The linearity and efficiency enhancement using 3-way Doherty amplifier with uneven power drive

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Abstract

This paper reports a 3-way Doherty power amplifier for repeater application. In general, 3-way Doherty amplifier provides better linearity than 2-way amplifier. And uneven power drive can give a bias adaptation effect, which guarantees better linearity and efficiency as well as maximum peak envelope power. Therefore, we can expect that the 3-way Doherty amplifier with uneven power drive enhances the PA performance. For verification, the amplifier is implemented with three silicon LDMOSFETs with 4 watt of peak envelope power. The linearity and efficiency are improved about 4dB and 13%, respectively, compared with conventional 3-way Doherty amplifier and 6dB and 4% compared with uneven 2-way Doherty amplifier at 28dBm for downlink WCDMA signal.

1. Introduction

LPA and HPA for current and next-generation systems require high linearity and linearity enhancement techniques such as Predistortion, Feedback, Feedforward etc. are employed. But those amplifiers have a poor efficiency because of the class AB amplifier operation. On the other hand, methods to improve efficiency have been studied already, for example, Doherty, EER, LINC, and Bias Control [1]. Among them, Doherty amplifier has a simple structure to implement without extra circuits, and high efficiency. Therefore it is widely used now as main amplifier of the systems and we have further extended performance of the Doherty amplifier.

2. Discussion of 3-way Doherty with uneven power drive

In the conventional Doherty amplifier, the peaking amplifier's current level doesn't reach to the full level because it is lower biased than the carrier amplifier. It causes an improper load modulation, and we can't get the theoretical performance of Doherty operation. As a solution, an adaptive bias control can be implemented [2], but it requires extra control circuits and increases complexity. For the reason, we have proposed the uneven power drive strategy [3], and reported 2-way Doherty amplifier with the drive. It delivers a better efficiency due to the lower peaking bias. In addition, the peaking amplifier generates full current level keeping up with that of carrier amplifier at peak power, and we can obtain maximum PEP (Peak Envelope Power). When the uneven power drive is applied to the 3-way Doherty amplifier, it is possible to get an enhanced linearity and efficiency. In addition, as there are two peaking amplifiers for 3-way, each peaking amplifier's bias control can be adjusted for not only IM3 cancellation but also IM5 cancellation of the carrier amplifier. Thus, we can expect further improved linearity. We have carried out the experiments and verified good performances of the 3-way doherty amplifier with the uneven power drive.

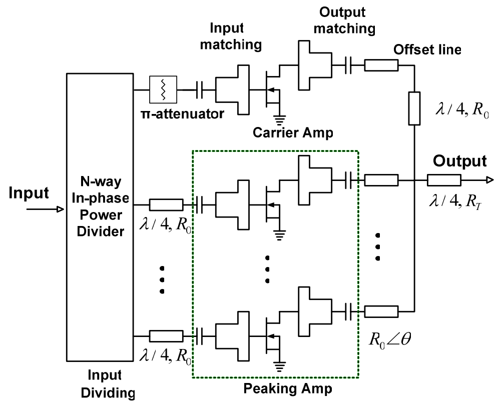

Figure 1. Block diagram of 3-way Doherty amplifier

3. Results and Conclusions

At first, we have simulated this amplifier to confirm the performance improvements and then conducted experiments by implementing with 4W PEP LDMOSFETs. Figure 1 is a block diagram of 3-way Doherty amplifier with uneven drive. Figures 2 and 3 are the simulation results that show the IM cancellations. The IM3 and IM5 cancel perfectly when peaking amplifier's IM component amplitude is a half of the carrier amplifier with 180° out-of-phase. The conditions maintain across a large power range. The improved linearity performances are presented in Figure 4. Figure 5 is a picture of the uneven 3-way Doherty amplifier. For the uneven power drive, we utilize π-type attenuator at the carrier input for 1.8 dB attenuation. Figure 6 shows the improved IMD3, IMD5, and drain efficiency for the two-tone signal with 1 MHz tone-spacing. Figure 7 shows the comparison data of the 3-way Doherty amplifier with even power drive and 2-way Doherty

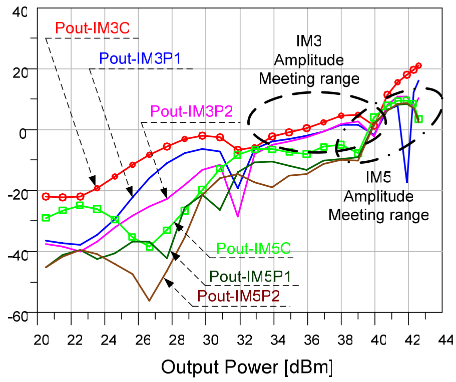

Figure 2. Two-tone simulations for IM3 & IM5 amplitudes of carrier and peaking amplifier

