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Design of Digital Predistortion Technique for RF Power Amplifier using Memory Polynomial

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ABSTRACT
Linearization of power amplifier has been an area of intense research from the last many years. The various types of linearization techniques are available for linearising PA but Digital Predistortion technique has been observed as one of the most common and effective method. But due to the issues like memory effects and exact characterization of non-linear behaviour of power amplifier, the implementation of existing predistortion technique suffers. So in this paper, a digital predistorter based on memory polynomial has been proposed that takes care of above mentioned issues. The presented technique is easy to implement and simple.

Keywords - AM/AM characteristics, Digital Predistortion (DPD), Memory polynomial, Power Amplifier (PA), Power Spectral Density (PSD).

I. Introduction

Now a days, wireless communication standards has focused on an intensive use of employing modulation schemes which require both high linearity and high efficiency power amplifiers to enhance spectrum efficiency and also to satisfy the increasing demand in transmission data rates. It is usually desirable to operate the PA near its saturation region in order to obtain high power efficiency; however, this means that nonlinear distortions are introduced at the output of the PA, which are undesirable specially when the input signal has a varying amplitude. Therefore a trade-off between the efficiency and linearity is always there. Non-linearity not only causes distortion but also degrades the bit error rate (BER) performance of power amplifier. To achieve both the high efficiency and the high linearity simultaneously in power amplifier design, is the most challenging task. Therefore, linearization of nonlinear power amplifiers has gained significant interest.

Many techniques are available to compensate the nonlinearities of PA but among these DPD method is of more concern as it provides high efficiency and good linearity. Different types of predistortion techniques have been proposed earlier, but they are complex to implement.

So in this paper a digital predistorter using a memory polynomial has been proposed, which is simple and easy to implement.

The organization of the paper is as follows: Section 1 is Introduction, Section 2 presents proposed digital predistortion technique and Section 3 presents simulation results. Finally, a conclusion is drawn in Section 4.

II. Proposed Digital Predistorter

Pre-distortion technique is one of the most efficient linearization techniques.

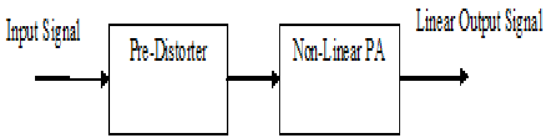

Fig. 1 Predistortion Technique

It consists of a pre-distorter which proceeds the nonlinear power amplifier and has inverse transfer characteristics of that of the power amplifier. Thus makes the overall amplification of system nearly linear.

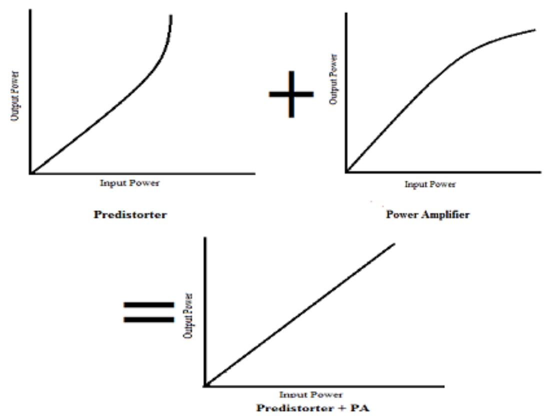

Fig. 2 Basic Steps of Pre-Distortion Technique

The pre-distortion technique (DPD) has high efficiency, adaptive ability and good Inter Modulation suppression. As it is operated before the power amplifier, which means the signal processing does not consume large power.

General Volterra series has better capabilities to model power amplifier's memory effects and its non-linearities. But it has a disadvantage of implementation complexity. Thus memory polynomial model which is a reduced form of Volterra Series consists of several delay taps and nonlinear static functions. Thus the number of parameters is significantly reduced as compared to general Volterra series. The following equation represents memory polynomial model

$$y(n) = \sum_{q=0}^{Q} \sum_{k=1}^{K} c_{2k-1,q} |x(n-q)|^{2(k-1)} x(n-q) \quad (1)$$

Where,
x(n) is input complex baseband signal
y(n) is output complex baseband signal
$C_{k,q}$ are complex valued parameters
Q is memory depth
K is order of polynomial

To find the output of the proposed digital predistorter, the least square (LS) algorithm has been used. The outline of the algorithm is described below:

