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Research Letter

A 2×1 LINC Transceiver for Enhanced Power Transmission in Wireless Systems

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A 2 × 1 LINC transceiver based on linear amplification using nonlinear components (LINC) architecture for wireless systems applications is proposed. The layout of the new architecture is presented and the simulation results show that the overall power efficiency of this architecture is superior by more than 300% when compared with that of a regular LINC amplifier. Also the adjacent channel power ratio (ACPR) is lowered to −64.2 dBc, compared to −26.1 dBc for regular LINC, which improves the system immunity against complex gain imbalances between LINC branches.

1. INTRODUCTION

The trend in the information technology field is pushing towards systems that offer higher transfer rates and free mobility. That implies moving towards wireless communication systems using digital modulation schemes to acquire maximum benefit from the scarce and crowded spectrum. At the same time, these systems should be more efficient concerning power handling. The employment of complex modulation schemes to efficiently use the available tight bandwidth and incorporate higher data rates comes with complex modulated signals containing high dynamics with increased peak-to-average power ratio (PAPR). This necessarily requires linear amplification over a large power range, forcing the use of a low efficiency power amplifier working in a high back off which results in lower efficiency. Meanwhile in the literature, one can find several approaches for improving the power amplifier (PA) efficiency while maintaining an acceptable linearity. One of which is the LINC power amplifier that is intended for use in wireless systems since it offers high efficiency and linearity [1–4]. In the meantime, signal linearity is an important factor in determining how well a wireless system works, be it a cellular network, WLAN network, and so forth. Indeed, power amplifiers are the main source of nonlinearities in these systems. Also emissions in the adjacent channel are of a great concern as they reduce the number of active users who can be operating at the same time. The bit error rate (BER) also increases due to those emissions reducing the system quality of service (QoS). The nonlinear behavior of the system is determined by ACPR, which can be used to accurately show the linearity of a system. Also complex signals like OFDM impose strict requirements on transmitted signal linearity to meet the error vector magnitude (EVM) specification.

In this paper, a 2 × 1 amplification system is proposed. Simulated results of the power efficiency, EVM and ACPR performance, as well as the assessment of branches imbalance effects on the system performance are presented. In Section 2, a brief description of the LINC concept is presented; Section 3 introduces the 2×1 LINC transceiver; while Section 4 presents the results of efficiency, ACPR, and EVM performances. Section 5 shows the imbalance behavior of the system. Finally, conclusions are presented in Section 6.

2. LINC AMPLIFIER

A regular LINC amplifier consists of a signal component separation block (SCS), two identical power amplifiers, and a combiner. The SCS divides the baseband signal into two constant amplitude, phase-modulated signals. The two signals

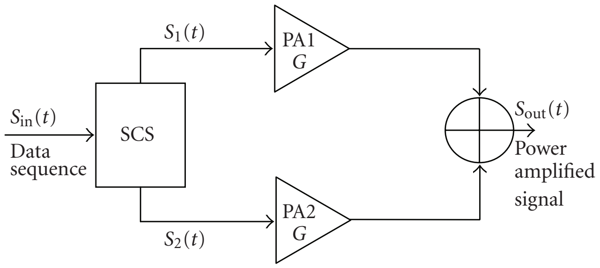

Figure 1: Regular LINC amplifier architecture.

are upconverted to RF, amplified, and summed by the power combiner to reconstruct an amplified replica of the input signal, as shown in Figure 1. In this manner, the RF power amplifiers are operated at saturation, and the two branch signals yield maximum amplifier efficiency and high linearity as the envelope of both signals is constant in magnitude [3–5].

3. THE 2×1 LINC TRANSCEIVER

In the proposed 2×1 LINC architecture, the amplified branch signals are transmitted, after being filtered to fit the standard mask for transmission, and amplified [5]. The receiver antenna performs the signal combination as shown in Figure 2. The transmitter contains a DSP block and a Tx RF front end. The DSP block contains the SCS and shaping filters. The SCS decomposes the baseband signal, $S_{in}(t)$, into two constant amplitude signals, $S_1(t)$ and $S_2(t)$, and calculates their rectangular representations (I_1, Q_1, I_2, Q_2), respectively. The digital shaping filters are used to fit the signal in each branch within the standard mask, and help lower out-of-band emissions, thus improving the ACPR of the resulting system. Filtering the branch signals of the LINC architecture introduces dynamics in the signal (the PAPR increases from 0.0 dB to approximately 3.6 dB), necessitating the use of linearization for the amplifiers, as they are working near saturation. Also the LINC transmitter contains the two antennas which are close enough such that it can be assumed that both transmitted signals will experience the same channel effect. This effect will be corrected for by the equalization algorithm performed at the receiver.

