第29卷 第11期
2008年11月

半 导 体 学 报
JOURNAL OF SEMICONDUCTORS

Vol.29 No.11
Nov.,2008

An InGaP/GaAs HBT MIC Power Amplifier with Power Combining at the X-Band

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Abstract: A MIC power amplifier with power combining based on InGaP/GaAs HBT is developed and measured for the application of the latest high power amplifier stage of the X-band. A novel InGaP/GaAs HBT power transistor with an on-chip RC stabilization network is used as the power combing cell to improve the stability of the circuit. A compact microstripe line parallel matching network is used to divide and combine the power. By biasing the amplifier at class AB: $V_{cc} = 7V$, $I_c = 230mA$, a maximum CW stabile output power of 28.9dBm and a power combine efficiency of 80% are achieved at 8.1GHz.

Key words: InGaP/GaAs HBT; power combining; MIC; power amplifiers
EEACC: 2560J; 2570B
CLC number: TN431 **Document code**: A **Article ID**: 0253-4177(2008)11-2098-03

1 Introduction

Power amplifiers (PA) are the key component in the RF front end circuits of wireless communication systems. InGaP/GaAs HBT can provide high output power with sufficient efficiency and linearity and meet the demands of the latest high power amplifer (HPA) stage of modern wireless communication, such as phase-array radars, the 3G handsets, Wlans, Wimaxs, and RFID readers. So, GaAs HBT PAs have been the main choice for high performance wireless systems and have become the hotspot of R&D[1,2]. In this paper, an InGaP/GaAs HBT power amplifier with power combining at the X-band is developed. The PA is designed by a MIC form that is often used in the implementation of last HPA stage. The PA can operate at 7.7 ~ 8.5GHz and has an output power of 28.9dBm with a power combining efficiency of 80% at 8.1GHz.

2 Power amplifier design

2.1 Technology of the HBT power transistor

Self oscillation easily occurs in the HPA that has multiple devices with power combining. In order to improve the stability of the circuit, a novel InGaP/GaAs HBT power transistor with on-chip RC stabilization network was used as the power combining cell, as shown in Fig. 1. Due to the on chip RC parallel network, the stability factor K of the power transistor is above 1 in a wide frequency range[3]. So the on-chip RC network improves the stability of the power transistor and suppresses the self oscillation that easily occurs in the HPA. The RC network includes a 50Ω TFR and a 0.8pF MIM capacitor and is placed at the input of the power transistor and barely affects the output power of the transistor[3]. The power transistor consists of ten one-finger 2 × 30μm emitter-area sub-cell HBT that are parallel by the interdigitated layout structure shown in Fig. 1. The sub-cell HBT has a 10Ω emitter ballast resistor in order to suppress the gain collapse of the HBT power transistor[4]. The GaAs HBT epitaxial wafer grown by MBE is offered by Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences. The power transistor was manufactured using a self-align process in a 100mm compound semiconductor process line of IMECAS[4]. For the HBT power transistor, the breakdown voltage BVceo is 20V; the maximum operating current density J_c is 50kA/cm^2; the output power density is about 1.6W/mm at the X-band.

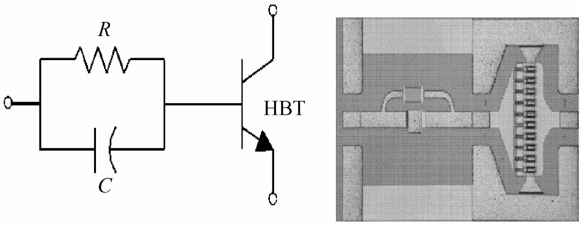

Fig.1 Chip graph of the HBT power transistor

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Received 18 June 2008, revised manuscript received 22 July 2008