To calculate the output (Y) of predistorter, the coefficients (C) of the pre-distorter and the input (X) to predistorter in the form of matrices are first defined as shown below:

The complex coefficients of the pre-distorter can be represented as

$$C = [c_0 \; \dots \; c_q \; \dots \; c_Q]^T \quad (2)$$

Where

$$c_q = [c_{1,q} \; \dots \; c_{3,q} \; \dots \; c_{2k-1,q}] \quad (3)$$

And
the input to the pre-distorter can be represented as

$$Z = [Z_0 \; \dots \; Z_q \; \dots \; Z_Q] \quad (4)$$

using

$$Z_{2k-1}(n) = |x(n-q)|^{2(k-1)} x(n-q) \quad (5)$$

Let the output of the pre-distorter can be represented as

$$Y = [y(n) \;\; y(n+1) \dots \;\; y(n+N+1)]^T \quad (6)$$

y(*n*) represents the output data elements.
N represents the size of output data
Then the following matrix equation can be used to find the output of the predistorter

$$Y = Zc \quad (7)$$

III. Simulation Results

The proposed digital pre-distorter has been implemented in MATLAB software. The signal used for the experiment is WCDMA. To calculate its coefficients using MATLAB, a simple and easy to implement method has been proposed.

By using the calculated data, the AM/AM characteristics of the actual power amplifier, pre-distorter and the linearized power amplifier has been calculated and then plotted as shown in figures below:

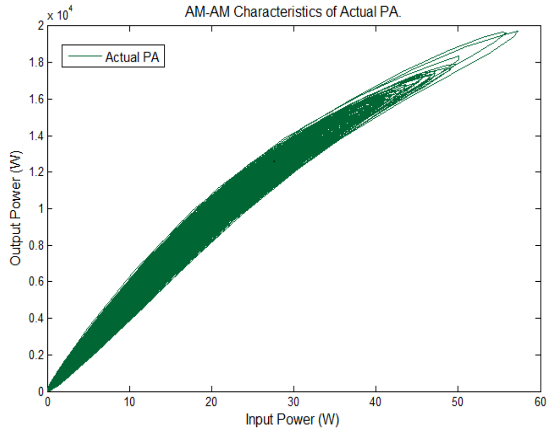

Fig.3 AM/AM Characteristics of Actual PA.

From above fig. 3 it can be seen that at higher input levels the power becomes non-linear.

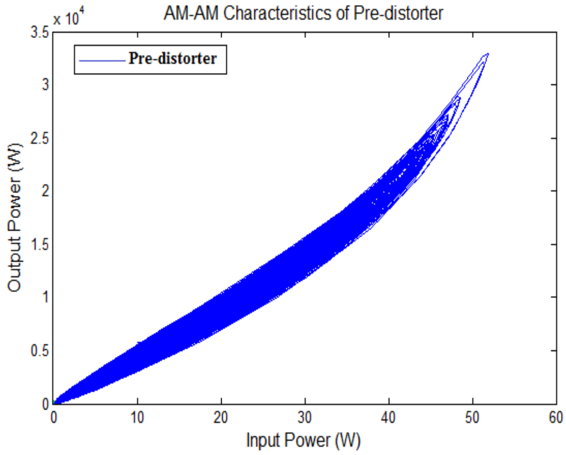

Fig. 4 AM/AM Characteristics of DPD.

Fig. 4 shows that the predistorter is having inverse characteristics as that of non-linear power amplifier.

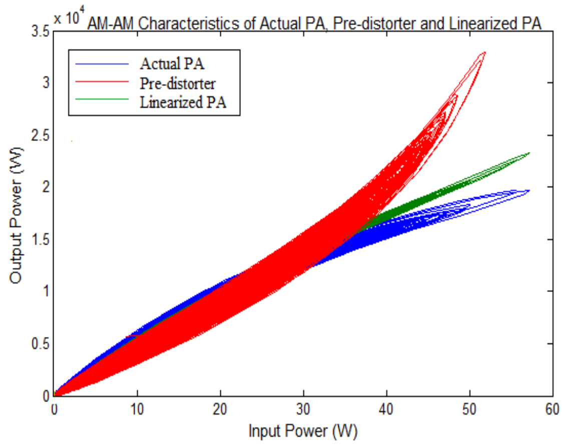

Fig. 5 AM/AM Characteristics of Actual, Predistorter and Linearized PA.

