Optimization and Linearization of the Power Amplifier

Mridula
Research Scholar, ECE Department, Punjabi University, Patiala (Pb)- India

Dr. Amandeep Singh Sappal
Assistant Professor, ECE Department, Punjabi University, Patiala (Pb)- India

ABSTRACT
The power amplifier is an important part of mobile communication, thus it should give ideal linear and amplified output but due to noise and internal memory effect, it generates non linear output. It is observed that filtering doesn’t eliminate all the nonlinearities. This paper highlights the nonlinearity effect and the ways to remove this in the power amplifier.

Keywords
Power Amplifier; feedforward linearization; feedback linearization; digital predistortion

INTRODUCTION
As the mobile communication has taken its toll in the daily life, the complexity of the devices and wireless protocols create an high demand for linear radio frequency (RF) parts and systems. These ubiquitous wireless devices require high performance test systems to characterize linearity. The requirement of linearity performance has become a characteristic feature of the wireless communication as it affects various parameters like power efficiency, channel density, coverage area and adjacent channel power ratio (ACPR).

The requirement of higher data rates, better spectral efficiency and cost reduction has induce a path towards linear modulation methods such as quadrature phase shift keying (QPSK), quadrature amplitude modulation (QAM), wideband code division multiple access (WCDMA), and orthogonal frequency division multiplexing (OFDM).[1] This results in a complex signal with a non-constant envelope and a high peak-to-average power ratio. Such characteristic makes these signals very sensitive to the intrinsic non-linearity of the radio frequency (RF) power amplifier (PA) in the transmitter as shown in figure 1.

![AM-AM Characteristics of a PA](image)

The non-linearity at the output is also due to the memory effect of PA as practically all wideband PAs exhibits memory. [2] The memory effects are due to thermal constants of the active devices in the biasing network that have frequency dependent behaviors. Thus the current output of the PA depends on the current input as well as the previous input values. So, a linearizer is required to remove the memory effects of Power amplifier.
OPTIMIZATION OF POWER AMPLIFIER

Non-linear signal processing algorithms have been growing interest in recent years. Numerous researchers have contributed to the development and understanding of this field. To describe a polynomial non-linear system with memory, the Volterra series expansion has been the most popular model in use for the last three decades.

Memory Polynomial model consists of several delay taps and non-linear static functions. This model is a truncation of the general Volterra series, which consists of only the diagonal terms in the Volterra kernels. Thus, the number of parameters is significantly reduced compared to general Volterra series. The Memory Polynomial model can be described as:

\[
y(n) = \sum_{q=0}^{Q} \sum_{k=1}^{K} c_{k-1.q} |x(n-q)|^{2(k-1)} x(n-q)
\]

where

- \( x(n) \) is the input complex base band signal
- \( y(n) \) is the output complex base band signal
- \( c_{k,q} \) are complex valued parameters
- \( Q \) is the memory depth
- \( K \) is the order of the polynomial

The calculation of \( c_{k,q} \) is a tedious task. Several approaches has been proposed in literature for proper identification of these parameters. But optimization techniques can be explored for identifying these parameters with better PA linearization. [3] The Optimization is necessary to obtain the best result under given circumstances. In design, construction and maintenance, we have to take many technological and managerial decisions at several stages to minimize the effort required or to maximize the desired benefit. [4,5]

The classic PA linearization techniques are Boot Up Bias, Dynamic Bias, Baseband Envelope Feedback, Polar Feedback, Cartesian Feedback, Envelope Elimination and Restoration, Adaptive Feed forward, radio frequency (RF)/intermediate frequency (IF) pre-distortion and digital pre-distortion technique. [6,7,8,9] The better technique along all other technique is digital predistortion due to its increased efficient and better linearity. [10]

DIGITAL PREDISTORTER AND ITS PERFORMANCE

The Digital predistortion (DPD) method uses the digital processing to generate the inverse transfer characteristic of a PA.

![Digital predistorter](Fig 2: Digital predistorter)

The DPD technique changes the baseband signal to a intermediate frequency which further mixed with a local oscillator. The IF frequency can also be generated using an Analog Quadrature Modulator (AQM). The DPD has a look up table or register table which stores the parameters with adaptive feedback. The Predistortion
scheme provides both amplitude and phase correction by working on the orthogonal I and Q components of the input and the feedback signals.[11]

The Predistorter should update the lookup table to cope up the changes in power, frequency; temperature and aging otherwise there will be degradation in IMD time. The digital predistortion technique is shown in the figure 2. The concept of predistortion is the insertion of nonlinear signal between the input signal and PA[12]. If it is known how a signal will be distorted during the transmission, it can be anticipated while creating the opposite signal at the predistorter.

Mathematically the output of digital predistorter can be written as [13]

\[ V_{\text{pred}}(t) = a_1 v(t) \cos(\omega t) + a_3 v(t) \cos(\omega t + \theta_3) + a_5 v(t) \cos(\omega t + \theta_5) + \ldots \] 

(2)

Where \( \theta_3, \theta_5, \theta_7 \ldots \) are the 3rd, 5th and 7th order phase distortion, respectively.

\( a_1, a_3, a_5 \ldots \) are the nonlinearity coefficients.

The equation can be further filtered to

\[ V_{\text{pred}}(t) = a_1 v(t) \cos(\omega t) + \frac{3}{4} a_3 v^3(t) \cos(\omega t + \theta_3) + \frac{5}{8} a_5 v^5(t) \cos(\omega t + \theta_5) + \frac{35}{64} a_7 v^7(t) \cos(\omega t + \theta_7) \ldots \]

(3)

The output of power amplifier can be written as

\[ V_{\text{out}}(t) = m_1 V_{\text{pred}}(\omega t) + m_3 V_{\text{pred}}^3(\omega t + \phi_3) + m_5 V_{\text{pred}}^5(\omega t + \phi_5) + \ldots \]

\[ = m_1[a_1 v(t) \cos(\omega t) - \frac{3}{4} a_3 v^3(t) \cos(\omega t + \theta_3) - \frac{5}{8} a_5 v^5(t) \cos(\omega t + \theta_5) - \frac{35}{64} a_7 v^7(t) \cos(\omega t + \theta_7) + \ldots + m_3[b_1 v(t) \cos(\omega t + \phi_3) - \frac{3}{4} b_3 v^3(t) \cos(\omega t + \theta_3 + \phi_3) - \frac{5}{8} b_5 v^5(t) \cos(\omega t + \theta_5 + \phi_5) + \frac{35}{64} b_7 v^7(t) \cos(\omega t + \theta_7 + \phi_7) + \ldots \]

(4)

From the above equation(4), it is clear that the coefficient can be rearranged in such a way so that the third order, fifth order and further higher order nonlinear distortion can be zeroed.

CONCLUSION AND FUTURE SCOPE

It is clear that the digital predistortion technique is very efficient but at the cost of its high complexity and cost for the lookup table and adaptive algorithm. The future scope for digital predistortion is the implementation of improved adaptive algorithm with a balance of complexity and efficiency.

REFERENCES


