International Journal of Electronics Engineering Research.
ISSN 0975-6450 Volume 9, Number 6 (2017) pp. 883-887

http://www.ripublication.com

Nonlinearities in Power Amplifier and its Remedies

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Abstract

Linearity performance has become a important parameter as it affects power efficiency, channel density, signal strength, and adjacent channel power ratio. To maintain high efficiency, PAs should be operated at their output saturation regions but this could not results into high bandwidth-efficiency for a single-carrier as well as multi-carrier high-order quadrature amplitude modulation (QAM) signals and orthogonal frequency division multiplexing (OFDM) signals. It is therefore very important to compensate the nonlinearity of the power amplifier (PA) in the design of a mobile system. There are many techniques for power amplifier linearization. This paper reviews these linearization techniques.

Keywords: Power Amplifier; adjacent channel power ratio; feedforward linearization; feedback linearization; digital predistortion

I. INTRODUCTION

As wireless communication becomes widespread, the increased complexity of the devices and wireless protocols create an unrelenting demand for linear radio frequency (RF) components and systems. These ubiquitous wireless devices require high performance test systems to characterize linearity. Linearity performance has become a defining characteristic as it affects power efficiency, channel density, signal coverage, and adjacent channel power ratio (ACPR).

The emphasis on higher data rates, spectral efficiency and cost reduction has driven the field towards linear modulation techniques such as quadrature phase shift keying (QPSK), quadrature amplitude modulation (QAM), wideband code division multiple access (WCDMA), and orthogonal frequency division multiplexing (OFDM)[1]. The result is a complex signal with a non-constant envelope and a high peak-to-average power ratio. This characteristic makes these signals particularly sensitive to the intrinsic non-linearity of the radio frequency (RF) power amplifier (PA) in the transmitter. The non-linearity will generate inter-modulation (IMD) components, also referred to as out-of-band emission or spectral re-growth, which interfere with adjacent channels. Such distortion, or so called Adjacent Channel Interference (ACI). Meanwhile, the nonlinearity also causes in-band distortion which degrades the bit error rate performance.

High power amplifier (HPA) is an indispensable component for any wireless communication system. To achieve high energy-efficiency, PAs should operate at their output saturation regions but this operational mode could not accommodate high bandwidth-efficiency single-carrier high-order quadrature amplitude modulation (QAM) signals as well as multi-carrier orthogonal frequency division multiplexing (OFDM) signals. It is therefore critical to compensate the nonlinearity of the power amplifier (PA) in the design of a wireless system.The non-linearity at the output is also caused by 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 present as well as the past input values. So, a linearizer should be designed to overcome the memory effects of PA also. Typically, the required linearity can be achieved either by reducing power efficiency or by using linearization techniques.

II. REMEDIES FOR POWER AMPLIFIER NONLINEARITIES

Literature survey is done on various PA linearization techniques and effects of predistortion techniques. The classic PA linearization techniques like 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 have some advantages over the other and some limitations also.

Boot Up Bias Technique is the most simplest way to improve the linearity and to drive the amplifier toward Class-A operation. The PA operates in the small signal linear region and decreases the corresponding out-of-band emission level. But this method has low efficiency and output power. In [3] the Dynamic Bias method has been used. This method requires a fast speed wideband envelope detector and a

DC-DC converter with high current capability but results in undesired phase distortion due to large changes in the bias level at a higher power level. Although this problem could be improved by using a phase feedback loop [4]. In Baseband Envelope Feedback Technique, the baseband signal is modulated onto the RF carrier and amplified by the PA, and output is demodulated and added to the input which further gives linearized output. The main disadvantage of Baseband Envelope Feedback Technique is the narrow bandwidth and high complexity and also the loop bandwidth must be within the MHz range to maintain stability. Polar Feedback scheme provides relatively high efficiency since the PA can operate completely non-linearly and this method will be robust since it has both amplitude and phase are corrected with the feedback. This technique is better as compared to envelope feedback as it reduces AM-PM distortion effects. For a narrowband application, the improvement in two-tone IMD is typically around 30 dB [5]. The polar feedback has a poor overall performance as it require different bandwidths for the amplitude and phase feedback paths, which further need improvement of the AM-AM and AM-PM characteristics.

In Cartesian Feedback [6] the I and Q components modulate the carrier before sending it to RF PA which is non-linear but efficient. The main advantages of Cartesian feedback over polar feedback is that it require lesser bandwidth (few megahertz) for the feedback loop thus resulting low IMD (10-30 dB of improvement) and easy to implement. Also the linearizing bandwidth is 5-10 times larger than the channel bandwidth [7]. It also reduces drifts in amplifier and non-linearities due to variations in temperature and power supply. But the main disadvantage of this scheme is the narrow bandwidth, difficulty of maintaining stability and the non-linearities of the down converting mixers.