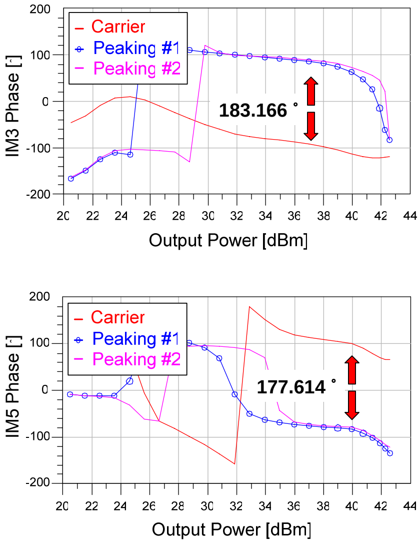

Figure 3. Two-tone simulations for IM3, IM5 phases of carrier and peaking amplifiers

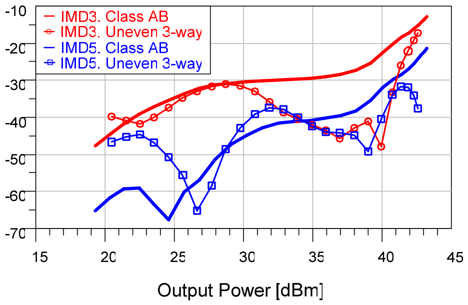

Figure 4. Two-tone simulations of IMD3 and IMD5

amplifier with uneven power drive for down-link WCDMA signal. The uneven 3-way Doherty amplifier has about 6 dB and 4 dB improved ACLR and 4 % and 13 % enhanced drain efficiency at P_{AVG} = 28dBm compared with uneven 2-way and even 3-way Doherty amplifier, respectively. The data clearly show that the 3-way Doherty amplifier with uneven power drive has the best linearity and efficiency at a low power range and is very suitable for repeater systems used at a large backed-off output power level.

References

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[3] J. Kim, J. Cha, I. Kim, and B. Kim, "Optimum Operation of Asymmetrical Cells based Linear Doherty Power Amplifiers: Uneven Power Drive and Power Matching," *IEEE Trans. Microwave Theory Tech. Vol. 53, No. 5, May, 2005.*

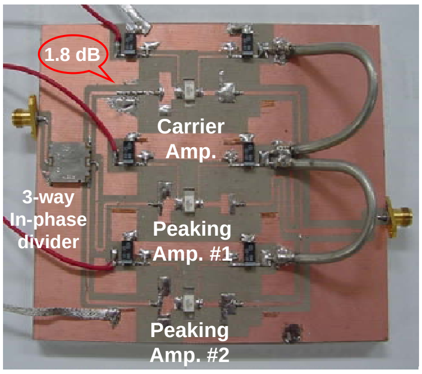

Figure 5. Implemented 3-way Doherty amplifier with uneven drive

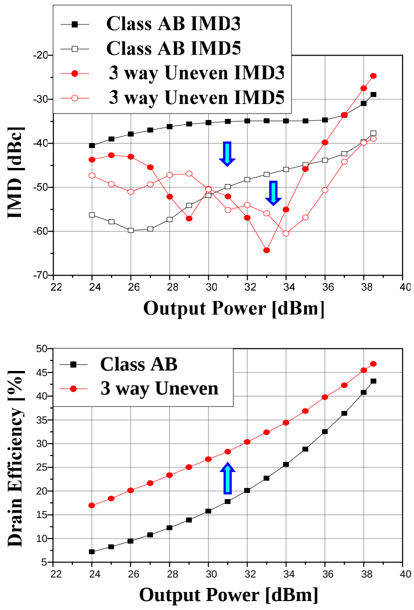

Figure 6. Two-tone measurements of IMD3, IMD5, and Drain Efficiency

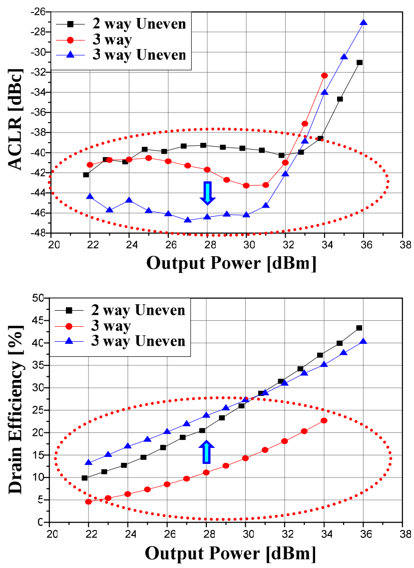

Figure 7. Measured ACLR and Drain Efficiency for WCDMA1FA signal