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Highly Efficient Balanced Power Amplifiers for 4G Applications

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***Abstract*— This paper presents a highly efficient balanced power amplifier for 4G applications using a microstrip branch line coupler. A compact U-shaped microstrip branch line coupler is used for the balanced power amplifier (PA) architecture. The balanced PA achieves a power aided efficiency (PAE) of 66.8% what makes it very applicable for the 4G and 5G communication systems. The simulated and measured S-parameters (S_{11} and S_{22}), gain, output power and power spectra densities for 3 MHz LTE signals at 1.5 GHz are presented.**

Keywords— Keywords— Branch Line Couplers; Power Aided Efficiency (PAE); ACPR (Adjacent Channel Power Ratio); U-Shaped Transmission line (USTL); 4G.

I. INTRODUCTION

There has recently been a massive growth in number of users and quality demands in mobile broadband communications. Moreover, high speed data and high definition multimedia applications are becoming the main drive for mobile traffic [1]. This has led to a growing demand for higher aggregate throughput and data rates to end users.

Carrier aggregation (CA) combines two or more component carriers to achieve higher data throughput by using more bandwidth. Due to this shift towards higher data bandwidth applications, the flexibility of adapting to traffic makes carrier aggregation (CA) a vital need for next generation mobile communication systems [2]. Wireless transmitter characteristics such as high power, high efficiency, linearity, gain flatness, and good input and output matching over the whole frequency bandwidth have become more stringent to meet the needs of the next generation networks.

To achieve these high data rates, the power amplifiers (PAs) in the wireless transmitters have to operate in the saturation region. At this region, there is a trade-off between efficiency and linearity and both are necessary for next generation networks. As the power is increased towards saturation, the PA becomes more nonlinear and its spectral efficiency reduces.

Poor efficiency has been observed in the output power back-off (OPBO) region of power amplifiers operating at saturation with 4G signals due to the OFDM's high peak-to-average power ratio (PAPR) [3]. Different linearization techniques such as digital pre-distortion (DPD), second harmonic injection have been used to improve the nonlinear performance of the PA but higher efficiency could be achieved with other amplifier configurations such as Doherty and balanced PA whilst maintaining good linearity [3].

The balanced PA configuration uses the load-insensitivity characteristics and multi-mode operation of the coupler to enhance power-aided efficiency [4]. Several balanced PA designs have been used in [4] - [7] to increase the power aided efficiency (PAE) of the PA. However, the size of the balanced PA architecture could be very large when using conventional coupler designs that operate at frequencies below 4 GHz. Hence, a compact coupler for such applications needs to be designed [7].

In this paper, a balanced PA configuration is used to achieve better efficiency and linearity by using a novel microstrip branch line coupler (BLC). The proposed configuration achieved improved s-parameter performance and achieved better efficiency and linearity. The proposed balanced PA is highly efficient, linear and will be very useful for next generation networks.

II. BALANCED POWER AMPLIFIER SETUP

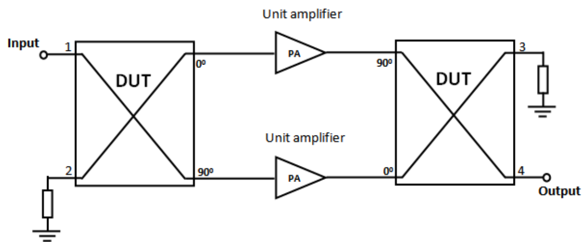

Fig. 1. Schematic of the balanced PA.

The schematic of the balanced PA configuration is depicted in Fig. 1. The balanced PA design makes use of two identical microstrip branch line couplers which are mirrored at the input and output of the PAs acting as shown in Fig. 1.

Composite right/left-handed (CRLH) transmission lines have non-linear phase responses and controllable zeroth-order resonance position, that allows for single and dual band designs. The designed coupler is designed to operate between 1.2 and 1.8 GHz with maximum performance at 1.5 GHz. Phase difference of 90 degrees between the transmitted and coupled ports was achieved for the coupler design so it could be used in the proposed balanced topology in Fig. 1.

The unit PA used is the ZHL-4240W Mini-circuits PA. This PA in conjunction with the USTL coupler is used for the balanced PA configuration. The input signal is split into two signals which are 90^0 out of phase by the first BLC and then passed through the unit PA and then combined again by the second BLC. It was optimized through the band to obtain improved PAE. Simulated and Measured results are presented for the balanced PA in section III and compared with the single ZHL-4240W PA.

III. RESULTS

This section will examine the impact of the proposed configuration with its single equivalent. Simulated and measured gains of the designed balanced PA and the single ZHL-4240W PA are shown in Fig. 2. The simulated and measured gain of the balance PA show a good match with the single PA from 1.3 GHz and 1.6 GHz. The gain bandwidth of the balanced PA is slightly narrower due to the characteristics of the USTL which acts as both the splitter and the combiner. The slight deviation from the simulation results could be caused by tolerances in the components and the milling of the PCBs.

