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Comparative Study of Power Amplifier Linearization Techniques

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Abstract:- This paper examines different linearization techniques which are used to linearize the power amplifier by emphasizing on weakness and strength of each technique. After complete analyze it has been concluded that Digital Pre Distortion (DPD) technique is the best linearization technique to linearize the power amplifier. DPD technique for linearizing a wideband radio frequency power amplifier has been studied in detail and different research issues in DPD technique are identified.

Keywords:- Power amplifier, Linearization, digital pre distortion, WCDMA, WiMAX, PAPR, IMD, FPGA etc.

I. INTRODUCTION

The demand for high data rate and the increase in number of users worldwide has led to the development of high spectral efficient transmission formats like Wideband Code Division Multiple Access (WCDMA) and Worldwide Interoperability for Microwave Access (WiMAX) [11,14]. But these formats suffer from the problem of high peak to average power ratio (PAPR). The AM-AM characteristics of power amplifier (PA) between its input power and output power are shown in Fig 1 [2-5].

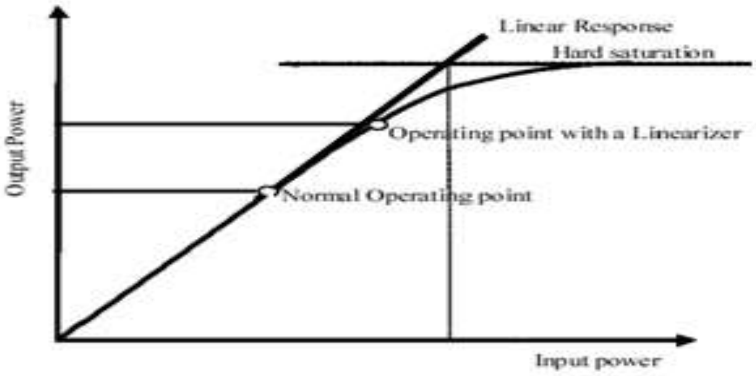

Fig. 1 AM-AM characteristics of a PA

High PAPR causes PA to operate in non-linear region, which further results in inter-modulation distortion (IMD) [6-8]. One method to reduce the IMD is to operate PA in linear region by backing off from its saturation point. The efficiency of PA will be very low if operating point is lower than saturation point. Hence, large amount of DC power will get lost in form of heat [2]. So, researchers are working on development of certain linearization techniques which could lead improvement in power efficiency without compromising with its linearity [2]. It is worthwhile to mention here that practically all wideband PAs exhibits memory. The causes of memory effects are thermal constants of the active devices and components in the biasing network that have frequency dependent behaviors [10-12]. This paper has been organized as follows: section I is introduction, section II study of PA linearization techniques, III explained the DPD technique, IV presents the issues in DPD technique and section IV is conclusion.

II. PA LINEARIZATION TECHNIQUES

A variety of PA linearization techniques like Boot Up Bias, Dynamic Bias, Baseband Envelope Feedback, Polar Feedback, Cartesian Feedback, Envelope Elimination and Restoration, Adaptive Feed forward, radio frequency (RF) or intermediate frequency (IF) pre-distortion and DPD technique have been quoted. Each technique has its own advantages and limitations [13, 15-18]. Correction, bandwidth, weakness and strength of these techniques are compared in Table.

Table: Quantitative comparison of different linearization techniques

S/N	Technique	Correction	Bandwidth	Weakness	Strength
1	Boot Up Bias	Few dB	Small bandwidth	-Very poor performance. -Only operated in the small signal linear region.	**The simplest way to improve the linearity.**
2	Dynamic Bias	1 dB	Small bandwidth	Very small input signal and the bias is set low.	**The gain decrease is sensed by the op-amp, which increases the bias to compensate.**
3	Baseband Envelope Feedback	Few dB	Small bandwidth	-Techniques is complex for large bandwidth -The loop bandwidth is within the MHz range.	**Can be operated at a higher frequency band or large bandwidth by using extra components in feedback path.**
4	Polar Feedback	30 dB	Narrowband	different level of improvement of the AM-AM and AM-PM characteristics	**-Relatively high efficiency. -Ability of envelope feedback.**
5	Cartesian Feedback	10-30 dB	Few MHz	Conditionally stable and need the setting of the phase shift adjuster.	**Automatically compensate for drifts in amplifier and non-linearity due to temperature and power supply variations.**
6	Envelope Elimination and Restoration	20-30 dB	2 MHz	-Slowness of the envelope restoration feedback loop. -The magnitude and phase information are amplified separately	**Always operated in an efficient switched mode.**
7	Adaptive Feedforwad	20-40 dB	3-50 MHz	-Amplitude and phase matching is a problem. -Only invented for distortion reduction in telephone repeaters	**Linearization performance over wide bandwidths.**
8	**RF/IF Pre-Distortion**	**25dB**	**45MHz**	**It is not digital technique.**	**-Pre-Distortion technique is introduced. -Ability to linearize the entire bandwidth.**

Table concluded that RF/IF Pre-distortion technique is the best technique from other linearization techniques. Fig. 2 shows an open loop pre-distortion system in its simplest form.

