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High Power Performance of 2.4 GHz HBT MMIC Power Amplifer

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1. Introduction

Monolithic millimeter-wave integrated circuits (MMIC) are key components for future communication and smart military applications which require components that are light weight, good reliability, high volume, and low cost. High power, high efficient, and low cost power amplifiers (PAs) have been developed by utilizing commerical GaAs Heterojunction Bipolar Transistors (HBTs) Technology. There are many advantages by using HBTs technology in power amplifiers, rather than using MESFETs or HEMTs-based approaches [1-3]. One of the largest benefit is the circuit and structure simplicity for the designers. In addition, HBTs do not require any negative voltages for operation, therefore, a charge pump is not required.

In this paper, we demonstrate a 2.4 GHz PA which is suitable for wireless communication, under a supply voltage of 3.6 V. This amplifier can provide a maximum output power of 25 dBm, a power gain of 25 dB and a power added efficiency (PAE) of 43 percent. In addition, we also add a power control circuit, which can be used for gain control in power amplifiers. All power amplifiers require some means of power-down control to reduce battery power consumption when PA is not in use. The power gain can be controlled between 18 dB to 25 dB with a control range from 2 V to 4V.

2. Device Simulation

The schematic diagram of two-stage Class-A power amplifier is shown in Fig. 1. The driver stage incorporates 10 emitter fingers, each have an area of 2.8x15 μm². The load stage incorporates 30 emitter fingers, which have an area of 2.8x15 μm². This amplifier is biased at $V_C = 3.6$ V, $V_B = 3$ V, and the operating frequency is 2.4 GHz. The CAD (AWR, Microwave2000) Load-Line analysis was used to determine the Large Signal Load for maximum output power. Fig. 2 shows the simulated load-line of dc and RF characteristics. For our design, the amplifier is composite of a driver stage, in which the linear power gain is 10 dB, and a load stage with a linear power gain of 14.5 dB. Fig. 3 shows the power gain simulation of the load stage. As shown in Fig. 3, this two-stage amplifier with a input power of 6 dBm, providing a power gain of 24.7 dB, and a maximum output power of 25 dBm at full power. In addition, the power gain can be controlled from 18 dB to 25 dB with a 2 V to 4 V control voltage, which is shown in Fig. 4. This power control design can provide the stability from bias shifting. Fig. 5 shows the photograph of the fabricated Chip. The overall size is 1 mm x 1 mm and the optimum load for the output stage is not including in this MMIC chip. The output match can be provided by the Load-Pull automatic load or by the series inductance formed from the output bond wires and a shunt capacitor external to the output load.

3. Result and Discuss

This MMIC chip is measured by the on-wafer load-pull measurements. Fig. 6 shows the small signal gain and input, output return loss for a typical MMIC chip from 1 to 5 GHz. The simulated and measured small signal gain (S_{21}) are 20.3 dB and 23.22 dB at 2.4 GHz, respectively. Fig. 7 shows the output power and power added efficiency performance, which is a function of the input power. With an input power of 6 dBm, a saturated output power of 25 dBm was measured, and the corresponding PAE is 43%. Based on our designed circuit, the simulated and the fabricated results are quite coincidence with each other.

4. Conclusion

A 2.4 GHz two-stage power MMIC chip with a overall size of 1 mm x 1 mm was successfully developed. The PA has achieved an excellent gain and high power efficiency performance. Table I shows the simulated and measured results of this MMIC circuit which is very suitable for 2.4 GHz high microwave power application.

References

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[3]Pin-Fan Chen, etal, IEEE Transactions on Microwave Theory and Techniques, vol. 47, no.8, pp1433-1437, 1999.

