PAE GaN power amplifier at X-band 8% relative bandwidth," *Proceedings of the Asia-Pacific Microwave Conference*, Dec. 2016.

[4] M. Kimura, K. Yamauchi, K. Yamanaka, H. Noto, E. Kuwata, H. Otsuka, A. Inoue, Y. Kamo, and M. Miyazaki, "GaN X-band 43% internally-matched FET with 60W output power," *Proceedings of the Asia-Pacific Microwave Conference*, Dec. 2008.

[5] J. Jeong, P. Kim and Y. Jeong, "High efficiency power amplifier with frequency band selective matching networks," *Microwave and Optical Technology Letter*, vol. 57, no. 9, pp. 2031-2034, Sep. 2015.

[6] J. Jeong, P. Kim and Y. Jeong, "Harmonics suppressed band-pass matching network for high efficiency power amplifier," *Proceedings of the European Microwave Conference*, pp. 280-283, Oct. 2017.