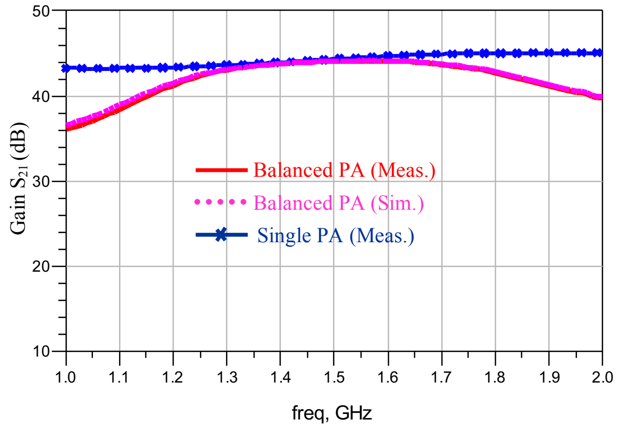

Fig. 2. Measured and simulated gains vs. frequency.

The input and output reflection coefficients (S_{11} and S_{22}) for the ZHL-4240W PA at the center frequency of 1.5 GHz are illustrated in Figs. 3 and 4, respectively.

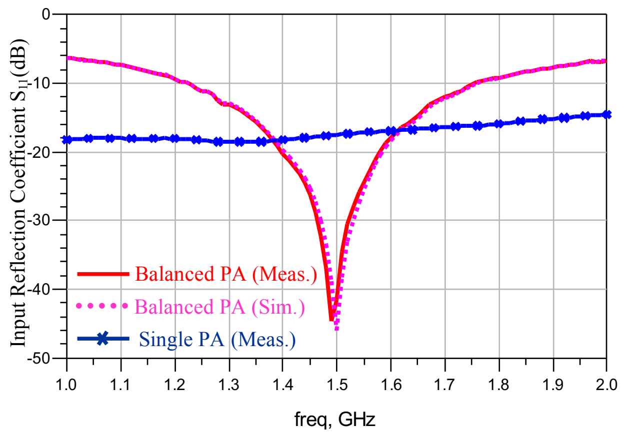

Fig. 3. Measured and simulated S_{11}-paramters vs. frequency.

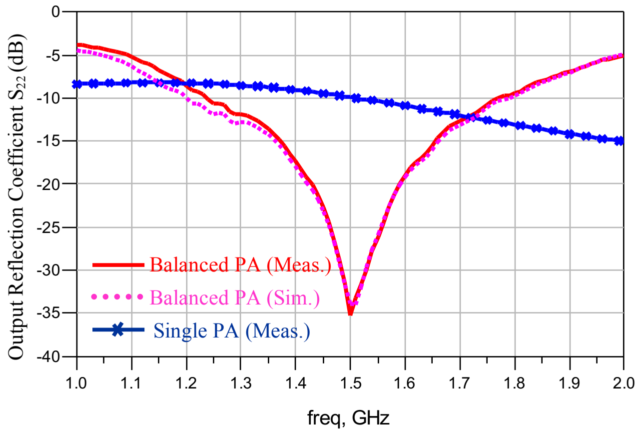

Fig. 4. Measured and simulated S_{22}-paramters vs. frequency

The large-signal measurements were obtained by power sweeps at several frequency points and the PA in the balanced topology uniquely uses the isolation port of the microstrip USTL branch line coupler as its signal path. The ZHL-4240W Mini-circuits PA under test delivers a maximum saturated output power (Pout) of 31 dBm. The maximum gain is around 46 dB and then it reduces as the input power reaches saturation as shown in Fig. 5. The balanced PA shows a large signal improvement delivering a maximum Pout of 35 dBm with maximum gain around 45 dB which also reduces as the input and output power moves towards saturation.

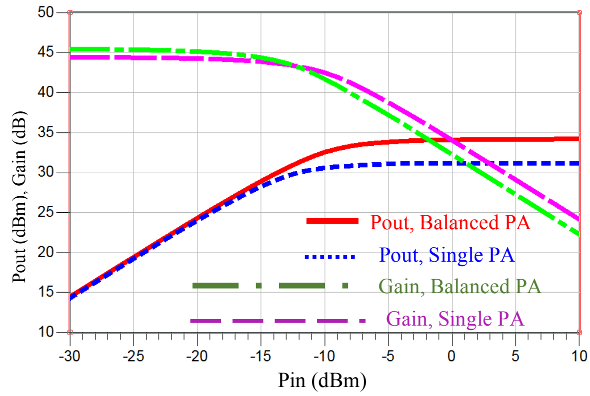

Fig. 5. Simulated output power and gain vs input power

Fig. 6 shows the power aided efficiency (PAE) improvement of about 13.5 %. The PAE of single ended and balanced PA versus frequency are shown in Fig. 7.

