# A 5 GHz High Efficiency and Low Distortion InGaP/GaAs HBT Power Amplifier MMIC

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***Abstract* — An InGaP/GaAs two-stage HBT power amplifier for 5 GHz Wireless-LAN applications was developed. By using a self-aligned base contact formation process and an external base region side etching process, a high gain HBT was realized. A small-sized via hole fabrication process was developed. The gain of multi-finger HBT was improved by locating via holes between each finger. Linearity was also improved by developing a new variable negative feedback circuit. A power amplifier MMIC utilizing this technology was fabricated, and 19.7 dBm output power, 22 dB gain, 22.5% power-added-efficiency (PAE), 5.0% error vector magnitude (EVM) were obtained at 54 Mbps transmission under a supply voltage of 3.3 V. These state of the art data represent the highest PAE reported for a the power amplifier MMIC in the 5 GHz Wireless-LAN application.**

## I. Introduction

In recent years, the 5 GHz wireless broadband communications system, especially IEEE 802.11a Wireless-LAN application, has been receiving a lot of attention. Since the power amplifier for 5 GHz Wireless-LAN is operated at higher frequency than for cellular phones (at 800 MHz ~ 2 GHz), higher gain is required for amplification devices (HBT, HEMT). The high gain not only raises the PAE of amplifiers, but also enable to adopt a feedback circuit for distortion control.

This paper describes technological features to improve the performance of power amplifiers for the 5 GHz Wireless-LAN applications. The gain of multi-finger HBTs is improved by self-aligned base contact formation process technology and small-sized via hole process technology. The linearity is also improved by a variable negative feedback circuit technology.

## II. Device Technology and Performance

Reduction of base resistance $R_B$ and collector capacitance $C_{BC}$ are effective in increasing the gain of a transistor[1-2]. A SEM photograph of fabricated HBT is shown in Fig. 1. By self-aligning the base contact to the emitter contact, $R_B$ is reduced. $C_{BC}$ is reduced by side etching of the external base region. Figure 2 shows $f_T$, $f_{max}$, and MSG/MAG of one-finger HBT using self-aligned technology. The effect of this self-aligned technology is that MAG is increased by 3.5 dB and $f_{max}$ by 13.5 GHz at collector current density Jc of 10 kA/cm$^2$.

Reduction of ground inductance $L_E$ is also effective in increasing the gain of a transistor. To this purpose we developed a process to fabricate small-sized via holes of 15 μm width[3]. Figure 3 shows MSG/MAG for two kinds of 6.4 x 60 μm$^2$ x 8-finger HBT power amplifiers. One HBT power amplifier has via holes located between each finger. The other HBT power amplifier has via holes located only at its extremities. When the via holes are located between each finger, the gain is 2 dB higher than the case where the via holes are located only at its extremities.



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The dependence of MSG/MAG on the number of fingers is shown in Fig. 4. The increase of gain, effected by the via holes between each finger, is remarkable for devices with a large number of fingers. Since via holes are small-sized, it is not necessary to enlarge the chip size and, hence, there is no gain degradation by the electrode line loss.

## III. Low Distortion Techniques

The circuit diagram of the power amplifier MMIC is shown in Fig. 5. The variable negative feedback circuit comprises a transistor HBT5 (the base and collector are short-circuited and it functions as a B-E junction diode), a capacitance C5 and resistance R5. The feedback circuit is connected to the first stage of the amplifier. Since the impedance of HBT5 is variable, the amount of feedback depends on the signal voltage between the base and emitter of HBT5. Figure 6 shows the simulated impedance between A and B of the feedback circuit in Fig. 5. In this circuit, the voltage between the base and emitter of HBT5 decreases and the impedance increases with increasing input signal. Therefore, the amount of feedback decreases with increasing input signal, and the gain roll-off in the high output region can be reduced. This would not be possible with a constant negative feedback circuit. The simulation result is shown in Fig. 7. Compared with constant negative feedback, it turns out that the gain is maintained to higher output power using the variable negative feedback.

## IV. Measured Results

Figure 8 shows a photograph of the fabricated power amplifier MMIC. The chip size is 0.81 mm x 1.22 mm. The substrate thickness of this chip is 70 μm. The InGaP/GaAs HBT power amplifier consists of 8-finger HBTs with emitter size 4.2 x 60 $\mu m^2$. This HBT power amplifier has via holes located between each finger. The input-output characteristic of power amplifier is shown in Fig. 9. Bias conditions are Vcc of 3.3 V, Vbb of 2.7 V, and Iq1/Iq2 of 16 mA/26 mA at a frequency of 5.25 GHz with 64 QAM-OFDM (54 Mbps) modulation conforming to IEEE 802.11a. When the maximum EVM is 5%, Pout of 19.7 dBm, Gain of 22.1 dB, PAE of 22.5%, and ACP1 of -33.8 dBc are obtained as the characteristic of the fabricated MMIC. These state of the art data represent the highest PAE reported for a the power amplifier MMIC in the 5 GHz Wireless-LAN application.

