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Design of Cellular Power Amplifier Using a Si/SiGe HBT

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Abstract

A cellular power amplifier using an APCVD(Atmospheric Pressure Chemical Vapor Deposition)-grown SiGe base HBT of ETRI[1] has been designed with a linear simulation CAD. The Si/SiGe HBT with an emitter area of $2\times 8\mu m^2$ typically has a cutoff frequency(f_T) of 7.0 GHz and a maximum oscillation frequency(f_{max}) of 16.1 GHz with a pad de-embedding A packaged power Si/SiGe HBT with an emitter area of $2\times 8\times 80\mu m^2$ typically shows a f_T of 4.7 GHz and a f_{max} of 7.1 GHz at a collector current (I_C) of 115 mA. The power amplifier exhibits a Forward transmission coefficient(S21) of 13.5 dB, an input and an output reflection coefficients of -42 dB and -45 dB respectively. Up to now the Ⅲ-Ⅴ compound semiconductor devices have dominated microwave applications, however a rapid progress in Si-based technology make the advent of the Si/SiGe HBT which is promising in low to even higher microwave range because of lower cost and relatively higher reproducibility of a Si-based process.

Ⅰ. Introduction

Since the advent of utilizing a wide-bandgap emitter to improve device performance, which was firstly proposed(1948) and patented(1951) by Shockley[2], there had been incessant efforts to make it in practice. Later Kroemer theoretically proved performance leverage of HBTs over homojunction bipolar transistors[3]. Major progresses in epitaxial techniques, such as Metal Organic Chemical Vapor Deposition (MOCVD) and Molecular Beam Epitaxy(MBE), enables new transistor design to exploit the "bandgap engineering" controling the flow of carriers and thereby result in superior device performance to that attainable in homojunction devices.

GaAs FETs have been mature in micro- and millimeter-wave market which needs a device operating at that high frequencies and speed. On the other hand, silicon bipolar transistor have been applied in a wide spectrum of analog, digital, and microwave circuits. Silicon bipolar technology, however, has still maintained a sizable market through the years for applications requiring high speed, high current drive, low noise, and where power dissipation is a secondary concern.

Recently, the demand on the high performance and low cost radio frequency integrated circuit (RFIC) has explosively increased for the wireless communication system. Si/SiGe HBTs have found applications in LNAs(Low Noise Amplifiers), VCOs(Voltage Controlled Oscillators), and power-amplifiers[4][5].

Ⅱ. Design of Power Amplifier by Si/SiGe HBT

The SiGe HBT with an emitter are of 2×8

μm^2 typically has a f_T of 7.0 GHz and a f_{max} of 16.1 GHz with a pad de-embedding. In order to increase I_C, an emitter area of $2\times8\mu m^2$ was parallelly connected with 80 transistors and its $I-V$ characteristics is shown in Figure 1. Early voltage was obtained $120V$ and breakdown was measured at $18V$ [Figure 1]. Figure 2 shows the plot of the common-emitter current gain versus collector current. Maximum current gain is 160 and nearly constant over three decades of I_C. The packaged power Si/SiGe HBT with the emitter area of $2\times8\times80\mu m^2$ typically shows a f_T of 4.7 GHz and a f_{max} of 7.1 GHz at Ic of $115mA$.

A hybrid-type power amplifier was designed using a linear simulation CAD. For the operating frequency is somewhat low, the circuit seems to be large. In order to reduce the size, the teflon substrate with a high dielectric constant ϵ_r=10 was used . At input and output, DC-blocking chip capacitors are located. Matching network consists of open stubs in input and output. In the input matching circuit, a radial stub was used in order to reduce the width and length of the open stubs. Since the DC feeder line should become as long as the total circuit, it was bended several times. The $\lambda/4$-shorted microstripe line having higher impedance than RF chocks was used. Figure 3 shows the negative film to be used in fabricating the hybrid MIC.

The simulation indicates a good matching characteristics, as shown in Fig. 4. Input and output reflection coefficients are -42 dB and -45 dB respectively at 850 MHz. Forward transmission coefficient is 13.42dB at 850 MHz [Figure 5].

Ⅲ. Si/SiGe HBT Circuit Performance

On the teflon substrate hybrid Si/SiGe HBT power amplifer was fabricated. Contrary to the expecation, there was some discrepancy between simulated values and measured. The power amplifier had 7.6 dB gain when the input power was supplied by 17 dBm, the output power produced 24.5 dBm($\approx$ 0.3W). S-parameter of the power amplifier was measured by HP 8510C and the output power with HP spectrum analyzer 8563E.

