A new approach for LUT- based digital predistorters adaptation

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Abstract

A new method for fast adaptation of LUT-based predistorters for power amplifier (PA) linearization is proposed. It is compared with more performing, but also more complex adaptation method for polynomial predistorters. Finally, the complexity of the different predistortion algorithms is estimated and compared.

Keywords : predistortion, LUT, power amplifier

1 Introduction

The nonlinearities present in power amplifiers (PA) cause amplitude and phase distortions of the PA output signal. These distortions are at the origin of undesirable spectral regrowth and constellation point's deformation if the PA input is a signal with non-constant envelope. Many techniques for compensations of the nonlinearities and their effects have been proposed [1]. Our work is focused on the Adaptive baseband digital pre-distortion technique. Its principle is to distort the PA input signal in that way that the nonlinearities in overall system (predistorter + PA) are negligible.

To compensate the PA distortion, the global system predistorter (PD)+PA must behave as a linear system with gain G_0. This gain depends on the Peak Back Off (PBO) representing the difference between PA saturation power and the maximal PA output power to transmit.

The digital baseband predistorters can be classified with respect to many criterias. According to the form of predistorter's characteristic two main groups can be distinguished – the Look-up-table (LUT) predistorters [4,5,6,7] and Parametric predistorters (e.g. polynomial predistorters [2,3]). The speed and the complexity of the predistorters adaptation is one of the crucial problems for their practical implementation.

In this paper, a new method for the adaptation of LUT-based predistorter is proposed. It uses the postdistortion adaptation (indirect learning) method similarly to [2,3]. The adaptation is simpler compared with the Secant method [6] or 3-step algorithm from [5] and able to follow the continuous changes of the PA characteristic which is the advantage over the real-time modeling method presented in [4]. All the derivations below will be done in the baseband equivalent domain and the memoryless character of the power amplifier (PA) will be supposed.

2 Adaptive digital predistortion using the postdistortion adaptation

The principle of predistortion system for proposed method is the same as in [2, 3] and is shown in fig. 1. Instead of the adaptation of the predistorter F_{pre} [6,7] or the PA characteristic identification with consequent inverse calculation [5], an equivalent postdistorter operator F_{post} is obtained by minimization of a least squares criterion:

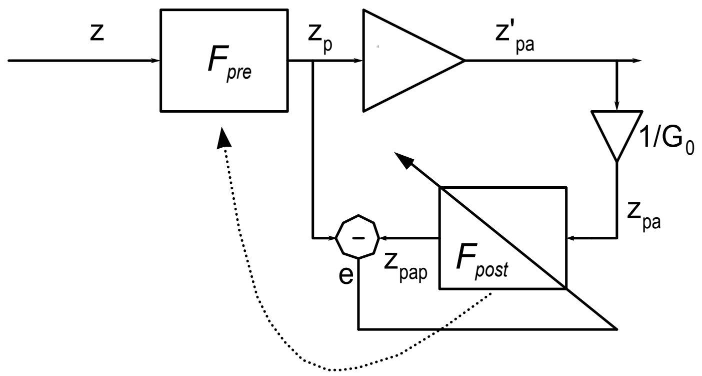


Fig. 1: Predistorter adaptation principle

$$J(n) = \sum_{l=1}^{n} \lambda^{n-l} \left| z_p(l) - F_{post}^{(n)}\left(z_{pa}(l)\right)\right|^2 . \tag{1}$$

Then, the postdistorter calculated at instant n is translated into predistorter for instant $n+1$:

$$F_{pre}(n+1) = F_{post}(n) \tag{2}$$

Note that the constant $\lambda<1$ serves to forget the old samples. In [3], both the predistorter and postdistorter operators had the form of polynomial with memory:

$$F(z(n)) = \sum_{k=0}^{N-1}\sum_{m=0}^{L} f_{k,m}\, z(n-mn_0)\left|z(n-mn_0)\right|^k = \mathbf{f}^T \mathbf{v}(n) \tag{3}$$

and the RLS algorithm was used. n_0 is the elementary delay important for PA's with memory.