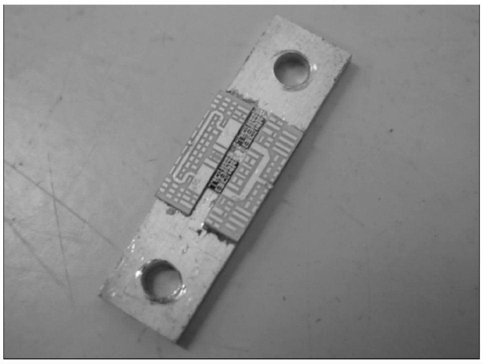

Fig. 2 X-band MIC PA consisting of two 2 × 300μm power transistors, microstripe line parallel matching networks for power divider and combiner

2.2 Circuit design

Figure 2 shows the picture of the power amplifier, which is a single stage X-band MIC power amplifier consisting of two 2 × 300μm HBT power transistors.

A microstripe line parallel matching network is used to divide and combine the power, as shown in Fig. 2. It also finishes the impendence match of the HBT at the same time. This network allows for less area consumption than the tradition Wilkinson combining. In addition, the on-chip RC parallel stabilization network placed in the input of each power transistor is also a part of the impendence matching network.

The PA is designed based on the small signal *S* parameter and the large signal load-pull parameters of the HBT power transistor. The input port was matched to 50Ω. The optimum load impendence matching for output power is obtained by the load-pull parameters. Due to the MIC form, the performance of the PA can be easily debugged after fabrication.

3 RF performance

The amplifier was packaged as shown in Fig. 2, and its size was 8cm × 15cm. All the measurements have been carried on the test fixture in the 50Ω environment in Fig. 3. Due to the RC parallel stabilization network, no self oscillation was observed during the test and no additional isolated resistor in the power combining was used.

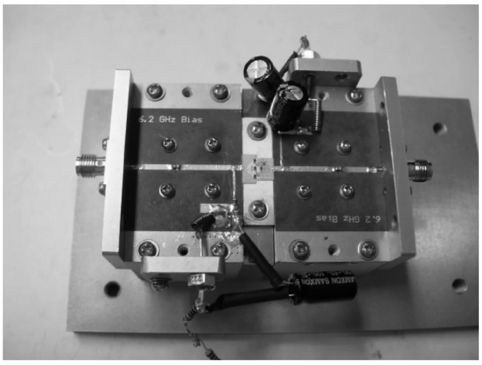

Fig. 3 Amplifier test fixture

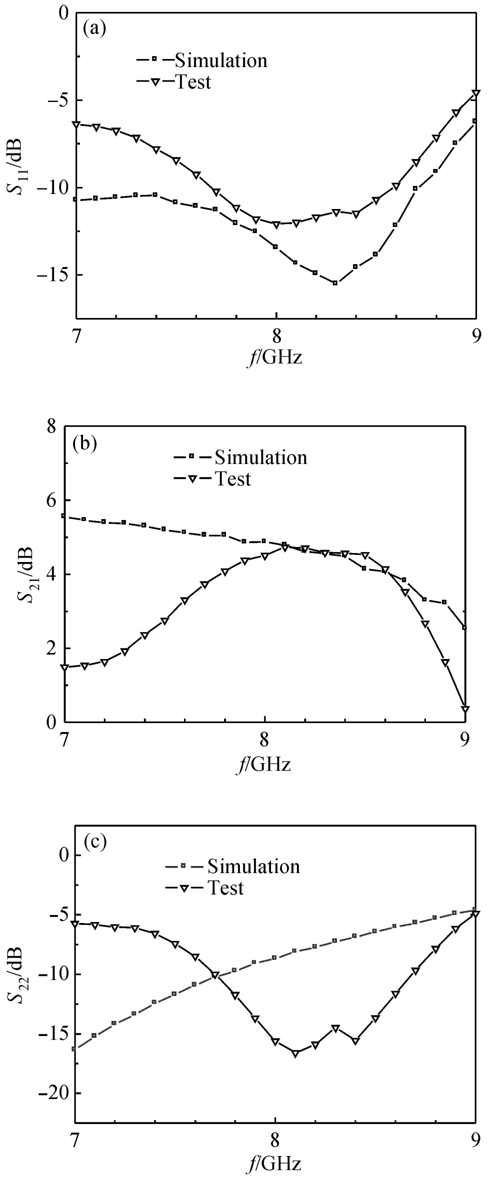

Fig. 4 Small signal performance of the PA Bias point: V_{cc} = 7V, and I_{cc} = 230mA

