Review Of Power Amplifier Linearization Techniques In Communication Systems

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ABSTRACT

Power amplifiers are indispensable components in a communication system and are inherently nonlinear. The nonlinearity generates spectral regrowth, which leads to adjacent channel interference and violations of the out-of-band emission requirements mandated by regulatory bodies. It also causes in-band distortion which degrades the bit error rate (BER) performance. To reduce the nonlinearity, the power amplifier can be backed off to operate within the linear portion of its operating curve. To improve the power amplifier efficiency without compromising its linearity, power amplifier linearization is essential. Various linearization techniques are used for linearity and efficiency improvement in mobile communication systems. Among all linearization techniques, digital predistortion is one of most important technique. Power amplifier's output suffers from noise especially when used for prolonged hours. The heat dissipated during the operation normally violates the faithful amplification of the input signal at desired gain. The heat dissipation is inherent in the system due to long run and can not be avoided, however can be compensated by using appropriate algorithm in order to keep track of faithful amplification. In the presented work, the thermal noise is modeled as Gaussian noise, the most random in nature and is made input along with the input signal. A modified least mean square adaptive filter is proposed to extract the input signal at the output with faithful amplification.

Keywords: GLCM → Gray Level Co-occurrence Matrix, DPD → Digital Pre-Distortion,

LMS → Least Mean Square, FPGA → Field Programmable Gate Array, PA→ Power Amplifier

INTRODUCTION

Power amplifier linearization is currently one of the most promising techniques for linearity and efficiency improvement in mobile communication systems. There are numerous techniques which have different levels of complexity, various advantages and limitations.

Different linearization methods may fit to different communication systems. For example more sophisticated high performance systems may be used for base station PAs whereas the systems usable in handsets should have low complexity, low cost and high efficiency. Although in general the main reason to implement these systems is to linearize the PA, they improve also the efficiency because a linearized PA can be driven closer to compression (operation with low back-off).

POWER AMPLIFIERS FEATURES

Gain and Output Power:

In mobile communications each system has its specifications which must be fulfilled. Obtaining output powers high enough for various applications is a very important task achieved by Power Amplifiers. In general the information signal is first modulated and up converted, and then sent to a PA. This input is multiplied with a gain factor and the desired output power is obtained.

Linearity:

Linearity is one of the key issues in Power Amplifiers used in new generation mobile communication systems. The linearity of a Power Amplifier is easily visible in its gain and phase characteristics.There are many linearization methods used for power amplifiers which give better linearity but at the cost of poor efficiency i.e. the method which give good linearity with efficiency should be used for linearization of power amplifiers.If an amplifier has a constant gain and phase response for an input power region, then the amplifier is said to be linear for this region.

Efficiency:

Efficiency is another key issue in mobile communications especially for battery operated mobile terminals. It has two widely used definitions, drain (or collector) efficiency and PAE (Power Added Efficiency). Drain efficiency is the ratio of output radio frequency (RF) power to input DC power