The predistorter from eq. 3 falls within the category of parametric (more precisely polynomial) predistorters. Besides, the LUT predistorters are also often used. The output of a complex gain LUT predistorter [6] is the multiplication of the predistorter input and corresponding complex gain $f_{pre,i}$. In the particular case $N=1$ and $L=0$, the eq. 3 represents the output of the postdistorter (or predistorter) having form of the LUT and the postdistorter output can be written as:

$$z_{pap} = f_{post,i} \cdot z_{pa} \tag{4}$$

where i denotes for the index of the LUT and $z_{pa} = \frac{1}{G_0} z'_{pa}$.

Using the eq. 4, the optimal solution for the LUT content $f_{post,i}$ is obtained by the minimization of criterion from eq. 1 (cancelling its gradient) and is equal to:

$$f_{post,i}(n) = \frac{\sum_{l=1}^{n} \lambda^{n-l} z_p(l) z_{pa}^*(l)}{\sum_{l=1}^{n} \lambda^{n-l} \left|z_{pa}^*(l)\right|^2} \tag{5}$$

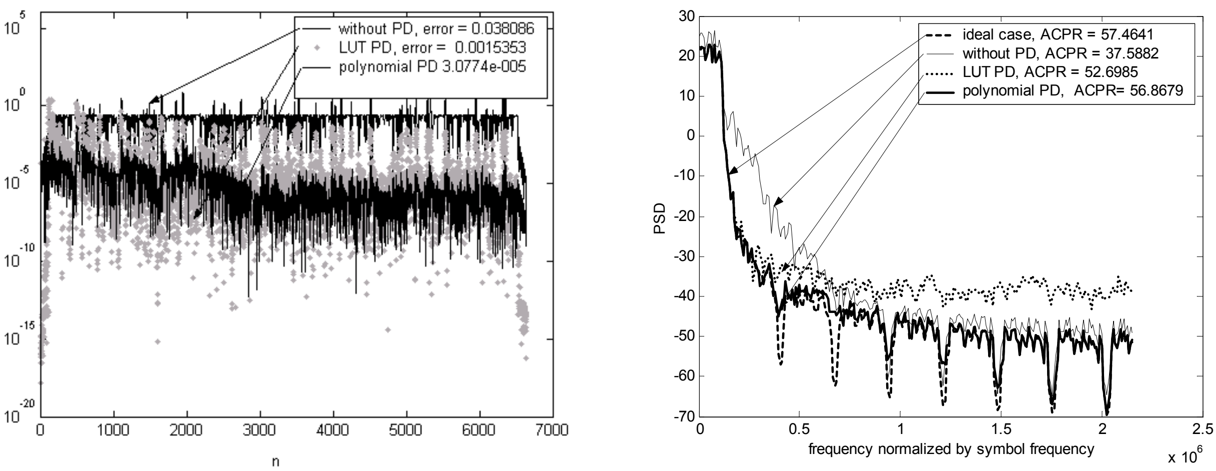
Finally, the content of the predistorter LUT is updated using the corresponding value from postdistorter LUT as:

$$f_{pre,i}(n+1) = f_{post,i}(n) \tag{6}$$

To further improve the precision of the predistorter's LUT, a linear interpolation between the LUT points can be performed.

3 Experiments and results

The proposed method was tested using the MATLAB simulations on the example of memoryless Saleh power amplifier model [1]. The system amplifer + predistorter was driven with the OFDM HIPERLAN 2-like signal with 64 subcarriers, 16QAM mapping and 16 samples per symbol. In figure 2a), the instantaneous amplitude error $\left(\left|G_0\right|\left|z(n)\right| - \left|z_{pa}(n)\right|\right)^2$ for the amplifier without the PD, the proposed LUT predistorter and the polynomial predistorter (according equation 3, L=0, N=6) are shown. Fig. 2b) represents the power spectral densities, again for the PA with no PD, both mentioned predistorters and for the case of ideally amplified signal. Note that for all the simulations, forgetting factor λ was set to 0.99 and the amplifier worked with Peak BackOff (distance between the saturation power and the maximum desired output power) of 0.45dB's. You can see that for the case of memoryless PA, the performance of the LUT predistorter (with 30 points in the LUT) is slightly worse than the performance of the polynomial predistorter but the LUT can still improve the performance significantly. The Error Vector Magnitude (EVM) have also been calculated on demodulated symbols and its values are 10.5% (PA without the predistorter), 1.4% (PA with the proposed LUT predistorter) and 0.4% for the polynomial predistorter. The Adjacent Channel Protection Ratio (ACPR) without predistortion is 37.6dB. Using the predistortion, the ACPR is improved to 52.7dB (LUT) and 56.9 dB (polynomial PD).



