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# SiGe HBT Class AB Power Amplifier for Wireless Communications*

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**Abstract:** Good performance SiGe power amplifiers applicable to wireless communications are demonstrated. The output power can reach more than 30dBm in class B mode. And in class AB mode, the output power at 1dB compression point ($P_{1dB}$) is 24dBm, the output third order intercept (TOI) power is 39dBm under $V_{cc}$ of 4V. The highest power added efficiency (PAE) and PAE at 1dB compression point are 34% and 25%, respectively. The adjacent channel power rejection for CDMA signal is more than 42dBc, which complies with IS95 specification.

**Key words:** SiGe; HBT; microwave power amplifier
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## 1 Introduction

Wireless communication systems require high performance RF/microwave devices and circuits. The mobile communication is now transforming into the third generation, in which the CDMA mode communication will become the essential mode. In this mode, the required output power will be smaller than that in GSM mode, but the linearity requirement is very demanding[1].

Recent trends are towards increasing the integrity of circuits. Hence more and more RF functions are implemented in silicon CMOS process. However, power amplifier is difficult to be integrated with other parts, and difficult to be realized in CMOS process as well. Although efforts are being taken in this way, in the near future, Si/SiGe BiCMOS process and Ⅲ-Ⅴ process will still be the main means. SiGe BiCMOS process provides high performance and can be integrated with Si CMOS process simultaneously. So SiGe BiCMOS process is the most promising candidate for the RF power amplifiers.

SiGe HBT process is mature enough to be promoted in commercial market. More and more power amplifiers[2~4] implemented in SiGe process are reported in recent years. In this paper, we report a high performance SiGe HBT hybrid power amplifier, which is believed to be the first report in China.

## 2 Power amplifiers

Our power amplifier is manufactured in hybrid microstrip form. The material epitaxy and active

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transistor manufacture were reported before[5,6]. The transistor's input and output impedance were estimated first, and then the external matching circuits were designed. Some adjusts were taken subsequently during the measurement. Then by measuring the passive matching circuits impedance, the transistor's input and output impedance were obtained. Hence the circuit was re-designed. After several iterations, the final circuit was obtained. The circuit schematic is displayed in Fig. 1.

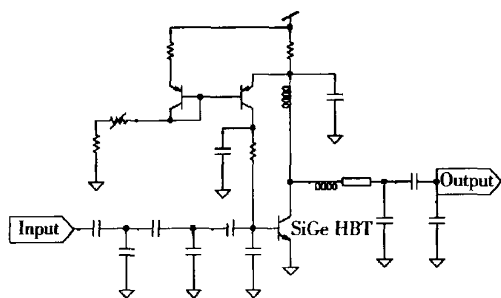


Fig. 1 Schematic of class AB SiGe power amplifier

The substrate of the demonstration board is teflon with dielectric constant of 2.3. The external matching components are composed of surface mount capacitors, inductors and microstrip lines. The power transistor can be biased in class AB or B mode, by adjusting a variable resistor in series with the base terminal and the base bias voltage. Class AB mode can achieve relatively high efficiency and linearity simultaneously, while class B will suffer linearity loss of some extend.

# 3 Results

The performance of the amplifier was measured under $V_{cc}$ of 3 and 4V. Figure 2 is the output power and power added efficiency (PAE) under $V_{cc}$ of 3V. In working frequency of CDMA band (836MHz), the highest PAE is 34% when output power is 27dBm. At 1dB compression point, the output power is 23.2dBm, with PAE of 17%. By increasing $V_{cc}$ to 4V, the output power at 1dB compression point can approach almost to 25dBm.

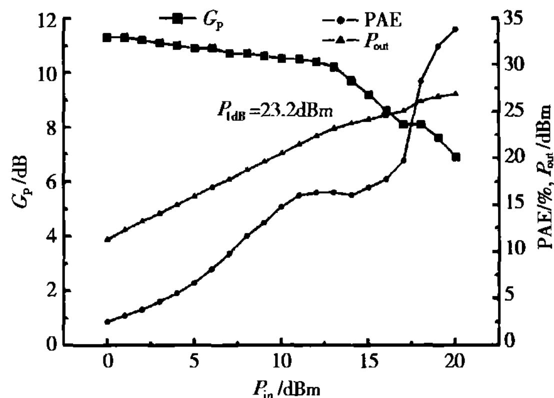


Fig. 2 Class AB SiGe power amplifier's output performance

Linearity is critical for CDMA operation. The third order intermodulation (IP3) and adjacent channel power rejection (ACPR) performance were measured. Figure 3 is the result under $V_{cc}$ of 4V. The output third order intercept (TOI) power is 39dBm. While IP3 is the measure in continuous operation mode, ACPR can give a more direct indication of the performance in the digital modulation communication environment. In IS95, the minimum ACPR is 42dBc, while the recommended is 45dBc. Our measurement got a result of 42.8dBc when the channel power is about 25dBm.

