High Efficiency and Linear Dual Chain Power Amplifier without/with Automatic Bias Current Control for CDMA Handset Applications

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Abstract — New architectures of the dual chain InGaP MMIC power amplifiers without/with automatic bias current control (ABC^2) have been developed for improving efficiency in the low-power region while maintaining the high linearity for all Pout regions. For low standby current less than 25 mA, the amplifiers initially operate using small HBT arrays. For small chip size, high load impedance in low-power region, and efficient power combining in high-power region, phase-compensating L-C matching circuits using low-pass and high-pass networks are used. A new simple power detection and bias current control circuit is employed to the power amplifier, resulting in automatic gain control for Pout variation. The fabricated ABC^2 power amplifier module shows good ACPR more -48 dBc over all Pouts, and high efficiency of 6 % PAE (conventional 3.5~4%) at Pout=9 dBm, and 37.5 % PAE at Pout=28 dBm.

I. INTRODUCTION

For long talk time in CDMA mobile handset, highly efficient linear power amplifier (PA) is strongly required. The efficiency at low-power region is of supreme interest for battery lifetime. This is due to the fact that for typical urban environment, the handset is mostly operated with the output power range below 16 dBm [1]. Thus recently, there have been some approaches to increase efficiency of low-power region in PA through dual chain and variable load lines [2-3]. In both cases, for preventing the degradation of high power properties such as efficiency and ACPR, the authors used lumped-elements [2] or $\lambda/4$ line [3] resonance matching circuits for as well as impedance

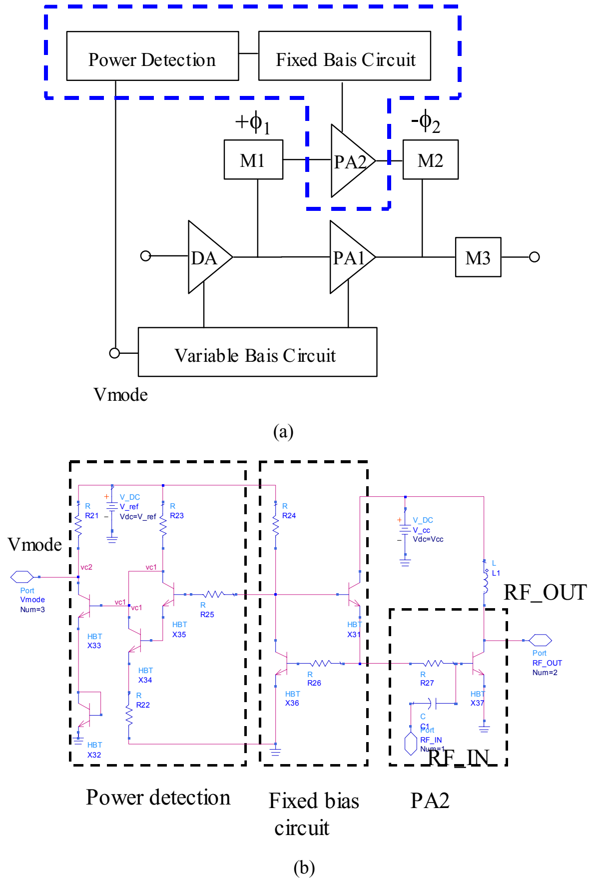

Fig.1. (a) Architecture of the dual chain MMIC power amplifier with automatic bias current control (b) schematic of the automatic bias current control circuit using the fixed bias circuit of PA2 as a power detection server.

transforming and the high isolation between outputs of two amplifiers. However, these matching networks are very frequency-sensitive and somewhat

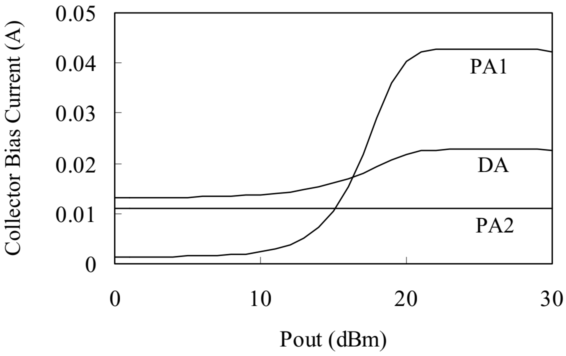

Fig.2. Simulated collector bias currents of the used HBT arrays (PA1, DA and PA2) vs. Pout

