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Linearization of volterra series model power amplifier for wideband WCDMA base stations

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Abstract: Digital pre-distortion techniques are widely used in linearization of RF power amplifiers. In this paper Look-up-table (LUT) type Adaptive Digital pre-Distortion (ADPD) is presented. In this algorithm, an output signal of the Power Amplifier (PA) is used as reference signal. It is used to update the coefficients of the LUT, so that characteristics of the PA, such as temperature dependence, do not have influence on the convergence performances. Simulation results have been presented.
Keywords: Digital pre-distortion (DPD), error vector magnitude (EVM), power amplifier (PA), look-up-table.

Introduction

Wideband signals such as those used in CDMA and W-CDMA systems are spectrally more efficient. However, they are subject to severe intermodulation distortion (IMD) when operated near saturation, cause intermodulation products that interfere with adjacent and alternate channels. This interference affects the adjacent channel leakage ratio (ACLR) and Error vector magnitude (EVM) and its level is strictly limited by FCC regulations (Kenney & Leke, 1995). To maintain linearity and power efficiency, one can apply linearization to the power amplifier (PA) through several techniques such as feed forward or more recently, digital pre-distortion (PD). Digital baseband implementations show higher efficiency at lower cost with greater pre-distortion bandwidth than traditional feed-forward techniques. Compared to feed forward linearization techniques, designs based on digital PD are showing higher efficiency at lower cost, and with recent advances in technology. The adaptation of wideband PD algorithms, such as least-mean squares (LMS) (Ding *et al*., 2004), requires sampling minimally 5 times the original signal bandwidth to accurately correct 3^{rd} and 5th order intermodulation products or IMD3 and IMD5 respectively. For such implementations, system cost is largely driven by the high-performance analog-to-digital converters (ADC) in the feedback path. Less costly alternatives have been proposed which utilize only narrowband feedback to adapt the PD (Stapleton & Costescu, 1992) and thus reducing the cost of the ADCs.

In this paper, we have presented adaptive pre-distortion algorithm based on magnitude and phase indexing used to calculate LUT values.

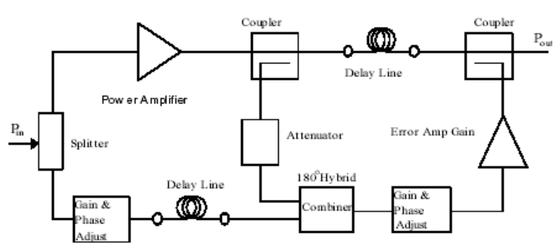

Fig. 1. Illustration of feedforward technique to linearize power AmplifierL

Lineariztion fundamentals

Here, some fundamental principles of digital pre-distortion, particularly the methods used to linearize a PA are presented. Current linearization techniques employ feed-forward pre-distortion to meet EVM and ACLR requirements. But, recent advances enable to use digital feedback as an alternate technique providing higher efficiency at a lower cost. Fig.1 shows an example of feed-forward technique to linearize a power amplifier.

In the feed-forward system the power amplifier is fed directly with the RF source signal. The delayed sample of the undistorted input RF signal is compared with an attenuated sample of the power amplifier output. The error signal is then amplified linearly to the required level and is recombined with the output, following a delay line in the main signal path, which compensates for the delay in the error amplifier. The error signal cancels the distortion present in the main path leaving an amplified version of the original signal. The distortion generated by the power amplifier is cancelled in the feedforward loop by subtracting the source signal from the power amplifier output. The resulting error signal is subtracted from the amplifier output RF components. Additionally, it does not require a phase-locked loop to maintain phase correction. The advantage of feedforward technique is the bandwidth is determined by frequency response of the couplers, delay lines, and phase shift components, which can be made to be very stable over a wide operating range (Kenington & Bennett, 1996; Strickland *et al*., 2001). The disadvantages are need for error amplifier which will be of a similar size as the main amplifier. Delay line in forward path needs to be rated for output power.

However, in recent years, there has been growing interest in linearization by digital pre-distortion (PD). Compared to feed forward, designs based on digital pre-distortion are showing higher efficiency at lower cost. Predistortion technique in its simplest form consists of a predistorter module preceding the nonlinear power amplifier which has the inverse transfer characteristics of the power amplifier.

Pre-distorter architecture

Fig. 2 shows the simplified block diagram of the digital predistortion technique used in this paper. The proposed predistorter requires two, one-dimensional look up tables to store the polar coordinates. The polar LUT table method also requires polar to rectangular (P/R) and rectangular to polar (R/P) conversions, which are carried out using CORDIC algorithm. The gain function from the look-up table is multiplied with modulated input signal. The resulting complex quantity is based on the envelope of the input signal and is represented by:

$$V_c(t) = V_{mod}(t) * F\{|Vmod(t)|^2\} \quad (1)$$

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where $F\{|Vmod(t)|^2\}$ represents the inverse transfer characteristics of the power amplifier.

Also, $V_c(t) = V_{mod}(t) * V_{pd}(t)$ (2)

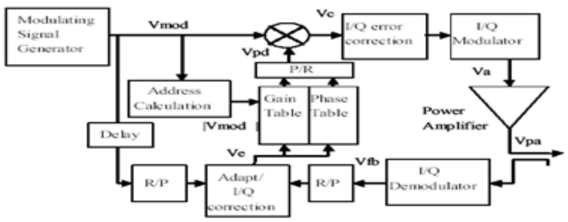

Fig. 2. Digital predistortion using gain and phase indexing of look-up-tables.