Ⅲ. Conclusion

A power amplifier using a APCVD-grown SiGe base HBT of ETRI was designed and fabricated for cellular application. In spite of good results of simulation: a forward transmission coefficient of 13.42dB, input and output reflection coefficients of -42 dB and -45 dB respectively at 850 MHz, the final circuit perforance was unsatisfactable. However, more research can make its perforance much better.

Reference

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[2] Shockley, W., U. S. Patent N0. 2,569,347, 1951.

[3] Kroemer, H., "Heterostructure Bipolar Transistor and Integrated Circuits," Proc. IEEE, Vol. 70, 1982, pp. 13.

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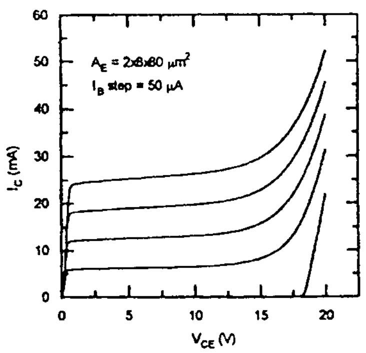

Figure 1. I-V characteristics of high power Si/SiGe HBT

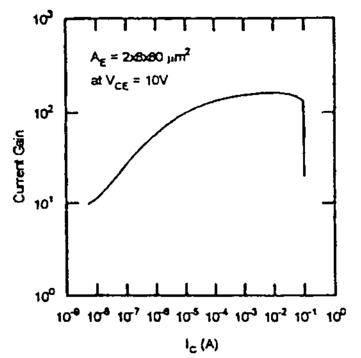

Figure 2. Current g ain versus collector current (I_C) of high power Si/SiGe HBT

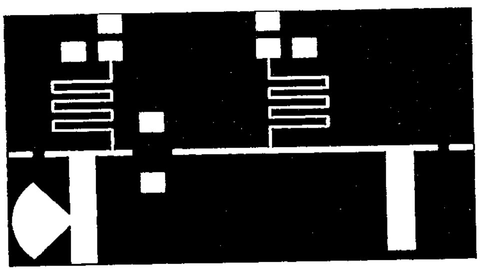

Figure 3. The negative film of hybrid power amplifier

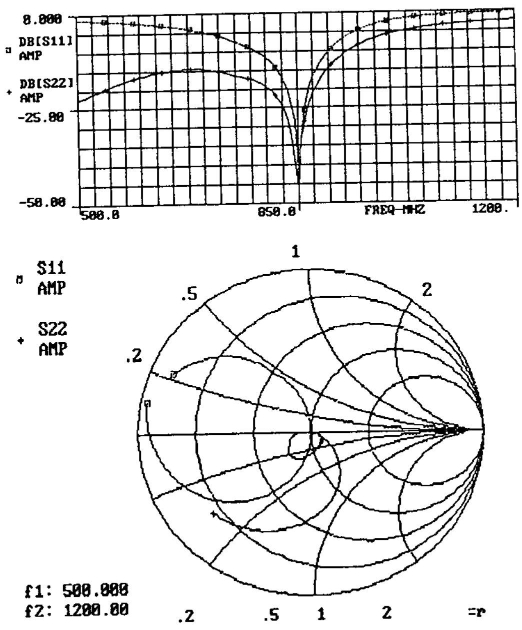

Figure 4. Input and output reflection coefficients (S11 and S22) of amplifier

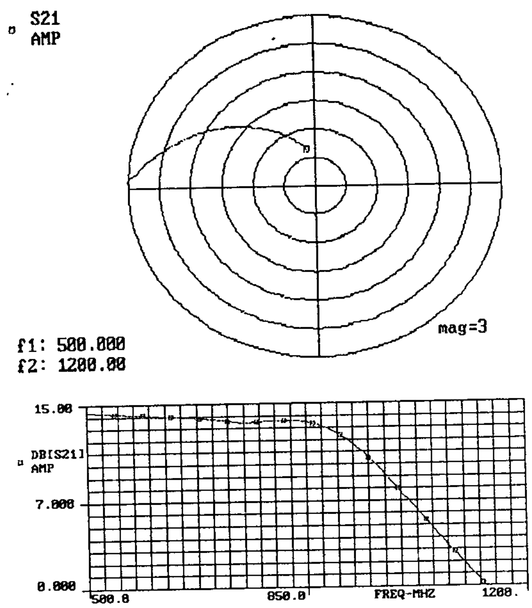

Figure 5. Forward transmission coefficient(S21) of amplifier