$$\eta = P_{out}\,RF / PDC$$

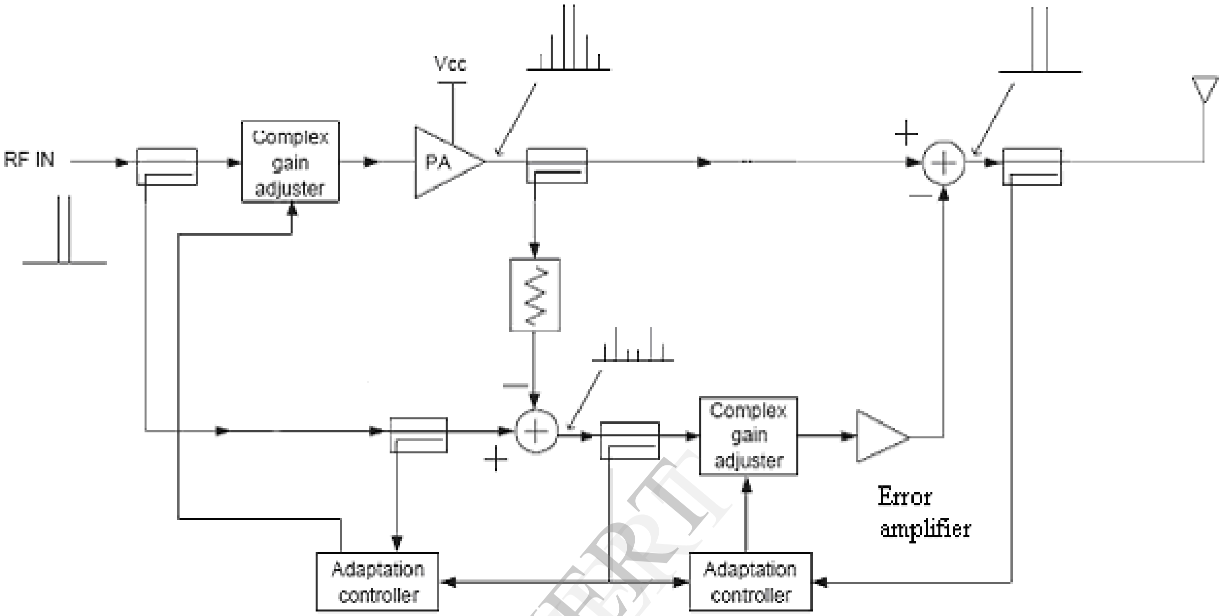
LINEARIZATION METHOD

FEEDBACK METHOD

Feedback linearization methods are relatively simple compared to feedforward and conventional predistortion. The idea is to force the PA output to follow its input. There are different types of feedback linearization topologies classified mainly as RF feedback and modulation feedback which can be divided again into two: polar and Cartesian feedback. In modulation feedback the modulation components (I&Q or R&θ) of PA input and output are compared whereas in RF feedback the RF signals are compared. Feedback systems can be implemented at RF, IF or baseband frequencies. A major issue in feedback linearization is the stability due to delays in feedback which is critical, especially in systems with discrete components. The group delay increases significantly due to PA matching circuits or filters and couplers in the loop.

FEEDFORWARD METHOD

The feed forward method allows high linearization performance and is currently used in base stations of mobile communications systems.

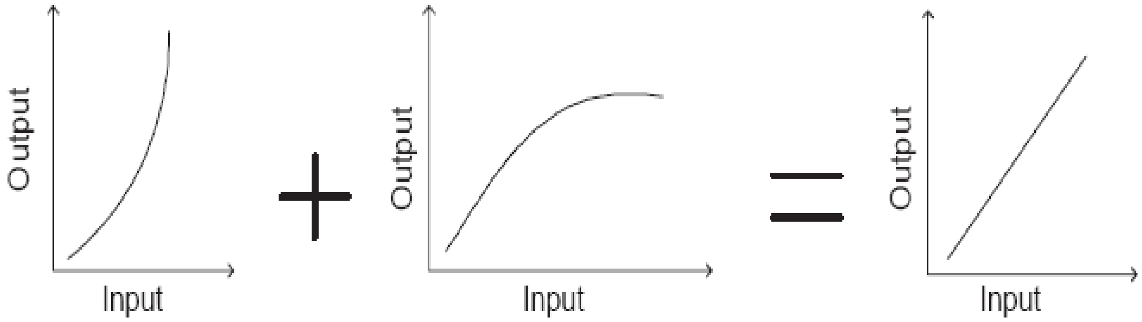


(Feed forward linearization block diagram)

The idea is to extract the distortion at the PA output, amplify it and add it to the PA output in opposite phase in order to cancel the distortion. Out of all linearization methods, only feedforward systems provide a very good distortion reduction over a wide bandwidth. The drawback of these systems is the low power efficiency due to high power requirement of the error amplifier operated in class A mode and losses due to couplers and delay lines in the system.