From fig. 5, it can be observed that the linearized power amplifier's output is perfectly linear.

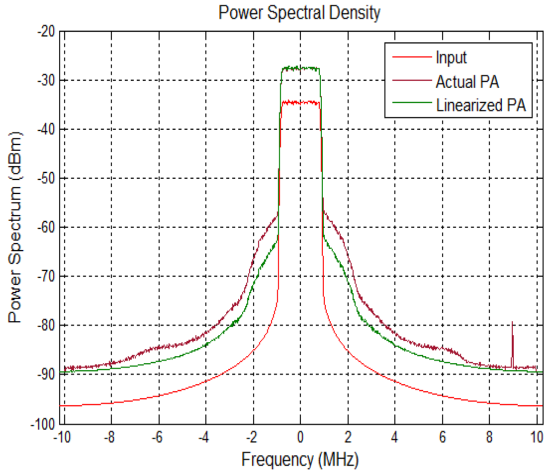

Fig. 6 Power Spectral Density of Input, Actual PA and Linearized PA

From fig. 6 it can be observed that the spectral regrowth of linearized power amplifier is less than that of actual power amplifier.

Table 1 Comparison of ACPR Improvement

Power Amplifier	ACPR (dB) at different frequencies					
	-6 MHz	-3.25 MHz	-1.75 MHz	1.75 MHz	3.25 MHz	6 MHz
Actual PA	-54.6137	-39.7490	-30.2695	-29.1170	-39.4203	-54.9440
Linearized PA	-63.1954	-45.4060	-36.2855	-35.1692	-45.3368	-64.3911

Table 2 Comparison of EVM Improvement

Power Amplifier	EVM
Actual PA	1.4221
Linearized PA	1.2827

From the above comparison, it has been observed that the proposed digital pre-distorter using memory polynomial has shown large improvement in both ACPR and EVM as compared to actual power amplifier.

IV. Conclusion

In this paper, a predistortion technique based on memory polynomial has been proposed. It has low hardware complexity and can be implemented unconditionally stable. *The proposed linearization technique has shown approximately 20% improvement in ACPR and about 10% improvement in EVM as compared to actual power amplifier.* Hence it can be concluded from the simulation results that the proposed linearization technique has produced better linear output than that of actual power amplifier.

References

[1] Amandeep Singh Sappal, Dr. Manjit Singh and Dr. Sanjay Sharma, "*Fast complex Memory Polynomial based Adaptive Digital Pre-Distorter*", International Journal of Electronics, Vol. **98**, No.7, Page, 923-931, July 2011.

[2] Amandeep Singh Sappal, Dr. Manjit Singh and Dr. Sanjay Sharma, "*Power amplifier Linearization using Digital Predistortion*" International e-Journal of Communication and Electronics, Volume 2, January 2009.

[3] Andrea, A.N., Lottici, V. and Reggiannini, R.(1996) RF Power Amplifier Linearization through Amplitude and Phase Predistortion. *IEEE Transactions on Communications*, *44*:1477-1484.

[4] Ding L., "Digital Predistortion of Power Amplifiers for Wireless Applications", *Ph.D thesis, Georgia Institute of Technology*, March 2004.

[5] Jeckeln, E.G. and Beauregard, F. (2000), "Adaptive Baseband/ RF Pre-distorter for Power Amplifiers through Instataneous AM-AM and AM-PM Characterization using Digital Receivers", *IEEE MTT International Microwave Symposium Digest, 2000.*

[6] Namiki, J. (1983), "An Automatically Controlled Predistorter for Multilevel Quadrature Amplitude Modulation", *IEEE Transactions on Communications, COM-31(5).*

[7] Ren, Q. and Wolff, I. (1997), "Improvement of Digital Mapping Pre-distorters for linearising transmitters", *IEEE Transactions on Microwave Theory and Techniques.*

[8] Ruchi Pasricha and Dr. Sanjay Sharma, "Modeling of a Power Amplifier for Digital Pre-Distortion Applications using Simplified Complex Memory Polynomial" Appl. Math. Inf. Sci. **7**, No. 4, 1519-1524(2013).