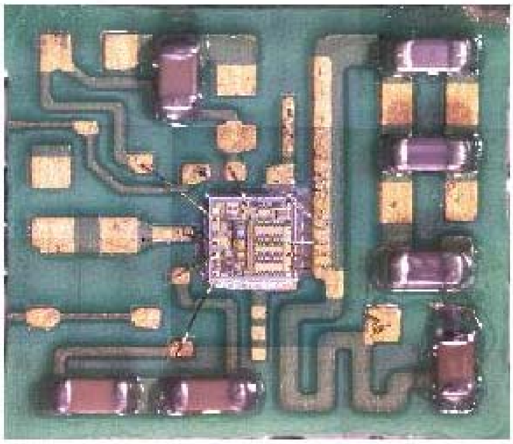

Fig.3. Photograph of power amplifier module

bulky, resulting in so difficulties for applying them to compact commercial MMIC PA chip.

In this paper, we introduce dual-chain MMIC PAs without/with ABC^2 for increasing the efficiency in low-power region with good linearity. For small chip size, high load impedance in low-power region, and efficient power combining in high-power region, simple phase compensating L-C matching circuits using low-pass and high-pass networks are used. And also in PA, a method reducing standby current and a circuit including power detection and bias current control are introduced.

II. DESIGN AND EXPERIMENT

Fig 1(a) shows the proposed architecture of the dual chain PA with ABC^2. In standby condition (low-power mode), small HBT array drive-amplifier (DA) and small HBT array output-amplifier (PA2) are ON-biased, but large HBT array output-amplifier (PA1) is almost OFF-biased, resulting in reduction of standby dc current consumption. (Icc = 12mA, 11mA, 1mA for DA, PA2, PA1, respectively). For increasing the efficiency of all low-power regions, low-pass type L-C impedance transformer (M2) is used between PA2 and output common load matching (M3). This results in high load impedance seen by output of PA2. Above Pout=20 dBm, for high gain and maximum output power with good linearity, the bias currents are designed to be high as much as 24mA, 11mA, 44mA for DA, PA2, PA1, respectively. These bias current variations are realized using the ABC^2 circuit shown in Fig. 1(b) where the fixed current circuit of PA2 is used as a RF power detection server. The ABC^2 circuit checks the dc current increase going through the fixed current circuit of PA2 according to the growing of Pout in PA2 and then generates a voltage to control bias currents of the other amplifiers (DA, PA1). For high power combining efficiency of both RF output signals from PA1 and PA2 in high-power region, a high-pass type L-C network (M1) is used at input of PA2, resulting in compensating the phase mismatching between RF output signals of PA1 and PA2 by the low-pass type impedance transformer, M2. Here, M1 and M2 were very simple in structure so that can be easily integrated in 1.1 x 1.2 mm^2 PCS MMIC PA. Fig. 2 shows the simulated collector bias currents of HBT arrays (DA, PA1 and PA2) versus Pout. From 10 dBm to 20 dBm Pout, the bias currents of DA/PA1 controlled by ABC^2 circuit change from 12mA/1mA to 24mA/44mA, showing good function of ABC^2. Fig. 3 shows the photograph of fabricated PA module (PAM, 6x6 mm^2). The measurements were performed at 1.88 GHz using an IS-95 reverse channel CDMA modulated signals and the supply voltage (Vcc) for PAM was 3.4 V. Fig. 4

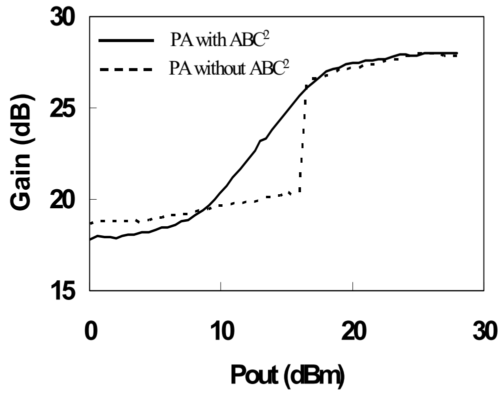

Fig.4. Measured gain (dB) vs. Pout for power amplifiers without / with ABC^2

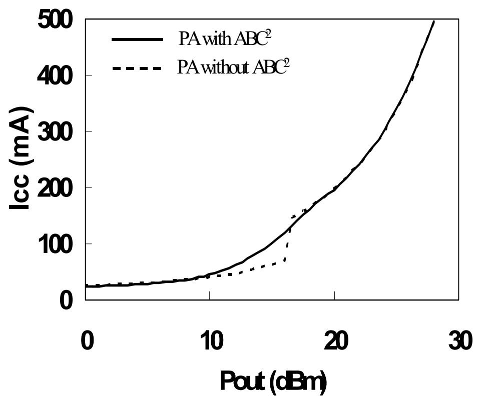

Fig.6. Measured consumed current vs. Pout for power amplifiers without / with ABC^2

