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A Survey on Closed-Loop Digtal Predistortion (DPD) Used to Linearize RF Power Amplifier

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ABSTRACT

Digital predistortion (DPD) used to linearize an RF power amplifier (PA) can achieve wide bandwidth distortion cancellation. Predistortion technique is one of the most effective linearization technique. Model based DPDs also called polynomial based DPDs, are mostly used for the linearization of PA. For memory less system, the polynomial model can be used to model the predistorter. For memory system, the models such as Volterra series model, generalized memory polynomial model, Hammerstein model and Wiener model all are used to model the predistorter. DPD architectures can be classified into two types Indirect Learning Architecture (ILA) and Direct Learning Architecture (DLA).In this paper a survey on different model digital predistortion used to linearize RF power amplifier in different works.

Keywords: *Amplifier Distortion, Digital Predistortion, Direct Learning Architecture (DLA), Memory less System, Power Amplifier (PA).*

1. INTRODUCTION

A Transmitter within a wireless base station converts a digital baseband input signal into an RF output signal. The final active stage of the transmitter, the power amplifier (PA), is often designed to operate near saturation to maximize efficiency. However, the PA exhibits a nonlinear behavior under such conditions, which must be linearized. The transmitter, shown in Fig. 1, comprises a transmit path and observation path. The transmit path performs the desired conversion of the digital baseband signal $x(k)$ into the amplified RF output signal $y_{RF}(t)$.Part of the RF output signal is coupled into the observation path, which converts it into a digital baseband output signal $y(k)$. This observation signal is used to monitor the quality of the transmitted waveform including distortion caused by nonlinearities within the transmit path.

The transmit path includes a DPD module, digital-to analog converter (DAC), modulator, and PA. DPD has a nonlinear response intended to compensate for the subsequent PA nonlinearity so that the transmit path appears linear. The DPD module is made adaptive using coefficients selected by an estimator that attempts to minimize the residual distortion measured by the observation path.

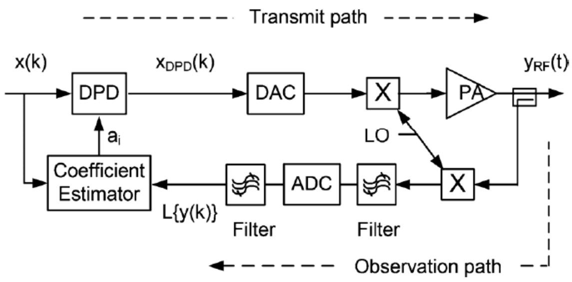


Fig-1 Digital Transmitter with DPD

Digital Pre distortion (DPD) is one of the most effective techniques to mitigate the distortions caused by power amplifier (PA) nonlinearity and memory effects. As the input signal bandwidth increases, the required bandwidth on the DPD feedback channel becomes even larger, i.e., normally five times the signal bandwidth. However, the DPD feedback bandwidth is often restricted by the non ideal electronic components, e.g., the anti-aliasing filter and associated circuits, which therefore introduce bandwidth mismatch between the PA model basis functions and the feedback signal, and thus degrade the linearization performances of the DPD. DPD structure, a feedback channel is required to down convert, filter, and capture the

PA output signal. Conventionally, the bandwidth of the PA output signal reaches about five times that of the input signal due to the PA spectral regrowth.

2. RELATED WORKS

The DPD coefficients are tuned using a closed loop estimator, which compares the input and output signals, and, respectively. This places the DPD module within the estimation loop, as shown in Fig. 1. Many researchers use an open-loop estimator where the PA nonlinearity (or its inverse) is estimated based on the pre distorted signal and the output signal. The DPD coefficients are derived subsequently from the estimate. This places the DPD module outside of the estimation loop, Different models DPD used in linearization.

2.1 Digital Baseband Predistorter Constructed Using Memory Polynomials

Lei Ding *and* Tong Zhou et al [7] proposed PA model and building a corresponding predistorter, directly on the predistorter structure .A memory polynomial model for the predistorter and implement it using an indirect learning architecture. Linearization performance is demonstrated on a three-carrier WCDMA signal. Memoryless PA (i.e., the current output depends only on the current input), memoryless predistortion is sufficient. Higher power amplifiers such as those used in wireless base stations exhibit memory effects. The cause of memory effects can be electrical or electro thermal .Nonlinear PA with memory, its inverse must also be a nonlinear system with memory. A memory polynomial is a good model for the PA, predistorter parameters are easy to extract, involving only linear least squares. The effectiveness of predistortion is demonstrated on a W–H system, a memory polynomial nonlinearity, a perturbed Wiener (full Volterra) system, and a parallel Wiener model.