PREDISTORTION METHOD

The idea behind predistortion is to expand the input signal prior a PA in such a way that the nonlinearities due to the PA are compensated. It is realized by implementing a nonlinear block in front of the nonlinear PA generating input signal level dependent distortion elements opposite of the distortion caused by the PA. As a result the cascade of these nonlinear blocks has a linear response.



Predistorter Power Amplifier Predistorter+Power Amplifier

(Basic steps of Predistortion)

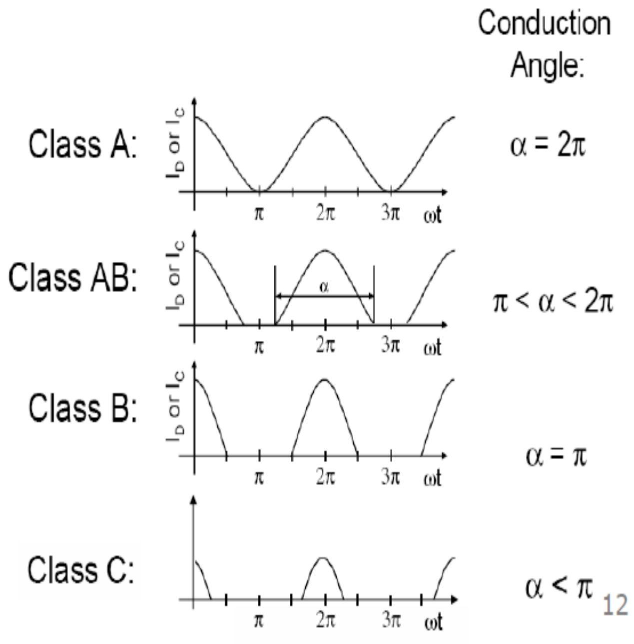
CLASSIFICATION OF AMPLIFIERS

Class A Power Amplifiers – In this case, transistor is so biased that the output current flows for the entire cycle of the input signal. Thus the operating point is so selected that the transistor operates only over the linear region of its load line. So such an amplifier can amplify input signal of small amplitude. As the transistor operates over the linear portion of load line, the output waveform is exactly similar to input waveform.The maximum possible overall efficiency with resistive load is 25%. The maximum possible collector efficiency with resistive load is 50%. In case an output transformer is used, both of these efficiencies are 50%.

Class B Power Amplifiers - In this case, the transistor bias and signal amplitude are such that output current flows only during positive half cycle of the input signal. At zero signals, the collector current is zero and no biasing system is required in class B amplifiers. The operating point is selected at collector cut-off voltage; Because of total absence of negative half cycle from the output the signal distortion is high. Zero signal input represents the best condition for class B amplifiers because of zero collectors current.The theoretical efficiency in class B operation is about 78.5% while it is only 50% in class A operation.

Class AB Power Amplifiers - An amplifier may be biased at a dc level above the zero base current level of class B power amplifiers and above one-half the supply voltage level of class A; this bias condition is class AB. Class AB operation still needs a push-pull connection to achieve a full output cycle, but the dc bias level is usually closer to zero base current level for better power efficiency. For class AB operation the output signal swing occurs between 180 degree and 360 degree and is neither class A nor class B operation.

Class C Power Amplifiers - A class C power amplifier is biased for operation for less than 180 of the input signal cycle and will operate only with a tuned or resonant circuit which provides a full cycle of operation for the tuned or resonant frequency. Such power amplifiers are, therefore, employed in special areas of tuned circuits, such as radio or communications.



RELATED WORKS

The new generation mobile communication systems are very sensitive to the nonlinearities in their transmitting paths. The power amplifier is a key component which generates the nonlinear distortions. Power amplifier linearization techniques are very important to reduce the distortion of the transmitted signal and the adjacent band interference of users. As its facility of implementation, adaptive ability and high efficiency, the pre-distortion technology becomes the first choice to minimize the nonlinear distortions.

