Doherty Power Amplifier integrating a novel adaptive biasing network

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1. Introduction

The efficiency improvement of microwave power amplifiers has been attracting continuous interests because power amplifiers consume most of energy in transceivers for modern wireless communication. High efficiency usually means low power consumption, and extended battery operating endurance [1],[2]. Besides, modern wireless communication systems always require high data rate and large channel capacity, which inevitably leads to large high peak-to-average power ratio (PAPR). To meet the stringent linearity requirement of suppressing in-band distortion and out-of-band spectrum emission, PAs have to operate at large back off region from saturation where efficiency is quite low. Doherty power amplifier (DPA) is an effective solution for efficiency enhancement at reduced power region, which relies on the concept of active load-pull [3],[4].

Fig. 1 shows the typical schematic of the Doherty power amplifier which consisting two parallel connected power amplifiers (carrier and peaking PAs) and an $\lambda/4$ impedance transformer. At low power region, only the carrier power amplifier operates and the impedance represented to it is $2Z_{opt}$. When the input power increases, the peaking starts to turn on, and the impedance reduces to Z_{opt} at full power. However, peaking PA can not give identical current with the carrier one at maximum power and immediately open up at half the maximum input voltage that are pre-assumed for optimal performance of Doherty power amplifier [4]. Uneven power division [5] or larger-sized transistor for peaking PA [6] provides an effective solution to the first problem. For the second problem which is mainly caused by the detrimental soft turn-on effect, adaptive biasing schemes can be helpful. Nevertheless, conventional approaches are complicated and bulky [7],[8]. This paper presents a simple and cost-effective self-adaptive biasing circuit which is integrated into the gate bias network of the peaking PA to solve the above two problems simultaneously. As a result, significant efficiency improvement is achieved at back-off power.

2. Analysis of adaptive biasing network

In previous works, adaptive biasing scheme (ADB) has been applied to improve linearity and efficiency of PAs [9],[10]. In this paper, the network is modified to adaptively control the gate voltage along with the input power. Fig. 2 gives a schematic diagram of the proposed ADB network. As suggested by [9], a fraction of RF power will be coupled to the upper branch of the network, and an amount of DC current will be produced due to the rectification of the diode. The rectified current flows from up to down, and its strength is directly proportional to the coupled RF power, the input power in other words. The diode Q_D and the shunt capacitor C_1 to ground determine the amount of rectified current for under fixed input power together.

When the RF power is small or off, the diode voltage drop V_{diode}, ratio R_1 / R_2, and supply voltage V_{gg} set the quiescent value of V_x and i_0, the value of R_1 should be large enough to look like open circuit for RF signal.

When the DC current in the network increases with input power, the voltage across resistor R_2 increases. As a result, the gate voltage rises simultaneously. As the gate bias voltage can be adjusted dynamically with the input power and no additional control circuit is needed, we call this self-adaptive biasing (SAB).

As shown in [7], an appropriate biasing scheme often gives higher efficiency for DPA architecture. By carefully selecting the components values in the SAB circuit, we can approach the ideal transfer characteristics for the peaking PA. In this particular design, the peaking PA is biased at class-C mode until the carrier PA saturates, and then it gradually rises to class-AB mode at maximum power because the bias voltage increases. As a result, the soft turn-on effect suffered by fixed biasing is greatly relieved which leads to higher efficiency for the whole Doherty power amplifier dynamic range.

3. Measurement Result

For verification, a Doherty power amplifier integrating SAB circuit is implemented operating at 2.14 GHz. A conventional Doherty PA and another class-AB PA is also fabricated for better comparison. When the input power is small, the peaking PA in the proposed DPA is biased at deep class-C mode as mentioned above, it then increases up to class-AB mode at high power level. In this particular design, for a fair comparison with the conventional design, we try to increase the gate voltage of the peaking PA to the same value as the conventional design, i.e. -0.8V at maximum power. The gate voltage for carrier PA and class-AB PA is set to -0.5V, while all the drain voltages are fixed to 3V. Simulated result is given in Fig. 3. The values for R_1, R_2 and C_1 are 1200ohm, 270ohm and 1.0 pF respectively. As we can see, the largest current value in the SAB circuit is about 0.9mA at the saturation state. Thus the power consumption in the SAB circuit is a very small fraction of the whole circuit supply power, thus it will not degrade the overall efficiency.