2.2 Digital Predistortion using Direct Learning With Reduced Bandwidth Feedback

Lei Ding et al [3] proposed model, it is capable of achieving near full-rate DPD performance and linearization bandwidth with significantly reduced feedback bandwidth. Measurement results on a Doherty
PA achieved more than 20 dB corrections over 200 MHz bandwidth for a 2-carrier WCDMA signal spanning 40 MHz with only 81.92 MHz feedback bandwidth. The direct learning architecture directly constructs a perverse, i.e., DPD, of a PA by minimizing the error between the original input x(n) and the PA output z(n) as shown in Fig. 2.

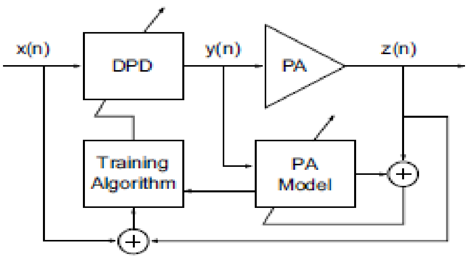


Fig-2 Direct Learning Architecture

To generate the gradient for DPD parameter adaptation, a PA model is typically required and estimated from PA input and output data. For each iteration in the training process, the PA model is first updated and then used together with the error signal to produce the update for DPD parameters. Comparing with the indirect learning architecture, the use of the PA model may lead to additional computation requirements. But the direct approach enjoys benefits such as avoiding parameter bias caused by measurement noise and more robust to spurs and distortions in feedback data.

2.3 Digital Predistortion Architecture Using Constrained Feedback Bandwidth for Wideband Power Amplifiers

Ying Liu et al [2] proposed a general DPD architecture for wideband PA systems with constrained feedback bandwidth. By using linear operations to cancel the bandwidth mismatch between the proposed model and the PA feedback signal, the full-band PA model parameters can be estimated with bandwidth-limited observations. This estimated PA model is subsequently used with the PA input signal to extract the DPD function by applying the direct learning algorithms.DPD architecture reduces the feedback bandwidth to less than two times that of the input signal, while it maintains its linearization performance, as in the full-band case.

DPD architecture with constrained feedback bandwidth is proposed to effectively compensate for the distortions caused by wideband PA nonlinearities and memory effects. The effect of feedback bandwidth restriction on the conventional MP model identification is analyzed, a band-limited PA model extraction method is proposed to mitigate the effect of feedback bandwidth restriction on a three-box PA model, where cross terms are included along with the conventional MPs. Direct learning algorithm is extended to an iterative form to cover the proposed PA model and derive the DPD function. Due to no restriction being placed on the DPD function derivation, this general DPD architecture can compensate for the distortion over the transmission bandwidth without either using a high-performance RF filter to suppress the sidelobe or combining multiple narrowband observations.

Microwave cavity filters are inserted to the feedback path to restrict the bandwidth. The modeling and linearization performances clearly proposed DPD architecture can mitigate the bandwidth constrains of the conventional system and provide excellent results even when the DPD feedback bandwidth is restricted to less than two times the input signal bandwidth. Linear operations to the proposed PA model basis functions and the band-limited feedback signal, the full-band PA model parameters can be extracted from band-limited feedback observations.

2.4 Digital Predistorters Using Principal Component Analysis

Gabriel Montoro1 et al [4] proposed apply order reduction in wide-band digital predistortion (DPD) linearizers using the principal component analysis (PCA) technique**.** PCA is a well-known technique suitable for converting a basis of observed and eventually correlated data into a basis of uncorrelated data. This property of eliminating redundancies can be used for order reduction in linear regression problems. This approach relaxes the computational load of the subsystem responsible for assisting the real-time FPGA device in the task of updating the DPD parameters, such as for example, a soft-core microprocessor (e.g. Xilinx Microblaze) or any other microprocessor device.

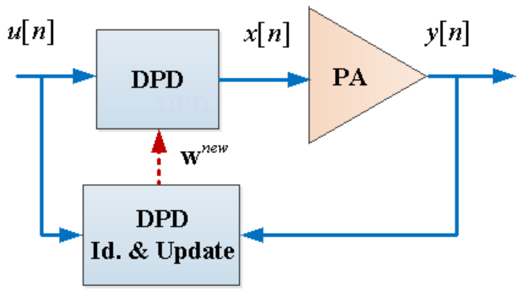
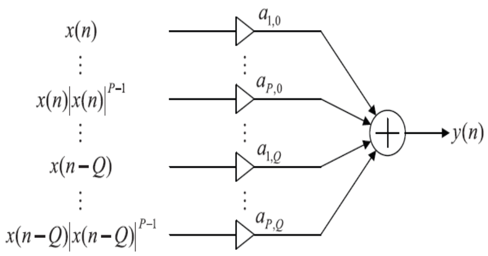