The receiver is of a regular WLAN architecture containing an RF front end, which consists of Rx receiver, RF/IF conversion stage, A/D converter, and a digital DSP block. In this way, the power efficiency is improved as the combiner losses are eliminated. At the same time, the LINC branch imbalance effects can be tolerated up to some extent. The values of the EVM and PAPR for this 2×1 architecture assuming an ideal channel are 0.39% and 3.66 dB, respectively. These results show superior performance when compared to the LINC and single branch amplifier.

4. EVALUATION OF SYSTEM PERFORMANCE

The performance of the proposed 2×1 LINC system is evaluated through simulations; the advanced design system (ADS) software from Agilent Technologies was used. An indoor Raleigh multipath fading channel was considered, as well as additive white Gaussian noise (AWGN) effects. An IEEE 802.11g OFDM signal with a 2.4 GHz frequency, 20 MHz bandwidth, 64 QAM modulation, 54 Mbps data rate, and signal power of −10.0 dBm was used. Two class AB amplifiers (HMC 408 from Hittite Inc.) were utilized to construct the LINC. The digital predistortion (DPD) technique was used to linearize the amplifiers to compensate for the PAPR increase due to filter effect. The LINC amplifiers characterizing data, (the AM-AM, AM-PM, and the synthesized AM-AM and AM-PM of the DPD) were measured and used in this study. The attenuation in the two LINC paths was assumed to be negligible. Meanwhile, the MATLAB software was used for filter synthesis. Digital FIR lowpass filters, with an order of 60, were used.

Simulations were carried out for the architectures single branch amplifier (Reg. Amp.), LINC (Reg. LINC), and 2×1 LINC. Results show that the branch signals to be transmitted after filtering fit within the transmission mask. Results also show that the efficiency of a regular LINC amplifier is 4.72%, while the EVM is 1.4% as shown in Table 1. When applying the filtering action in the 2×1 LINC system, and transmitting the branch signals, it is found that the new system efficiency is enhanced by about 3.4 times (from 4.72% to 16.17%), and the EVM remains almost constant. The branch signal of the 2×1 LINC system is complying with the standard mask; meanwhile the ACPR performance of the system is improved. A comparison between the 2×1 LINC transmitted signal spectrum and that of the regular LINC in adjacent channels is shown in Figure 3. It can be noted from the figure that the ACPR had improved significantly, especially when the least square filter was used. The use of the least square filter results in a sharp stable spectrum; and the ACPR was improved by 43 dB and by 37 dB when compared to the standard specification and the LINC amplifier, respectively. In addition, the system efficiency is enhanced due to the removal of the combiner. This result implies that the system can tolerate higher channel interference levels and also can self-compensate for LINC imbalances. The ACPR improvement for this new transmitter is also illustrated in Figure 4 [5] for different input power levels compared to those of an LINC and single branch amplifier.

5. IMBALANCE EFFECTS

The parallel RF branches of the LINC transmitter suffer from unavoidable difference in their magnitudes and phase responses. Imbalance effects between the two LINC branches are studied. This effect was corrected using different techniques that are complex implementations [6]. Meanwhile in the proposed 2×1 LINC, and due to using the branch digital filtering, a solution without any overhead on the system is achieved. The filters improve the ACPR performance of the system and help it to tolerate the imbalance effect.

Table 2 shows the imbalance values between the two branch signals' magnitudes and phases, the entries in the table show the EVM values. The ACPR did not change significantly: it was lowered by only 1.3 dB in the case when a 3-degree phase and 0.1 magnitude imbalance was considered.

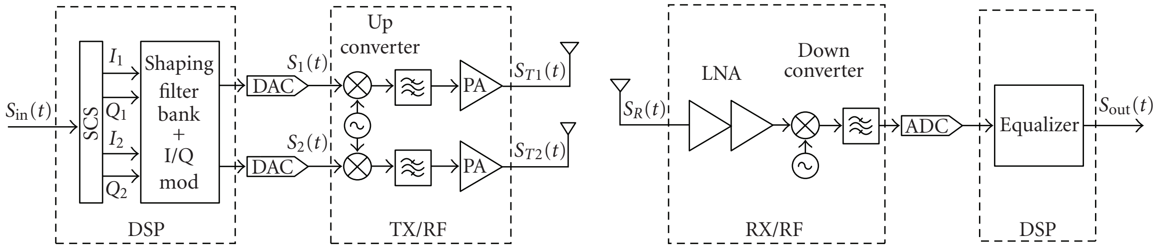

Figure 2: Detailed layout of the proposed 2 × 1 LINC architecture.