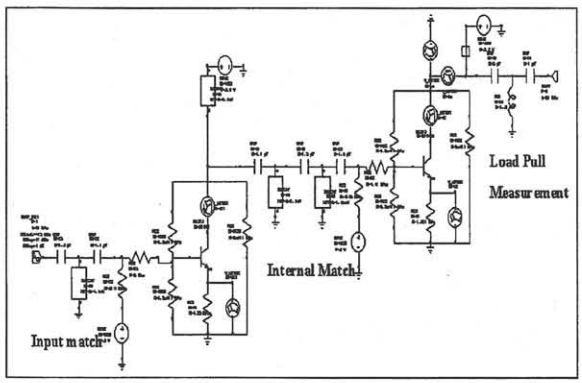


Fig1: The schematic diagram of a two-stage power amplifier

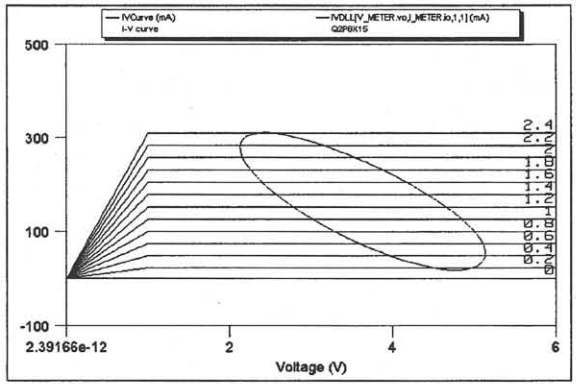


Fig2:The Load-Line Simulation

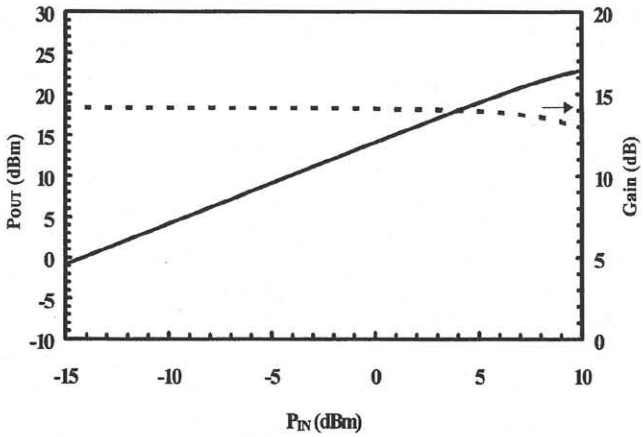


Fig3:The power gain performance of load stage

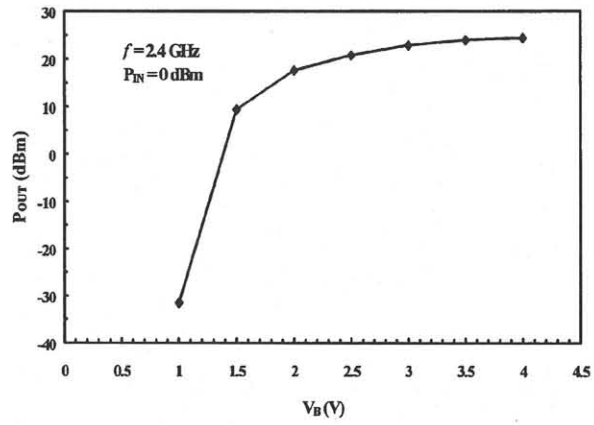
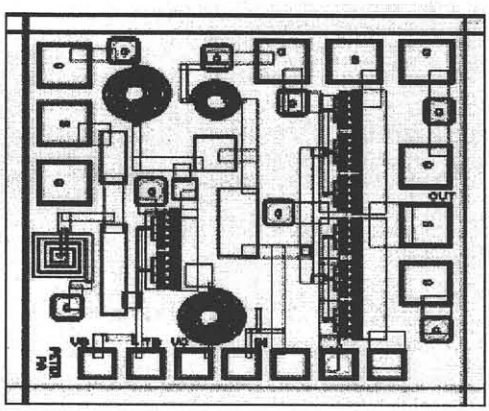


Fig4:The simulated result of power gain control circuit



Fg5: The chip's layout (1mm x1mm)

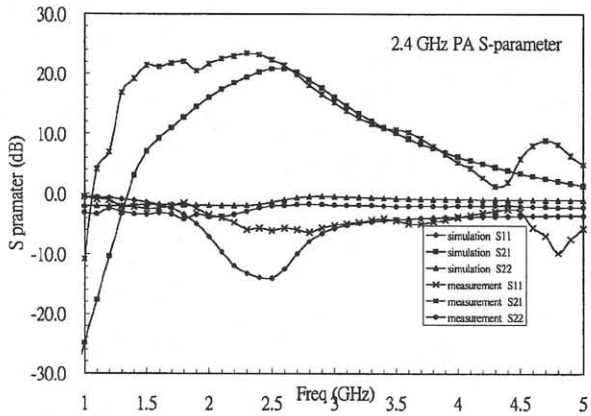


Fig6:The simulation and measured S-parameter

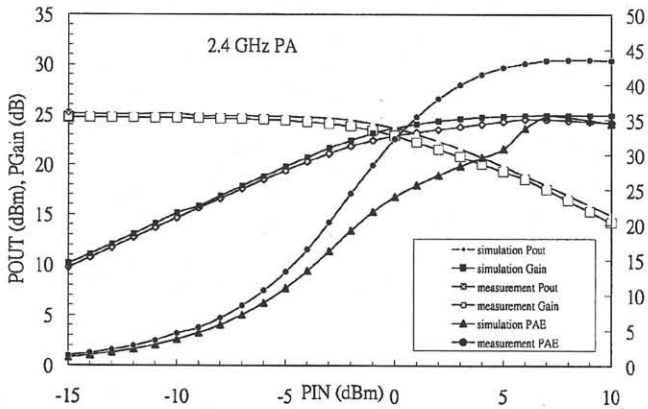


Fig7:The amplifier's power performance

Spec	Simulation	Measured
frequency(GHz)	2.4	2.4
DC bias V_C(volts)	3.6	3.6
DC bias V_B(volts)	3	3
Linear Power Gain(dB)	24.6	25.1
P_{1dB} (dBm)	21.9	22.45
PAE@P_{1dB} (%)	19.1	24.42
Pout,max(dBm)	24.5	25
PAE@Pout,max(%)	35.5	43.42
small signal gain(dB)	20.3	23.22

Table I :The Performance of 2.4GHz MMIC power amplifier