Fig-3 Direct Learning Approach

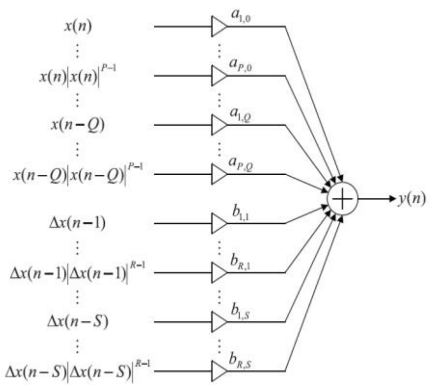
Applying order reduction techniques also improves the conditioning of the basis waveforms used.

2.5 Digital Predistortion of Power Amplifier based on Compound Memory Polynomial

Zhuohui He et al [5] proposed a compound memory polynomial (CMP) model to enhance the accuracy. The CMP model is constructed by adding the term concerning the difference of input to the MP model.



(a)



(b)

Fig-4 Block Diagram of (a) MP Model (b) CMP Model

2.6 Least Squares Extraction for Volterra Series Digital Predistorter in the Presence of Feedback Measurement Errors

You-Jiang Liu et al [6] proposed a generalized analysis for the Volterra-series DPD system is presented in the presence of feedback measurement errors. The DPD coefficients are biased due to these errors. A modified least squares (MLS) method is then proposed for DPD coefficients extraction, which can eliminate the detrimental effect of feedback measurement errors without using a post-compensator.

The proposed MLS method has the advantage of being free of behavioral modeling for the feedback path or the post-compensator. The feedback measurement errors have an important effect on the Volterra-series DPD. A generalized analysis based on the indirect learning architecture and least squares (LS) extraction algorithm is presented to show that the DPD coefficients are biased due to the errors. Conventional compensation techniques for these errors (I/Q imbalance, dc offset, and/or nonlinearity) using post-compensators based on separate modeling a modified least squares (MLS) extraction method is proposed.

2.7 Closed-Loop Digital Predistortion (DPD) Using an Observation Path with Limited Bandwidth

R. Neil Braithwaite et al [1] proposed system having (DPD) used to linearize an RF power amplifier (PA) can achieve wide bandwidth distortion cancellation using measurements obtained from a narrow bandwidth observation path. The DPD module creates a correction signal using a set of nonlinear basis waveforms, weighted by adjustable coefficients. The coefficients are optimized using a closed-loop estimator. Using superposition that the basis waveform sets used in the DPD module and closed-loop estimator can differ by a linear transformation, which includes filtering. By filtering the waveforms presented to the estimator, coefficients are optimized for distortion cancellation in a specific part of the spectrum corresponding to the observed bandwidth. The narrow bandwidth coefficient estimate provides wide bandwidth distortion cancellation when used by a DPD module having the unfiltered basis waveform set. Success of the approach relies on further filtering within the estimator to attenuate (notch) the input signal bandwidth, thereby reducing biases in the closed-loop estimation. The closed-loop estimator is forgiving with respect to in-band errors within the transmitter and made robust when the in-band notch attenuation, observation bandwidth, and model order of the estimator are selected properly. As the input signal bandwidth increases, reducing in-band errors (or EVM) in the transmitter becomes more challenging, making the closed-loop estimator the better choice. Signals presented to the coefficient estimator are filtered: to fit within the bandwidth of the observation path and to attenuate the in-band errors. Such filtering reduces sensitivity to linear impairments within the transmitter. If adequate in-band suppression is not possible, the model order of the estimation is reduced to avoid degradations outside of the observation bandwidth.

2.8 Digital Predistortion to Power Amplifiers Used in Third Generation Systems

B. Abdulrahman et al [8] proposed a new method of adaptation, called the slope-dependent is then Introduced and compared with the direct method concerning their time of convergence and the residual error after convergence. The Slope-dependent Method is a simplified stochastic gradient adaptation algorithm. The motivation for this choice is its simplicity in implementation especially when dealing with high rate systems such as W-CDMA. It is based on the slope of the P.A.

3. CONCLUSION

This review presents a detailed survey of different model digital predistortion used to linearize RF power amplifier. Polynomial based DPDs, are mostly used for the linearization of PA. All Digital predistortion easy to implement, doesn't have delay, doesn't consume large power, and cancelling distortions.

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