## V. Conclusion

An InGaP/GaAs two-stage HBT power amplifier for 5 GHz Wireless-LAN application was developed. The gain of HBT was increased by using a self-aligned base contact formation process and an external base region side etching process. A small-sized via hole fabrication process was developed. The gain of multi-finger HBT was improved by locating via holes between each finger. The adoption of a variable negative feedback circuit was enabled by the increase in gain, and linearity was thereby improved. An MMIC circuit which utilized such technology gave Pout of 19.7 dBm, Gain of 22 dB, PAE of 22.5%, and EVM of 5.0% at 54 Mbps transmission.

## Reference


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[3] H. Koh et al, "A High Efficiency InGaP/GaAs HBT Power Amplifier MMIC for the 5GHz Wireless-LAN Application", Proc. EuMC 2002, pp.469-472, 2002.

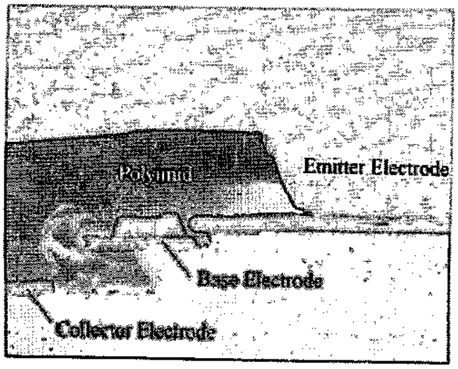


Fig. 1 SEM photograph of fabricated 6.4 x 60 μm² HBT cross section.

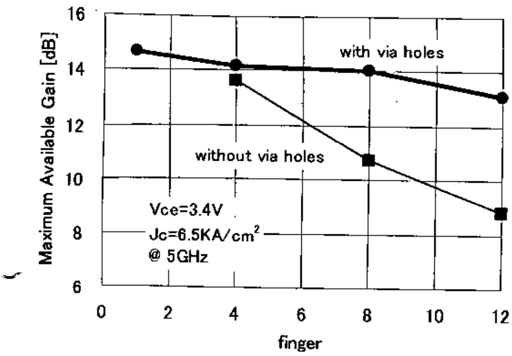


Fig. 4 Measured MAGs of 6.4 x 60 μm² HBT as a function of a number of fingers.

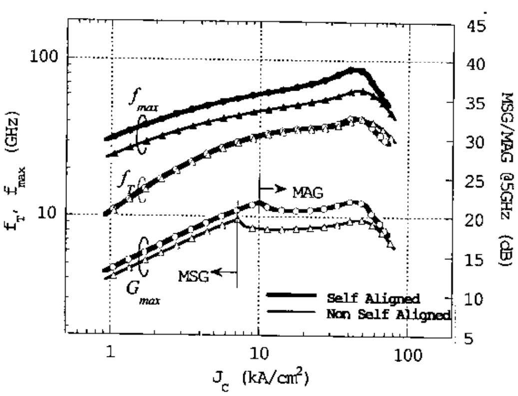


Fig. 2 Measured small signal performance of 4.2 x 60 μm² one-finger HBT (Vce = 3.0 V).

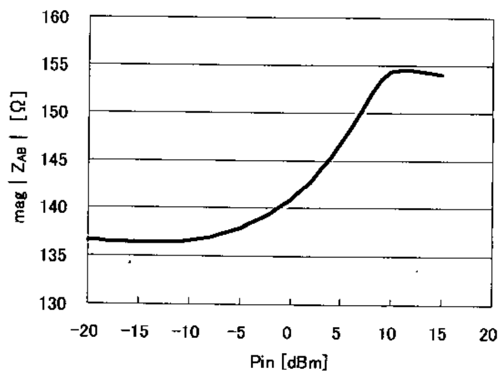


Fig. 6 Simulated impedance $Z_{AB}$ of feedback circuit in Fig. 5.

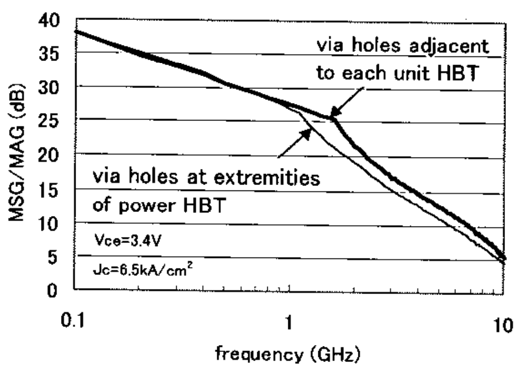


Fig. 3 Measured MSG/MAG for two kinds of 6.4 x 60 μm² x 8-finger HBT power amplifiers. One power amplifier has via holes located between each finger. The other power amplifier has via holes located only at its extremities.