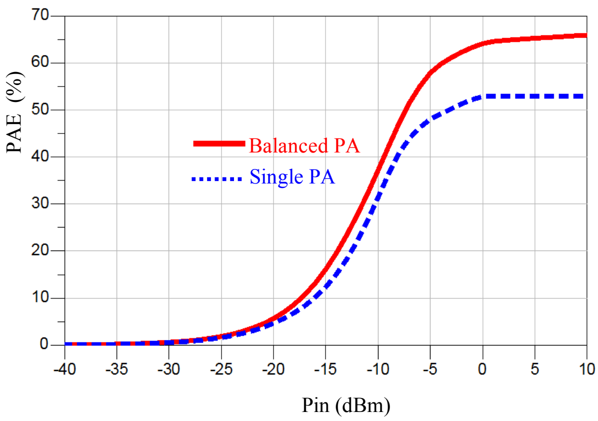

Fig. 6. PAE vs. input power

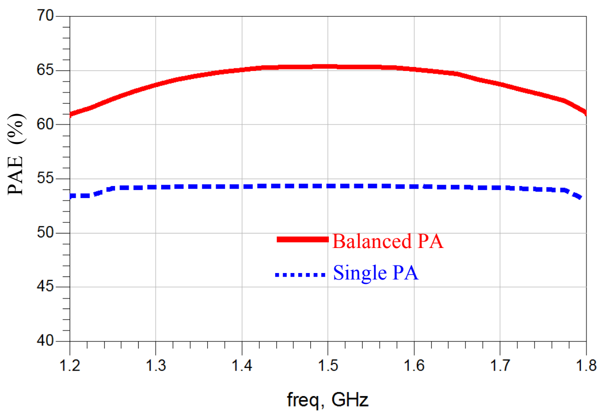

Fig. 7. PAE vs. frequency at saturation

The balanced configuration aims to achieve both good efficiency at saturation at the same time unlike other techniques that trades-off both requirements. Figs. 8, 9 and 10 present the output power spectra densities of balanced power amplifier for 3 MHz LTE signals with input powers of -20 dBm, -15 dBm and -10 dBm respectively. The input powers of -20 dBm and -15 dBm are at 10 dB and 5 dB back-off from saturation respectively.

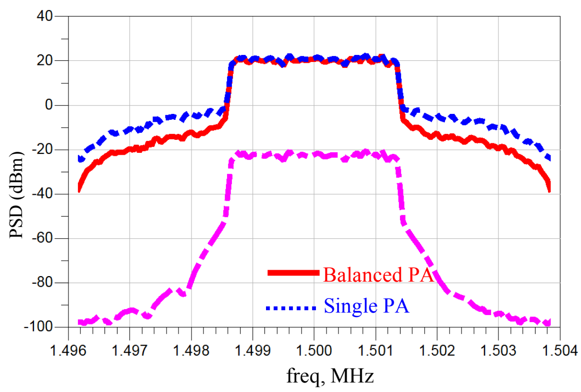

Fig. 8. Simulated Input and output power spectra densities of balanced PA for input power of -20 dBm

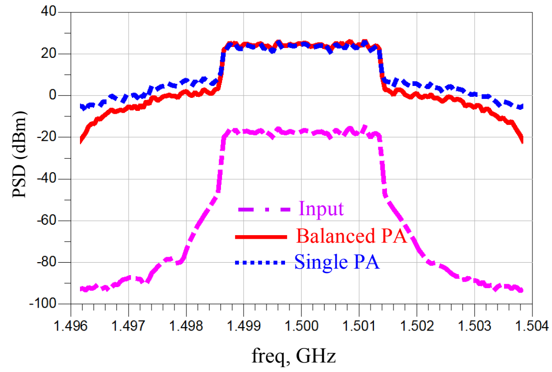

Fig. 9. Simulated Input and output power spectra densities of balanced PA for input power of -15 dBm.

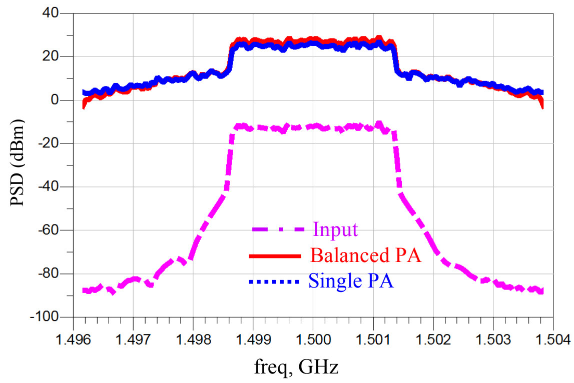

Fig. 10. Simulated Input and output power spectra densities of balanced PA for 3 MHz LTE signal and input power of -10 dB

CONCLUSION

A highly efficient balanced power amplifier has been illustrated in this paper. ZHL-4240W transistor amplifiers were used in conjunction with USTL branch line coupler in balanced PA configuration. The simulated and measured S-parameters (S_{11} and S_{22}), gain, output power and power spectra densities for 3 MHz LTE signals at 1.5 GHz have been presented. The designed balanced PA has achieved the PAE of 66.8%. and could be very useful for 4G and 5G wireless communication systems.

ACKNOWLEDGMENT

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