LINEARITY ENHANCED DOHERTY POWER AMPLIFIER USING ANALOG PREDISTORTION

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Received 18 May 2010

ABSTRACT: *We propose a linearity-enhanced Doherty power amplifier using an analog predistortion (APD) technique, which incorporates an intermodulation (IM) generator. Because the IM generator is configured with antiparalleled diode structure, the resulting Doherty power amplifier behaves differently from a conventional one. Using antiphased IM generated by the hybrid coupler before the auxiliary amplifier, linearity for the whole power amplifier is improved because the IM from the main amplifier can be cancelled out at the combining section. The output power of the proposed Doherty power amplifier is observed 28 dBm at the maximum in measurement, whereas the adjacent channel leakage ratio is 18 dB improved at 5 MHz offset compared with that of the Doherty power amplifier without APD.* Microwave Opt Technol Lett 53:403–404, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.25701

Key words: *Doherty amplifier; analog predistortion; power amplifiers*

1. INTRODUCTION

Recently, considerable research has been focused on power amplifiers at the microwave frequency band. The growth of digital wireless communication systems has created increasing demands for improved WCDMA system development. With this in mind, industry specialists have begun rethinking the manufacturing processes and structural configurations of power amplifiers in hopes of optimizing power gains, size, cost effectiveness, energy efficiency, and linearity. The Doherty power amplifier has only an advantage that of high efficiency. It is not known for improved linearity. Though the Doherty power amplifier is considered to be well developed, very few Doherty power amplifier designs using the intermodulation (IM) generator have been reported. One strategy used to overcome the nonlinearity issue has been to incorporate a predistortion technique using the IM generator. In this article, a novel approach to achieve enhanced linearity for the Doherty power amplifier using analog predistortion (APD) is proposed. Simulation and measurement results are also provided. It is believed that this approach offers immediate practical applications; combining the IM generator and Doherty power amplifier would meet the wireless communication industry's demand for an amplifier technique, which could provide both acceptable power-added efficiency (PAE) and linearity [1–4].

2. DESIGN THEORY

A conventional Doherty power amplifier is utilized, because this configuration improves efficiency at the high power input by complementing the saturation of the main amplifier with the turn-on characteristics of the auxiliary amplifier. This Doherty amplifiers show dependably higher efficiency than other amplifiers [1, 2].

The APD technique offers an effective method for alleviating the linearity issue. The IM produced by APD has a proper magnitude, 180° out of phase in comparison with that generated by the main amplifier. This allows the APD to control the IM3 (third-order IM) component in the IM generator and the enhanced linearity can then be obtained in the power amplifier design [5–7].

The APD consists of the 90° hybrid coupler, an antiparallel-fashioned Schottky diode and an RC network as shown in Figure 1. Because of the antiphased IM3 component generated by the IM generator for APD, the IM3 occurred by the main amplifier is cancelled out. This is performed through the preinsertion of distortion components into the auxiliary amplifier input signal at the predistortion circuit [5]. There are two paths in the IM generator as shown in Figure 1. The upper path (through port 2) mainly transmits the fundamental component and the lower path (through port 3) carries the IM3 component. The RF input signal enters the port 1 and is then reflected by an antiparallel-fashioned Schottky diode at the port 3, which generates various IM components. At the port 2, the incident RF signal is reflected in phase into port 1 and 90° phase-delayed into port 4 by the RC network reflector. The incident RF signal is also reflected 180° out of phase into the port 1 and 90° phase-delayed into port 4. Therefore, the fundamental component of the RF input signal is transmitted to the port 4 in 90° phase delay. The IM3 component generated from port 3 is transmitted to the port 4 in 270° phase delay. The magnitude of fundamental component is adjusted by RC network ($R = 280\ \Omega$, $C = 1$ pF used for this design) at the port 2. The APD generates the IM3 component with 2 dBc/dBm slope according to the output power. This indicates that fundamental and IM3 components will appear as desired at the APD output, and finally the suppression of IM3 component and adjustment of the fundamental component are achieved.

Figure 1 presents a schematic illustration of the proposed Doherty power amplifier. The transistors operate in the class-A mode for the main amplifier and the class-C mode for the auxiliary amplifier. Also, $\lambda/4$ delay transmission lines are needed both at the main and auxiliary amplifier paths for Doherty power amplifier operation. As the APD provides 90° phase delay for the fundamental component and 270° phase delay for the IM3 component, a separate $\lambda/4$ transmission line is not needed at the auxiliary path. As the load impedance network is designed based on the conventional Doherty amplifier theory, the load impedance (Z_{LOAD}) of 35 Ω is used in this work. It is important to always keep the impedance matching condition, and the load impedance value must be chosen properly.