a) b)

Fig. 2: a) Instantaneous amplitude error **b)** Power spectral densities

4 Complexity of predistortion methods

The number of basic mathematical operations (additions, multiplications, divisions) necessary to calculate the predistorters output and to actualize the predistorter are estimated and summarized in the table I for different methods of predistortion. Real numbers of operations depend on practical implementation and can be slightly different. The operation of the LUT predistorter according the equation (4) is supposed. For all LUT-based predistorters, the LUT index *i* corresponding to input signal has to be found. Exact number of operations needed for this step can differ according the type of LUT addressing (amplitude, power, …). The polynomial PD without memory (*L*=0) is supposed to have *N* coefficients. The number of calculations and the need for the square root in the case of the polynomial PD can be reduced using only coefficients $f_{k,m}$ with even k as in [2].

Method		Secant	Substitution	Polynomial	Proposed LUT
PD output calculation	ADD/SUB	2	2	4N-1 (23 for N=6)	2
	MPY	4	4	6N (36 for N=6)	4
	DIV	-	-	-	-
	Others	LUT index calculation	LUT index calculation	SQRT	LUT index calculation
one iteration of the adaptation algorithm	ADD/SUB	17	10	$12N^2+10N+1$ (493 for N=6)	6
	MPY	18	18	$14N^2+18N+4$ (616 for N=6)	11
	DIV	1	1	1	1
	Others	-	-	SQRT	-

Table I: Complexity of different predistortion methods

5 Conclusions

A method for the adaptation of the LUT-based predistorter using the equivalent postdistorter has been presented. Although the results of the simulations are not as impressive as for the polynomial predistortion, they confirm its ability to improve the linearity of memoryless amplifiers. Moreover, the computational complexity of the proposed approach is significantly reduced with respect to previously used LUT methods (secant, substitution, 3step method) or polynomial predistortion method. We are now extending this approach to the LUT-based predistorters able to linearize the PA's with memory.

References

[1] KENNINGTON, P.B., "High linearity RF Amplifiers design", Artech House 2000.

[2] MARSALEK R., JARDIN P., BAUDOIN G, "From post-distortion to pre-distortion for power amplifiers linearization", IEEE Communication Letters, Vol. 7, July 2003

[3 BAUDOIN G, JARDIN P., MARSALEK R., 'Linearisation des amplificateurs de puissance par pre-distorsion avec prise en compte de l'effet memoire', accepted for publication at GRETSI 2003, September 2003, Paris.

[4] JECKELN E.G., GHANNOUCHI F.M., SAWAN M., 'Adaptive Digital Predistorter for Power Amplifiers with Real Time Modeling of Memoryless Complex Gain', IEEE MTT-S 1996 International Microwave Symposium, San Francisco, CA, June 1996.

[5] HAN D.S., HWANG T., 'An Adaptive Pre-Distorter for the Compensation of HPA Nonlinearity', IEEE Transactions on Broadcasting, vol. 46, No. 2, June 2000, pp. 152-157

[6] CAVERS J.K., 'A linearizing predistorter with fast adaptation', Proc. 40th Vehicular Technology Conference, May 1990, pp. 41-47.

[7] CAVERS J.K., 'The Effect of Quadrature Modulator and Demodulator Errors on Adaptive Digital Predistorters for Amplifier Linearization', IEEE Transactions on Vehicular Technology, Vol. 46, No. 2, May 1997.