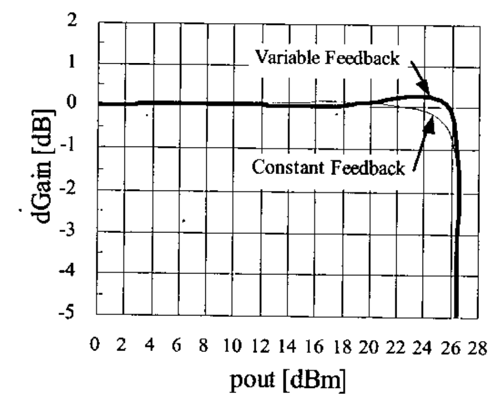


Fig. 7 The effect of variable negative feedback circuit (Simulation).

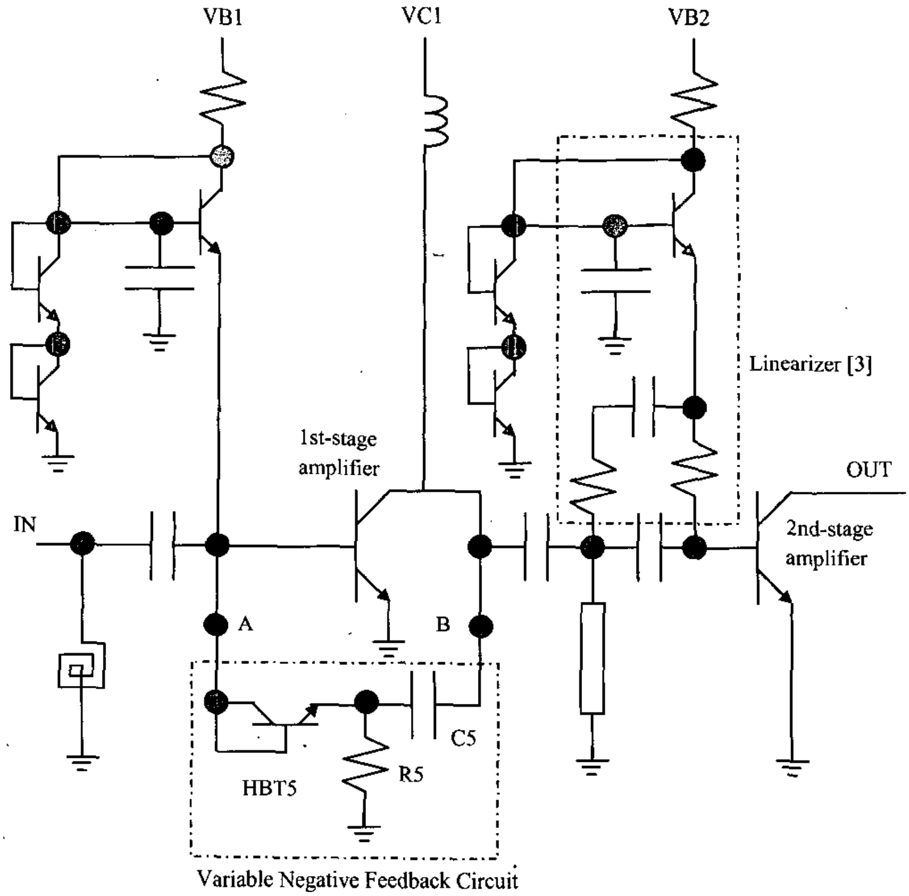


Fig. 5 Circuit diagram of the power amplifier MMIC

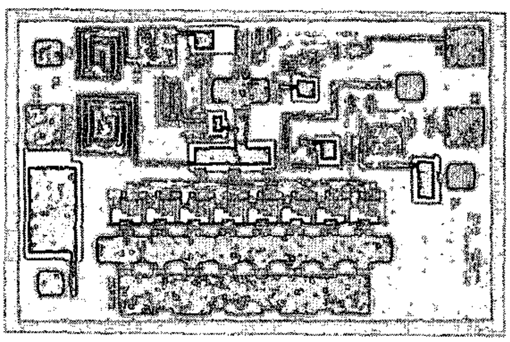

Fig. 8 Photograph of fabricated MMIC (chip size is 0.81 mm x 1.22 mm).

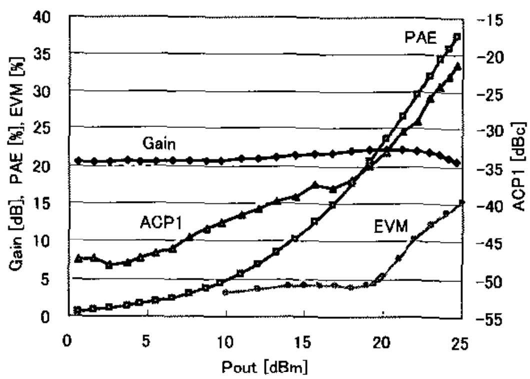


Fig. 9 Measured input-output characteristics of the power amplifier MMIC at 5.25 GHz.