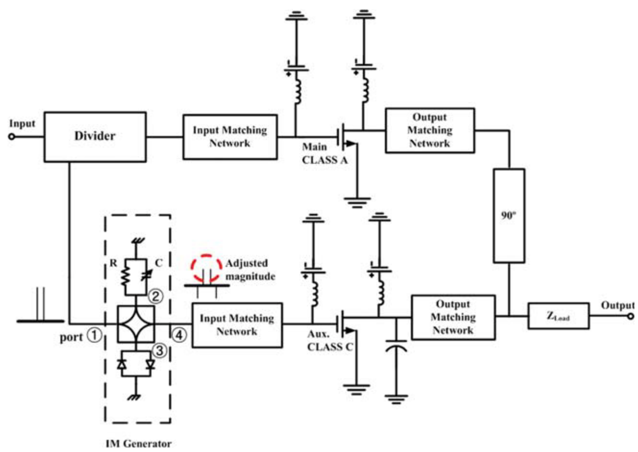

Figure 1 Block diagram of the proposed Doherty power amplifier. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

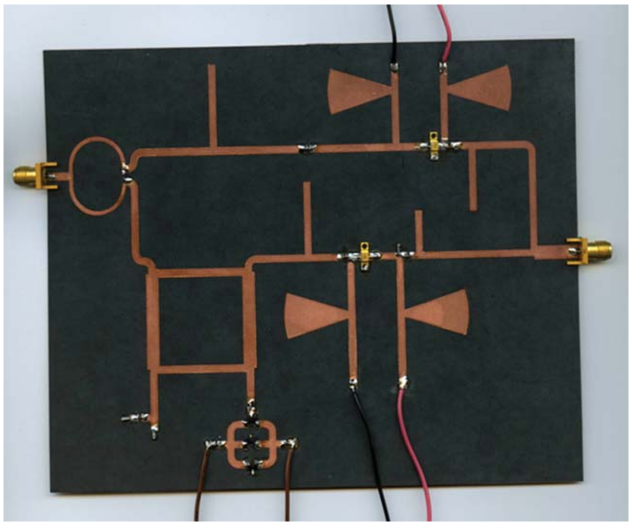

Figure 2 Photograph of the fabricated proposed Doherty power amplifier. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

3. SIMULATION AND EXPERIMENTAL RESULTS

To verify the proposed APD Doherty power amplifier using the IM generator, we simulated it with Agilent ADS2008 and fabricated it by using the Mitsubishi MGF2430A (GaAs FET) and the Avago HSMS2822 (the antiparallel fashioned diode) at 1.95 GHz. The fabrication of the proposed Doherty power amplifier is shown in Figure 2. Figure 3(a) shows the simulated and measured PAE of the proposed Doherty power amplifier. The conventional Doherty power amplifier shows about 44% PAE, and the proposed Doherty power amplifier with APD does about 47% PAE on simulation and 45% PAE on measurement. The WCDMA signal test has been performed using test model 1 with a DPCH of 16. The measured adjacent channel leakage ratio (ACLR) characteristics of the Doherty power amplifier with and without the APD are compared in Figure 3(b), whereas the output power level is swept. The improved ACLR characteristic is achieved over a whole output power range. The ACLR is 23 dB improved at the 5 MHz offset compared with the Doherty power amplifier without APD. Table 1 summarizes the results for the proposed Doherty power amplifier.

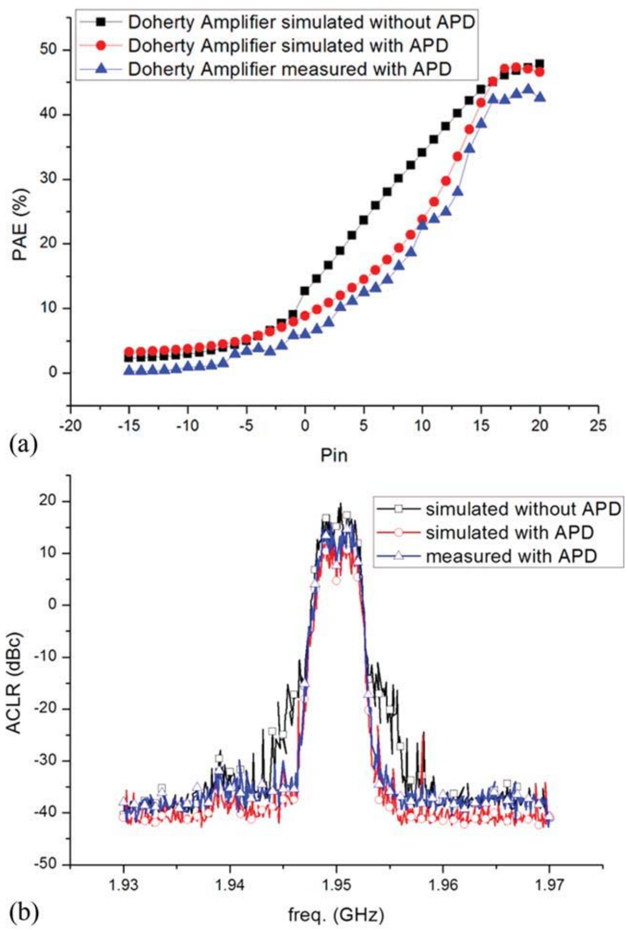

Figure 3 (a) PAE results of the Doherty power amplifiers and (b) ACLR results of the Doherty power amplifiers. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

TABLE 1 Performance Summary of the Proposed Doherty Power Amplifier

	Results		
	Simulated without APD	Simulated with APD	Measured with APD
Maximum Pout (dBm)	32	32	28
Maximum PAE (%)	47.5	46	44
IMD3 (dBc) [Pin = 0 dBm]	21.5	30.5	42
ACLR (dBc) [±5 MHz Offset]	31	54	49

4. CONCLUSIONS

The Doherty power amplifier using APD shows linearity enhancement in that ACLR performance has been significantly improved compared with that of the conventional Doherty power amplifier. Applications will be available in a variety of IM generator structure for linearity enhancement of the power amplifiers maintaining the power efficiency.

ACKNOWLEDGMENTS

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MEST) (2008-0061676).

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