The polar table can be represented as:

$V_c = F\{R(V_e), \emptyset(V_e)\}$ (3)

Where $R(V_e)$ and $\emptyset(V_e)$ represents gain and phase error respectively. In order to generate $V_c(t)$, the output from the polar table is converted back to IQ representation. Therefore, the gain function obtained after polar to rectangular conversion from polar tables is identical to the gain function in IQ representation look-up table. This gain function is multiplied with modulated input signal.

Assuming a perfect modulator $V_c = V_a$, we can write,

$V_a(t) = V_{mod}(t) * V_{pd}(t)$ (4)

The look-up table is updated on continuous basis and its contents are shown in Fig. 3. The input $V_{mod}(t)$ is delayed to align with feedback $V_{fb}(t)$ from the power amplifier and the resulting difference $V_{error}(t)$, which only contain the distortion is computed on sample by sample basis. $V_{error}(t) = V_{mod}(t) - V_{fb}(t)$ (5)

There are various adaptation techniques described in the literature for of look-up table entries, such as linear convergence, secant method, rotate and scale, and steepest decent method (Ruchi Pasricha & Sanjay Sharma, 2008). The method of adaptation selected determines the speed of convergence, stability of the system and computation load on the DSP. The rotate and scale method of adaptation is used and equation 5 is used to calculate gain and phase error.

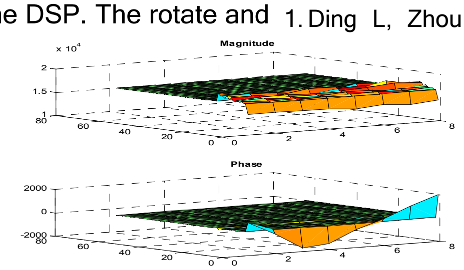

Fig. 3. Look-up-table entries for gain and phase LUT's.

Simulation results

Fig. 4 shows the performance of proposed predistorter. Results show that the Predistorter is able to suppress most of the spectral regrowth. Fig. 5 shows input vs output characteristics of power amplifier, without and with pre-distortion. The response of power amplifier is quite non-linear without application of pre-distortion, but when pre-distortion is applied the proposed algorithm results in a linear response. Results also show that EVM decreases by 9.189%, the average sideband magnitude of 3rd order IMD falls from -70.194dB to -69.348dB and average sideband magnitude of 5th order IMD falls from -80.872dB to -79.359dB.

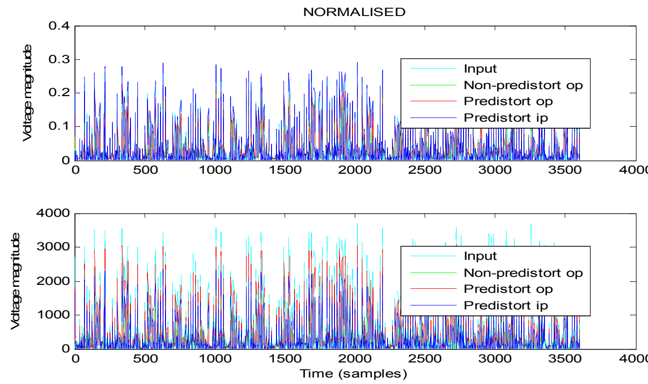

Fig.4. Power amplifier characteristics with pre-distortion and without pre-distortion.

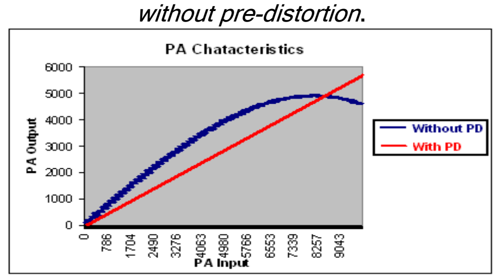

Fig. 5. Power amplifier characteristics with and without pre-distortion.

Conclusion: The design of digital predistortion systems to linearize power amplifiers with memory effects was considered. By adding a digital predistorter in the baseband, the power amplifier is allowed to operate into its nonlinear region, thereby significantly increasing its efficiency. The efficiency gain translates into electricity and cooling cost savings for service providers and longer battery life for mobile terminal users. The challenge here is to address the memory effects exhibited by the higher power amplifiers or the power amplifiers for wideband signals. In addition, analog components in the transmitter have imperfections that need to be compensated as well.

References

1. Ding L, Zhou GT. et al. (2004) A robust digital baseband predistorter constructed using memory polynomials. *IEEE Trans. on Comm.* 52 (1) 159-165.
2. Kenington PB and Bennett DW (1996) Linear distortion correction using a feedforward system. *IEEE Trans. Veh.Tech.* 45, 474-480.
3. Kenney JS and Leke A (1995) Wireless report: power amplifier spectral regrowth for digital cellular and PIIS applications. *Microwave J.* 3. 74-92.
4. Ruchi Pasricha and Sanjay Sharma (2008) Digital Predistortion in WCDMA Power Amplifier using Embedded Processor. *ICGST Intl. J. Program. Devices, Circuits Systems.* 3, 1-10.
5. Stapleton SP and Costescu FC (1992) *An Adaptive Predistorter for a Power Amplifier Based on Adjacent Channel Emissions*, IEEE Trans. Veh. Tech. 41 (1), 49-56.
6. Strickland LP *et al.* (2001) CE phase III final review (July). Raytheon Systems Co.