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Modeling of RF Power Amplifier with Memory Effects using Memory Polynomial

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ABSTRACT
Power Amplifier is one of the most important component in a communication system. It is inherently non-linear and having memory effects. But current communication systems require highly linear response as nonlinearities contribute to gain compression and produce harmonic distortion. But for linearization of power amplifier, it is necessary to model PA's memory behavior accurately. So in this paper, a memory polynomial based power amplifier model is presented which takes into account its memory effects for wideband applications. This paper also presents a comparison of proposed model with actual RF power amplifier in terms of power spectral density and AM/AM characteristics. Simulation results shows its efficiency and accuracy.
***Keywords* -** AM/AM characteristics, MATLAB, Memory Effects, Memory polynomial, Power Amplifier (PA).

I. Introduction

Power amplifier is an indispensable component in a communication system. RF power amplifier is used to raise the power level of signal during transmission of the signal. For achieving good power efficiency, PA should work around its saturation point. But due to compression behavior of the power amplifier operating in its saturation region, the response is highly non-linear. The nonlinearities broadens the input signal bandwidth [4].This is known as spectral re-growth which is undesirable since it causes interference with adjacent channels. When the output of PA depends on current input of amplifier as well as on previous input, then it is called memory effect. This occurs due to broadband nature of the signals and attributed to thermal constants of active devices or components in biasing network that are having frequency dependent behavior. So, a model that takes into account both the nonlinearities and memory effects must be used to accurately model the power amplifier's distortion. Therefore a memory based polynomial is used to model the RF power amplifier that takes care of above mentioned issues.

The organization of the paper is as follows: Section 1 is Introduction, Section 2 presents a memory based polynomial model of power amplifier. Section 3 presents simulation results. Finally, a conclusion is drawn in Section 4.

II. Memory Polynomial Model

The memory polynomial consists of several delay taps and nonlinear static functions. This model is a truncation of 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 [5]. The equation (1) represents memory polynomial model

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

Where,

x(n)= input complex baseband signal

y(n)=output complex baseband signal

$C_{k,q}$=are complex valued parameters

Q=memory depth

K=order of polynomial

For simplicity of implementation [1], the equation (1) can be rewritten as follows

$$y(n) = \sum_{i=0}^{n} Fq(n-q) \tag{2}$$

$$=F_0(n)+F_1(n-1)+F_2(n-2)+F_3(n-3)+\cdots\cdots+F_Q(n-Q) \qquad (3)$$

where

$$F_q(n)=\sum_{k=1}^{K} C_{2k-1,q}|x(n)|^{2(k-1)}x(n) \qquad (4)$$

In its expanded form, equation (4) can be written as

$$F_q(n)=C_{1,q}x(n)+C_{3,q}|x(n)|^2x(n)+C_{5,q}|x(n)|^4x(n)+\cdots\cdots+C_{2K-1,q}|x(n)|^{2(K-1)}x(n) \qquad (5)$$

III. Simulation Results

The memory polynomial equation is implemented using MATLAB. The AM/AM characteristics and Power Spectral Density of actual and modeled power amplifier at different values of memory depth (Q) and order of polynomial (K) are plotted as under:

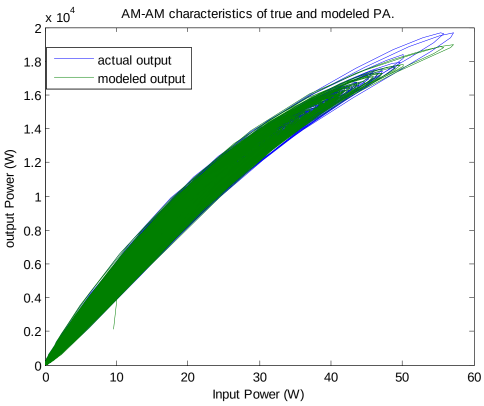
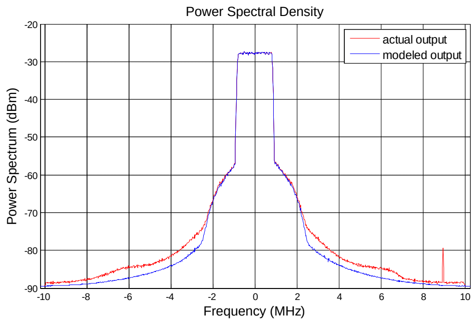
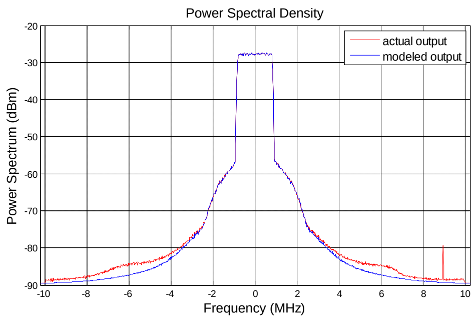


Fig.1: Comparison of AM/AM characteristics of actual and modeled PA

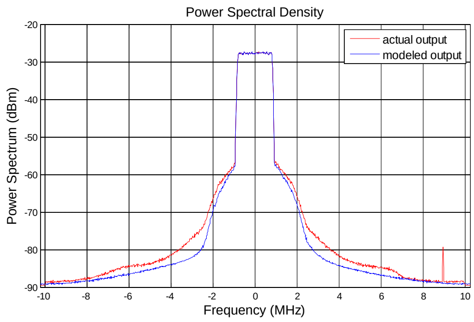
From Fig.1, it can be observed that memory polynomial model very closely approximate the actual behavior of power amplifier.



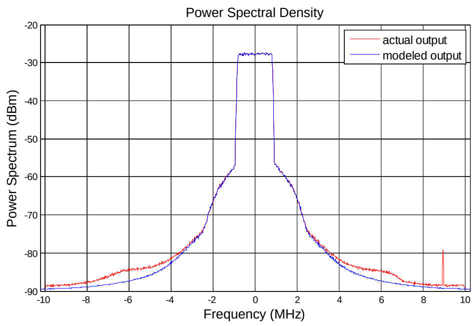
(a)



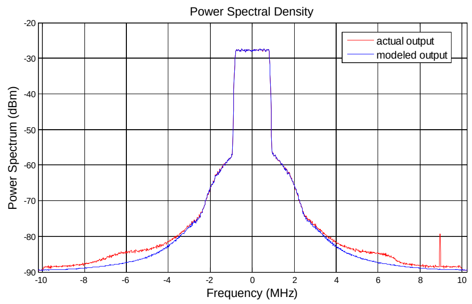
(b)



(c)



(d)



(e)

Fig. 2: Power spectral density (PSD) of actual and modeled PA showed for: (a) Q=2, K=3, (b) Q=2, K=5, (c) Q=3, K=2, (d) Q=3, K=5 and (e) Q=5 , K=5.

From Fig. (a) and (b) it can be observed that by keeping memory depth (Q) constant and increasing the order of polynomial (K) the response is very much close to the actual response and from Fig. (d) and (e) it can be observed that by keeping K constant and changing the value of Q, the output of modeled PA is not affected.

IV. Conclusion

For the implementation of any linearization technique, exact modeling of PA is an important issue. In this paper an easy and simple method using memory polynomial is implemented to model power amplifier and results of implementation have indicated its effectiveness. Using different values of memory depth (Q) and order of polynomial (K), outputs are calculated and plotted, which shows their comparison in terms of power spectrum. From simulation results, it can be observed that the proposed memory polynomial model has accurately modeled the behavior of the actual power amplifier with memory effects.

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