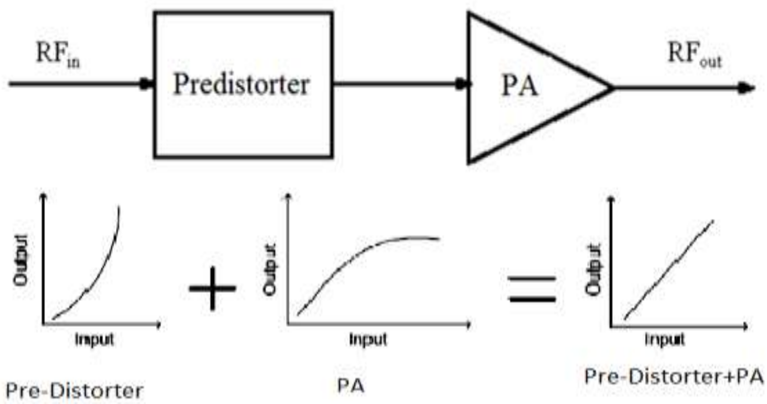

Fig. 2 Concept of pre-distortion technique to linearize PA

In pre-distortion technique a pre-distorter is added in the baseband to create an expanding non-linearity that is complementary to the compressing characteristic of the PA. Ideally, the cascade of the pre-distorter and the PA becomes linear. When pre-distortion technique is converted into digital form, it is called digital pre-distortion (DPD) technique. DPD takes up various advantage of the already existing digital part of a transmitter and it also eliminates problems regarding RF hardware adjustments and loss of power in additional RF components. DPD also benefits from high flexibility, controllability and possibilities to provide adaptation by combining with feedback and feed forward techniques. DSP provides a wide possibility of generation of the pre distortion characteristic and different combinations with the other linearization techniques that can be used in order to improve the DPD performance [14, 19-21].

III. DPD TECHNIQUE

As the demand of wide bandwidth more different styles of DPD techniques are invented. A comparison of these different styles of DPD techniques becomes more important for re-researchers. DPD can be categorized as Look Up Table (LUT) DPD, baseband distortion components injection DPD and polynomial based DPD. In earlier times the DPD technique was based on the mapping pre-distorter principle, in which each possible signal level was directly mapped to another output level. LUT DPD uses two, one dimensional LUTs and is based on the concept of maintaining constant loop gain at all power levels. This is achieved by addressing the LUT with the magnitude of the input complex envelope to obtain complex gain scale factor stored in the LUT. The input signal is then multiplied with the complex gain to obtain a pre distorted output which is the inverse of the PA. The LUT table can be based on I/Q representation or polar coordinates. Both approaches require additional signal processing to perform complex multiplications [2,3-5]. In addition, the polar co-ordinate table also requires polar/rectangular conversions. The gain function from the LUT is multiplied with modulated input signal. The resulting complex quantity is based on the envelope of the input signal. Therefore, the gain function obtained after polar to rectangular conversion from polar tables is identical to the gain function in IQ representation LUT. The LUT has been addressed by the magnitude of the source signal [20].

In the baseband components injection DPD technique, components are injected in the baseband block with the same amplitude and 180^0 phase shift in order to compensate with the distortion of the PA. However, the distortion compensation limits the technique due to its inability to compensate memory effects of PA's significantly [12-13].

In Memory Polynomial based Adaptive DPD technique each digital data sample is processed in the pre distorter not according to a LUT but according to a polynomial function. This polynomial function can be of 3rd, 5th or of more order, depending on the desired degree of linearization in adjacent and alternate channels. Pre distorter polynomial is made to fit to the opposite of PA characteristics and is controlled by an optimizer or adapter. The adaptation unit adjusts the polynomial coefficients, which should be in complex form in order to correct both gain and phase non-linearity [21-24]. Also, in Polynomial Pre distorters the forward path must be continuous as in LUT. The coefficients can be stored in a small LUT and can be optimized by algorithms. The amount of mathematical operations in this unit can be quite high depending on the order of Pre distorter [10-12].

IV. ISSUES IN DPD TECHNIQUE

Although the basis of digital pre-distortion cannot be changed but certainly there is always a room for improvement in earlier done research works. It has been concluded that PA not only suffers from non-linearity but also exhibits memory effect. The research on development of a new digital pre-distortion technique was incomplete until an accurate model of PA was developed. Research on digital pre distortion is motivated by memory effects which affect the digital pre distortion and wider bandwidths for emerging wireless technology. These memory effects are complex to implement and depend on number of interactive variables. Therefore, a simple solution to the problem of memory effects can't be useful. It is also possible to add even order nonlinear terms to the bias control network to allow more degrees of freedom that will result in better control of the distortion cancellation. Future work can be focused on introducing some kind of parallelism into the algorithms. There is no comparison of error vector magnitude (EVM) of transmitted and received data performed for the given standard implementation. The work can be implemented into a field-programmable gate array (FPGA) board or digital signal processing (DSP) board and compared with existing work. Despite modeling of PA with memory, the proposed DPD should also be able to compensate these memory effects. Extraction method of coefficients value and to optimize these values of PA and DPD can also be another research area.

V. CONCLUSION

Linearization of PA using DPD can take benefits from the continuous improvements of DSP and FPGA circuitry. Thus, the use of DPD for PA linearization can provide significant accuracy and flexibility, better power efficiency and reduced implementation complexity.

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