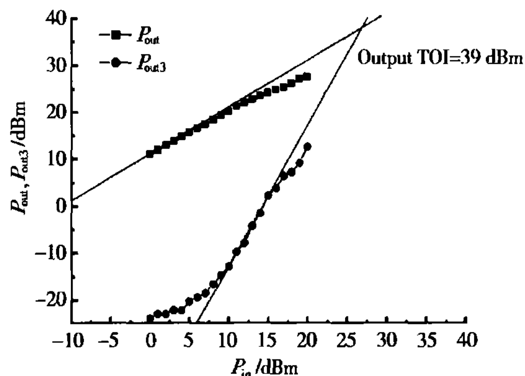


Fig. 3 Class AB hybrid SiGe power amplifier's performance in two tone operation $f_1$=835MHz and $f_2$=836MHz

Figure 4 shows the circuit performance in class B configuration. $V_{cc}$ is increased a little to 4.1V to achieve higher output power. In this condition, at 1dB compression point the output power

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can reach 30dBm with PAE of 30%.

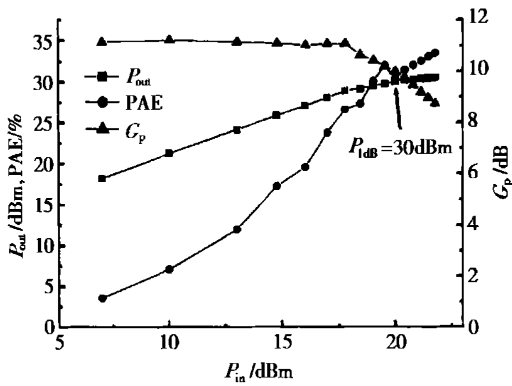


Fig.4　Output performance in Class B mode operation

# 4　Conclusion

SiGe HBT power amplifiers with good performance applicable to wireless communications were demonstrated. Both high output power and linearity can be obtained. The highest output power is 30dBm, and ACPR is more than 42dBc. The hybrid circuit is the basis for power amplifier modules. Generally speaking, there are two kinds of industrialized commercial power amplifiers, power modules and monolithic integrated circuits (MMICs). Power module is implemented with the advanced package method such as chip on board and surface mount components. It can be developed from its counterpart of hybrid microstrip circuits by decreasing the components' size and some necessary circuits alteration. With the development of more and more high quality and small footprint surface mount components, power module can be realized more and more easily. So the hybrid circuits can be improved into power modules for practical application. The research of power transistor model is being performed to facilitate the integrated power amplifiers design.

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## References

[1] Noh Y S, Lee T W, Park C S. Linearized high efficient HBT power amplifier module for L-band application. Technical Digest-GaAs IC Symposium, 2001:197

[2] Erban U, Wahl M, Schuppen A, et al. Class-A SiGe HBT power amplifiers at C-band frequencies. IEEE Microwave Guided Wave Lett, 1995, 12(5):435

[3] Schuppen A, Gerlach S, Dietrich H, et al. 1W SiGe HBT's for mobile communication. IEEE Microwave Guided Wave Lett, 1996, 6(9):341

[4] Schuppen A. SiGe-HBTs for mobile communication. Solid-State Electron, 1999, 43(8):1373

[5] Jia Hongyong, Zhu Wenbin, Liu Zhinong, et al. Development of microwave SiGe heterojunction bipolar transistors. Chinese Journal of Semiconductors, 2000, 21(10):970

[6] Jia Hongyong, Lin Huiwang, Chen Peiyi, et al. Epitaxy of SiGe HBT structure by high vacuum/rapid thermal processing/chemical vapor deposition. Chinese Journal of Semiconductors, 2001, 22(3):251

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# 用于无线通信的 SiGe 异质结双极型晶体管 AB 类功率放大器*

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**摘要**：报道了一种性能良好的 SiGe 功率放大器，具有用于无线通信的前景. 在 B 类模式下工作时，输出功率可以达到 30dBm. 在 AB 类模式下，电源电压为 4V 工作时，1dB 压缩点输出功率($P_{1dB}$)为 24dBm，输出功率三阶交截点(TOI)为 39dBm. 最大的功率附加效率(PAE)和在 1dB 压缩点的功率附加效率分别达到 34% 和 25%. 处理 CDMA 信号时的邻道功率抑制超过 42dBc，符合 IS95 标准.

**关键词**：锗硅；异质结双极型晶体管；微波功率放大器

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