Three independent power amplifiers corresponding to the carrier PA and two peaking PAs in the proposed and conventional DPA are fabricated and measured respectively. As shown in Fig. 4(a), the proposed DPA achieves about 16% and 27% drain efficiency improvements over the conventional DPA and class-AB PA at 6dB backoff point. Fig. 4(b) gives out the measured performance of the proposed Doherty power amplifier.

4. Conclusion

In this paper, a Doherty power amplifier (DPA) with a novel self-adaptive biasing (SAB) network is presented. The proposed SAB circuit is integrated into the gate bias network of the peaking PA, and then the gate voltage can be adaptively adjusted with the input power. Due to the presence of the simple but effective circuit, the detrimental soft tune-on effect is mitigated which results in better efficiency than the conventional design with constant biasing. A DPA including the proposed biasing scheme is implemented and compared with both the conventional DPA and Class-AB PA. About 16% and 27% efficiency improvement are achieved at 6 dB backoff, respectively.

Acknowledgments

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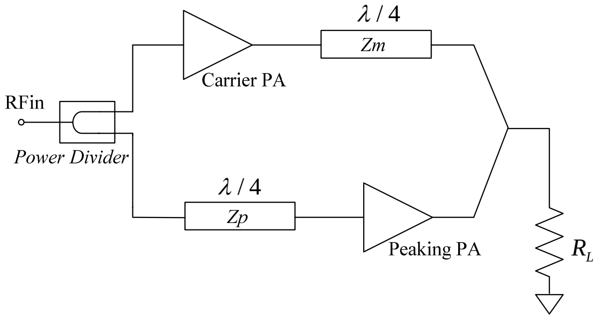

Figure 1: Schematic of conventional Doherty power amplifier.

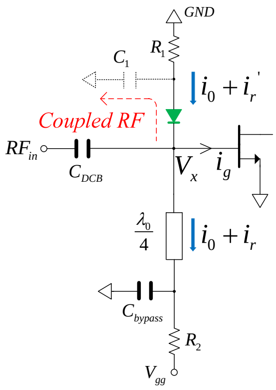

Figure 2: Schematic diagram of proposed biasing network for peaking PA.

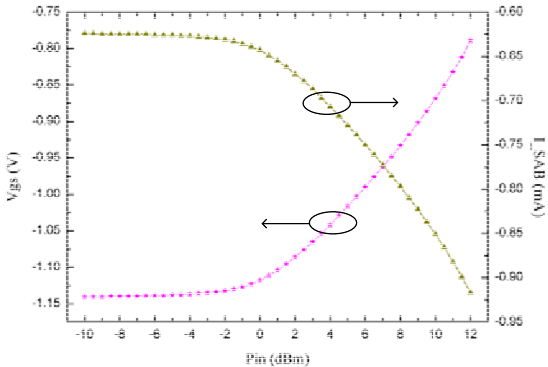

Figure 3: Simulated current in the SAB network and gate voltage for peaking PA.

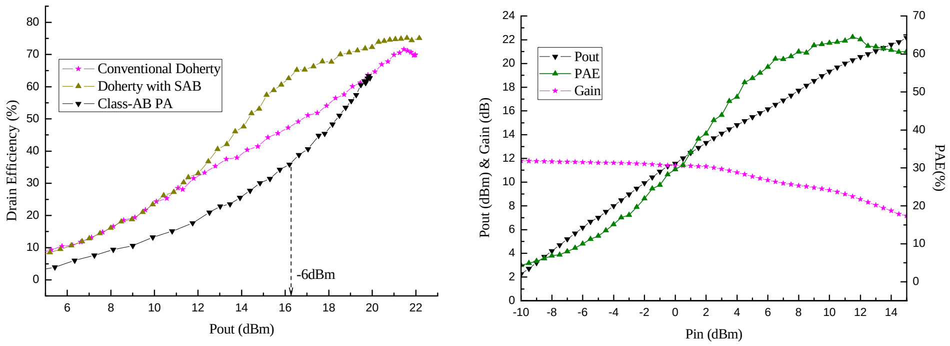

Figure 4: Measured performances for the proposed, conventional DPA and class-AB PA(a); (b)Measured performance of the proposed Doherty power amplifier.

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