In the Envelope Elimination and Restoration (EER) linearization, [8] a constant amplitude phase signal is generated by eliminating the envelope of input is by a limiter but the magnitude is extracted by an envelope detector. Then both magnitude and phase are amplified separately and recombined using high efficiency switched-mode RF PA for the desired RF output. This method is efficient but has leakage in ac power and slows due to feedback loop. It also require phase modulation to avoid phase variations. Practically, the dynamic range of EER is 20-30 dB.

Adaptive Feed forward Technique was invented as means of distortion reduction in telephone repeaters[9]. Feed forward linearization can improve performance up to 20dB-40 dB over a wide range of bandwidth (3 MHz-50 MHz) with the advantage of inherent stability[10]. The main disadvantage is the amplitude and phase matching as the temperature and time changes, the amplifier characteristics also changes. The manufacturing tolerances also lead to change the characteristics. A DSP processor can be used at this point to implement the adaptive algorithm [11]. RF/IF

Predistortion technique has a Predistorter with a preceding nonlinear PA which gives the inverse transfer characteristics of the PA. It is not a feedback loop system as the earlier techniques. There are many predistortion techniques in literature. Some networks use non-linear devices to input, while other networks curve-fit the distortion characteristics of the PA. The RF Predistorter linearize the entire bandwidth of the PA, while the IF Predistorter can work upon a range of carrier frequencies by changing the Local Oscillator (LO) frequency.

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

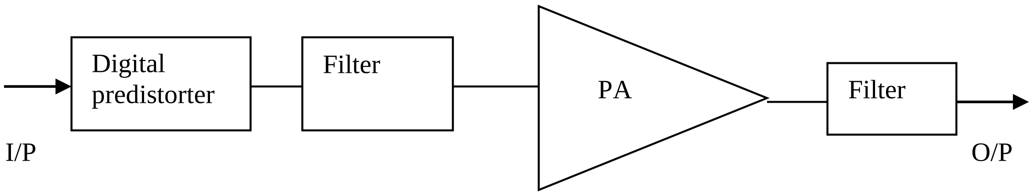

Fig. 1 Digital Predistortion Technique to linearize Power Amplifier

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.

III. CONCLUSION

The discussed linearization techniques has a tradeoff between efficiency, complexity and cost. The additional hardware also need more delay lines to compensate the synchronization of additional inputs. The digital predistorter technique is better among the othersbut also need additional circuitry and complexity but the adaptive algorithm can be made more efficient to give high efficiency power amplifier.

REFERENCES

[1] Fadhel M. Ghannouchi, Oualid Hammi, Mohamed Helaoui-Behavioral Modelling and Predistortion of Wideband wireless Transmitters-Wiley, 2015.

[2] Amandeep Singh Sappal, Dr. Manjeet Singh Patterh and Dr. Sanjay Sharma

(2011) Fast Complex Memory Polynomial Based Adaptive Digital Pre-Distorter. *International Journal of Electronics, (Taylor and Francis).* 98(7). pp 923-931.

[3] Cripps, Steve C. *Advanced techniques in RF power amplifier design*. Artech House, 2002.

[4] Sowlati, T., Greshishchev, Y. and Salama (1997). Phase Correcting Feedback System for Class-E Power Amplifier. *IEEE Journal Solid-State Circuits*, *32*(4). pp 544-550.

[5] Raab, F.H. and Asbeck, P. (2003) *RF and Microwave Power Amplifier and Transmitter Technologies.* High Frequency Electronics. pp 46-54.

[6] Petrovic, V. (1983) Reduction of Spurious Emission from Radio Transmitters by Means of Modulation Feedback. *Proceedings of IEEE Conference on Radio Spectrum Conservation Techniques.* pp 44-49.

[7] Cardinal J.S. and Ghannouchi, F.M. (1995) A new Adaptive Double Envelope Feedback (ADEF) Linearizer for Solid State Power Amplifier. *IEEE Transactions on Microwave Theory and Techniques, 43(7)*. pp 1508-1515.

[8] Kahn, L. (1952) Single-sided Transmission by Envelope Elimination and Restoration. *Proceedings IRE.* pp 803-806.

[9] Black, H.S. (1928) Translating System. *U.S.P.1.* pp 686-792.

[10] Kenington, P.B, Cope, M., Bennett, R. and Bishop, J. (2001) A GSM – EDGE High Power Amplifier Utilising Digital Linearization. *IEEE MTT International Microwave Symposium Digest*.

[11] Cavers, J.K. (1990) Amplifier Linearization Using a Digital Predistorter with Fast Adaptation and Low Memory Requirements. *IEEE Transactions on Vehicular Technology*, *39(4)*. pp 374-382.