Bertran, E. et. Al presents the design of an adaptive digital predistorter (DPD) for power amplifier (PA) linearization whose implementation and real time adaptation can be fully performed in a field programmable gate array (FPGA). The distinctive characteristic of this adaptive DPD is its straightforward deduction from a nonlinear auto regressive moving average (NARMA) PA model and the possibility to be completely implemented in a FPGA without the need of an additional digital signal processor performing the DPD adaptation. The adaptive DPD presents a NARMA structure that can be implemented by means of look-up tables (LUTs). This configuration results in a Multi-LUT implementation where LUT contents are directly updated by means of an LMS algorithm. Details on the internal adaptive DPD organization as well as its linearization capabilities are provided, taking into account memory effects compensation[1].

Zheng Gao ET. Al present a digital predistortion technique to improve the linearity and power efficiency of a high-voltage class-AB power amplifier (PA) for ultrasound transmitters. The system is composed of a digital-to-analog converter (DAC), an analog-to-digital converter (ADC), and a field-programmable gate array (FPGA) in which the digital predistortion (DPD) algorithm is implemented. The DPD algorithm updates the error, which is the difference between the ideal signal and the attenuated distorted output signal, in the look-up table (LUT) memory during each cycle of a sinusoidal signal using the least-mean-square (LMS) algorithm[2].

Traverso, S. et. Al propose to improve a linearization technique called baseband digital predistortion. The new algorithm differently processes the samples depending on their power. Predistortion improvement is studied in simulation on a class A PA and then applied on a 50W peak power GaN PA with a 64QAM OFDM signal. Simulations and measurements show an improvement of the out-of-band linearity performance with very slight in-band linearity degradations[3].

Kim, Y. et. Al propose an adaptive digital pre-distortion (DPD) linearization based on an affine projection (AP) algorithm for WCDMA power amplifier applications. The performance of the affine projection algorithm is compared with the least-mean-square (LMS) algorithm and recursive-least-square (RLS) algorithm, respectively. From the compared results, the AP algorithm has the advantage of more efficient computational complexity than the other algorithms and also the convergence speed of the AP algorithm is faster than that of the LMS algorithm. An affine projection algorithm based DPD has been simulated and compared with a DPD using LMS and RLS algorithms, respectively[4].

Qingyun Dai et. Al proposed a new technique, based on the pre-distortion principle for linearizing a power amplifier, which is modeled by a Wiener model. The Wiener model is used to take into account the nonlinearities and the memory effects of the power amplifier. He also propose an efficient and original method for extracting the parameters of the power amplifier's Wiener Model. Simulation results have been provided for showing the performances of this technique [5].

RF linearization and digital predistortion have been shown to be effective at counteracting the distortion due to the non-linear behavior of high-power amplifiers operating near the power-efficient saturation point. The low cost and simple implementation of digital predistortion has made it a highly desirable alternative to expensive and power hungry RF linearizers. A digital predistorter scales and rotates the input samples based on the samples' magnitude. The adjustment coefficient depends on the amplifier nonlinearity. These coefficients can be obtained directly by measuring the amplifier characteristics with a network analyzer. The coefficients can also be arrived at by adaptively adjusting an initial estimate such that an error metric is minimized. The error metric is typically the difference between the transmitted and the received samples. The adaptation is accomplished using a standard gradient descent algorithm such as least mean squares (LMS). Traverso, S et. Al present measurement results comparing the two approaches. The measurements were performed for a space-qualified traveling wave tube amplifier (TWTA). We show that the adaptive approach provides better frequency domain performance (shoulder reduction). However, the improvement in signal to noise ratio and bit error rate is almost identical for the two approaches [6].

CONCLUSION

The proposed review work presents the thorough study of the existing linearization techniques for power amplifiers in communication system. Based on the merits and demerits of the existing techniques, an improved methodology for low cost, high efficiency and high degree of linearity power amplifier design is presented in the proposed thesis work.

The proposed thesis work focuses on the Modeling of Input Signal System as Test Input with open parameters like freq., phase and amplitude and Implementation of modified LMS Adaptive Algorithm for linearizing the o/p of the amplifier. Thermal noise is modeled as Gaussian noise, the most random in nature and is made input along with the input signal. A modified least mean square adaptive filter is proposed to extract the input signal at the output with faithful amplification.

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