3.1 Small signal performance

The measured small signal performance of the amplifier at the class AB bias point V_{cc} = 7V, I_{cc} = 230mA is displayed in Fig. 4. In this figure, two group curves are shown: One is the simulation curve, and the other is the final test result, which is tuned carefully. Because of the MIC structure, the bond wire tuned cell can be tuned easily to eliminate the parasitic effect of the layout and package. After tuning, the small signal results of the PA were close to the simulation curve and can operate at 7.7 ~ 8.5GHz. The small signal gain is 3.7~4.7dB, and the gain flatness is under 1dB.

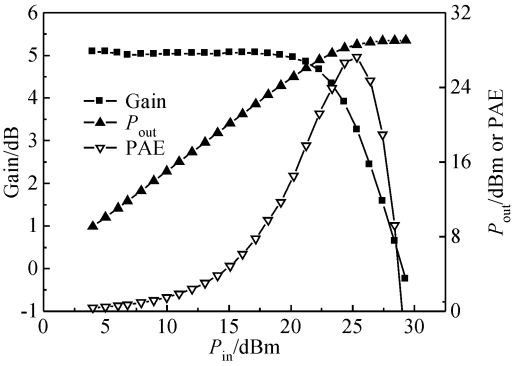

Fig.5 CW power performance of the amplifier at 8.1GHz Bias point: V_{cc} = 7V, and I_{cc} = 230mA. P_{outmax} = 28.9dBm, PAE_{max} = 27% and P_{1dB} = 28dBm

3.2 Large signal performance

Figure 5 illustrates the power performance of the amplifier at 8.1GHz. By biasing the PA at class AB: $V_{cc}=7V$, $I_{cc}=230mA$, a maximum CW output power of 28.9dBm and a maximum PAE of 27% were measured. The low PAE mainly resulted from the low power gain of this PA due to the high frequency operation of the X-band and the trade-off of several performance factors. Some power gain of the HBT device is sacrificed for the design of stability and bandwidth of the PA. The output power at the 1dB gain compression point P_{1dB} is 28dBm. For a $2\times300\mu m$ device, the power transistor is capable of outputting a P_{1dB} of 26dBm. So, the power combining efficiency of the PA is about 80%.

4 Conclusion

The 7.7～8.5GHz InGaP/GaAs HBT MIC power amplifier with the power combining was designed, fabricated, and measured. The on-chip RC parallel stabilization network improved the stability of the circuit and simplified the stability design of the MIC with power combining. The highest CW output power at 8.1GHz was 28.9dBm with a power combining efficiency of 80%.

Acknowledgments The authors would like to thank Prof. Qi Ming and Doctor Xu Anhuai from Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences for GaAs HBT epitaxial wafer. The author would also like to thank the Nanjing Electronic Devices Institute for the backside process and the Sichuan Longrui Microelectronics Co., Ltd for the test support.

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InGaP/GaAs HBT X波段混合集成功率合成放大器的研制

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摘要：研制了面向X波段应用的InGaP/GaAs HBT混合集成功率合成放大器模块. 电路采用一种新颖的具有片上RC稳定网络的InGaP/GaAs HBT功率管作为功率合成单元以提高电路的稳定性，并采用紧凑的微带线并联匹配网络进行功率分配和合成. 在8.1GHz，偏置为$V_{cc}=7V$，$I_c=230mA$的AB类工作条件下，连续波最大输出功率为28.9dBm，功率合成效率达到80%.

关键词：InGaP/GaAs HBT；功率合成；混合集成电路；功率放大器
EEACC：2560J；2570B
中图分类号：TN431 **文献标识码：**A **文章编号：**0253-4177(2008)11-2098-03

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2008-06-18 收到，2008-07-22 定稿