Table 1: ACPR, efficiency, and EVM without and with filtering.

Filter type	ACPR@11 MHz	ACPR@20 MHz	ACPR@28 MHz	Efficiency	EVM
Specs	−20 dBc	−28 dBc	−40 dBc	—	5.62%
Reg. LINC	−26.1 dBc	−51.1 dBc	−56.9 dBc	4.72%	1.40%
2 × 1 LINC	−63.1 dBc	−70.2 dBc	−70.2 dBc	16.17%	1.53%

Table 2: EVM values for different phase and magnitude imbalances.

Phase/Mag.	0.1	0.2	0.3	0.4	0.5
1^0	2.05%	2.78%	3.48%	4.28%	5.13%
2^0	3.37%	3.88%	4.44%	5.12%	5.88%
3^0	5.04%	5.32%	5.77%	6.34%	7.00%

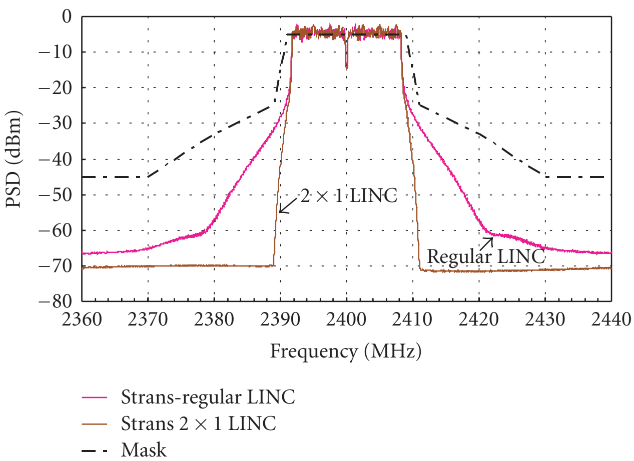

Figure 3: Comparison of the spectrum of transmitted signals of 2×1 LINC system $S_{T2}(t)$ and the regular LINC system $S_{out}(t)$ shown in Figure 1, with respect to the mask of the 802.11g standard.

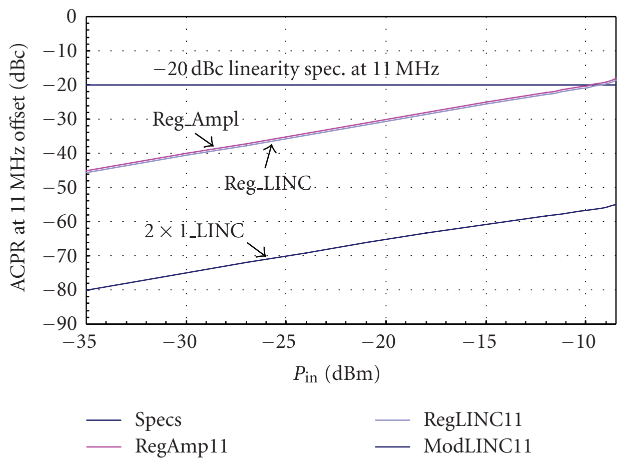

Figure 4: ACPR at 11 MHz offset for the 2 × 1 LINC, regular LINC, and regular amplifier for different input power levels.

In addition, the efficiency was lowered to 4.22%. Of course, cases where the EVM exceeded 5.6% are not accepted as they were over the standard limit.

6. CONCLUSION

A 2 × 1 LINC transceiver architecture suitable for wireless transceivers is proposed. It is based on DSP implementation where the LINC input signal separation and branch signal filtering are carried out. The signal combining is carried out at the antenna of the receiver side. This new layout is designed to overcome the problems associated with the transmitter combiner losses. The results show improved backoff operation for the branch amplifier from 9.4 dB for a single branch amplifier to 3.66 dB. It is close to that of regular LINC, which implies an overall power efficiency improvement from 1.43% for a single branch amplifier, and 4.72% for LINC, to 16.17% for the proposed 2 × 1 LINC. The EVM is 1.53% which is low compared with the standard allowed value of 5.6%. In this system, the signals in the two LINC branches are filtered to fit the transmission mask and lower their ACPR. The ACPR performance is greatly improved, which enables the toleration of higher channel interference levels and LINC branch imbalances; meanwhile the system's overall efficiency is improved as the combiner in the transmitter is removed.

Results show that the ACPR is improved by 43 dB when using the least square filter. In the meantime, the system efficiency is enhanced by 3.4 times when compared to that of an LINC amplifier. The filter action does not affect the system performance in regard to the EVM, as the results show. This new 2 × 1 system has the advantage of having standard receiver architecture while delivering an improved system performance regarding efficiency, ACPR, and EVM.

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