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LINEARITY IMPROVEMENT OF BROADBAND LINEAR POWER AMPLIFIER

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1. Introduction

Fourth-generation (4G) and fifth-generation (5G) wireless systems requires amplifier as its key component to operate with high efficiency and linearity over a wide frequency range to enable multi-band and multi-standard operation. These systems utilize advance modulation techniques such as Orthogonal Frequency Division Multiplexing and Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing which is characterized by its high peak to average ratio (PAPR) contributed by the rapid fluctuations of time varying power [1]. To achieve highly linear performance, the Power Amplifier (PA) operates at a less-efficient back-off power region [2]. To improve the low efficiency at the peak average output power level, various methods have been introduced such as Doherty PA [3], Switch mode PA [4], Envelope Tracking [5] and Envelope Elimination and Restoration (EE&R) PA [6].

The Doherty PA utilizes load modulation technique to provide the optimum load impedances for high efficiencies at the 6-dB power back-off (PBO) and the maximum rated output power. The load impedance of the carrier PA is modulated using a quarter-wavelength transformer. However, the quarter-wavelength transformer is narrowband thus limiting the operation bandwidth [7]. Besides, the Doherty structure also has many bandwidth limitation factors such as the phase compensation network and offset line [8]. Degradation of linearity and efficiency is observed as a result of differences in biasing requirements of the carrier (class AB) and peaking (class C) amplifiers [9]. Furthermore, the effective input capacitance of the class C biased peaking amplifier varies significantly according to the operation power level, generating an improper load modulation [10]. An offset line at the input of the peaking amplifier can be used to optimize linearity and efficiency of Doherty amplifier [11]. The quarter-wave-length transmission line can be replaced by a lumped quarter-wave-transformer and a bulky input power divider can be removed by a direct input-power-dividing technique [12]. The direct dividing technique is able to optimize the load modulation through a proper input drive and reduce the number of components at the input. To improve the back off efficiency, the Doherty PA with the bias modulation technique was introduced by [13].

However, this method does not improve the linearity performance. In [14], the gain modulation property of the carrier amplifier is analysed and optimized to obtain a flat AM-AM characteristic. Suitable lumped element quarter-wave-transformer and harmonic terminations are introduced to improve the linearity. Recently, Doherty PA using CMOS process was designed and fabricated for operation at 880 MHz [15]. Voltage-combined method which is proven to be more robust to load variations and achieves larger BW compared with current-combining method is used and does not require additional offset line to de-embed the output capacitances.

Switch-mode amplifiers such as Class-E, Class-F, inverse Class-F, or mixed Class-E/F mode [16] are able to improve the efficiency by controlling the second and third harmonics of the load network. Switch-mode Class-E power amplifiers with shunt capacitance is gaining high interest due to its simplicity and high efficiency [17]. In [18], the bandwidth and efficiency of Class E amplifier is improved by using shunt filter instead of series filter in the load network configuration. However, linearity performance is poor as a result of operation in saturation mode. In Class-F power amplifier operations, the load impedance must be short at even harmonics and open at odd harmonics [19]. The drain current waveform includes