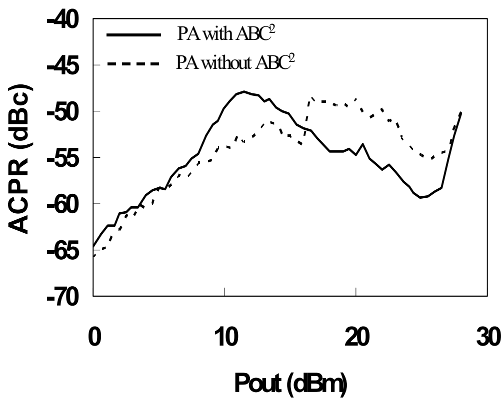

Fig.5. Measured ACPR vs. Pout for power amplifiers without / with ABC^2

shows the measured gain versus Pout for the PAM without/ with ABC^2. Here, PAM without ABC^2 was simply made by cutting the connecting line between ABC^2 and bias current circuits of DA, PA1. Thus, their bias currents were changed in 2-step mode using external control voltages (0 and 2.8 V). As expecting from the bias current variation characteristics of Fig. 2, Fig. 4 shows that the gain of the fabricated PAM with ABC^2 continuously vary from 18 to 28 dB over Pout region from 0 to 28 dBm. Fig. 5 shows the measured ACPR versus Pout for the PAM, and both graphs show good linearity more than -48 dBc over all Pouts. Here, an ACPR hump near Pout=12 dBm was made due to rapid bias current change of PA1 but still comparable to the case of PAM without ABC^2. The good linearity was obtained through the initial bias current (1mA, not zero) control of PA1 and matching circuits (M1, M2) improving the amplification of PA2 in low-power region. The further studies for reducing the peak of ACPR hump in ABC^2 PA are still going on in our group. Fig. 6 shows the measured consumed current versus Pout for the PAM. Both cases without/with ABC^2 show good efficiency of 6 % PAE (conventional 3.5~4%) at Pout = 9dBm because of high load impedance by M2 and M3. However, at Pout =16 dBm, the PAM with ABC^2 has 9.5 % PAE while the one without ABC^2 has 16 %. This is due to the continuous bias current control considering good ACPR. Both PAM shows almost same PAE of 37.5 % with more than ACPR of -50 dBc.

III. CONCLUSIONS

New architectures of the dual chain InGaP MMIC power amplifiers without/with automatic bias current control for improving efficiency in low-power region have been designed and experimented. Through the phase-compensating L-C matching circuits using high-pass and low-pass networks connected to in/out ports of PA2 respectively, the ABC^2 PAM had small chip size (1.1x1.2 mm^2), high efficiency of 6 % PAE (conventional 3.5~4%) at Pout=9 dBm, and 37.5 % PAE at Pout=28 dBm with good ACPR more than -48 dBc over all RF output power regions. And the proposed simple ABC^2 circuit gave good automatic gain control (18 ~ 28 dB) for Pout variation (0 ~ 28 dBm) with high linearity to the applied PA.

REFERENCES

[1] J. F. Sevic, “Statistical characterization of RF power amplifier efficiency for CDMA wireless ommunication system,” in *Wireless Conf.*, pp. 110-113, Boulder, CO, Aug. 1997

[2] J. H. Kim, J. H. Kim, Y. S. Noh, Y. S. Kim, S. G. Kim, and C. S. Park, “ An MMIC smart power amplifier of 21 % PAE at 16 dBm power lever for W-CDMA Mobile communication terminals,” *IEEE GaAs digest*, 2002, pp.181-184

[3] S. Bae, J. Kim, I. N. Nam, Y. Kwon, “Bias-Switching Quasi-Doherty-Type Amplifier for CDMA Handset Applications,” *IEEE RFIC-S Digest*, PP. 137-140, Jun. 2003.