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Full Length Research Paper

Power amplifier- memory-less non linear modeling

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The power amplifier's nonlinearity broadens the input signal's bandwidth. This is known as spectral re-growth which is undesirable since it causes interference with adjacent channels. It also causes distortions within the signal bandwidth, which affects the bit error rate at the receiver. Most recent transmission schemes, such as wideband code division multiple access (WCDMA) or orthogonal frequency division multiplexing (OFDM), are especially vulnerable to the nonlinear distortions due to high fluctuations in their power levels. To ensure that linearity is maintained to a high degree, it is necessary to examine the nature of amplifier distortion. Audio amplifier distortion is of concern for many years. The conventional feedback techniques used at audio frequencies are not applicable to many RF amplifiers due to following problems: 1. Stability at high bandwidth.2. Cost for high gains in RF stages. Memory less or Instantaneous Nonlinear Model assumes that the PA has no memory effects, that is, it has no knowledge of past events and hence the present o/p signal is only a function of present i/p signal. The model is further simplified by restricting the analysis to signal and distortion contained within the first harmonic zone, such models are referred to as band pass memory-less nonlinear models and are further simplified since they do not need to model even order nonlinearities. A memory less nonlinear model can be modeled in polar (amplitude and phase) or Cartesian (I and Q) form.

Key words: Nonlinearity, memory-less, distortion, intermodulation.

INTRODUCTION

Memory-less modeling has been used for many years because of its generally easier computational implementation, its relative efficiency in system simulations and its acceptable level of accuracy in many situations. Historically, this approach has found particular favour in predicting intermodulation distortion problems in the robust multicarrier travelling-wave tube amplifiers (TWTAs) used in communication satellite transponders. Any memory-like effects will be those introduced by the channelizing demultiplexers on the input, which mainly result in multipath crosstalk effects, and by the zonal filters that are used on the output to remove especially harmonics but also out-of-band intermodulation products (IMPs).

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MEMORYLESS NONLINEAR MODELS

Memory-less nonlinear models are those in which the output envelope reacts instantaneously to variations in the input envelope. The paper discusses polar and Cartesian form of nonlinear models. Approximate forms of memory less nonlinear models are also discussed.

Polar form of memory less nonlinear model

This model treats the AM/AM and AM/PM components of nonlinearity as separate items and produces a model which is effectively a cascade of two processes. This model may be considered at two levels, namely, first by considering the effect of model on a single RF sine wave and secondly by extension of this to a modulated signal. For this, we consider a CW signal, c (t) at a frequency fc and with an amplitude A:

$$C(t) = A\cos(2\pi f_c t+\theta) \qquad \text{(i)}$$

The distorted o/p signal D (t) of a bandpass memory-less

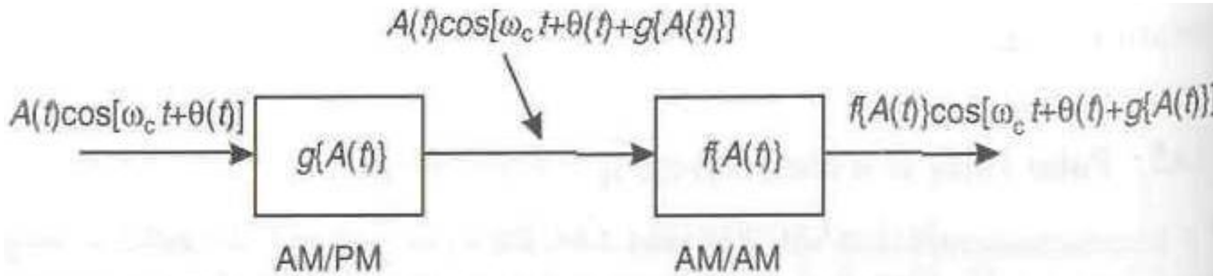


Figure 1. Polar form of envelope nonlinearity for AM/AM and AM/PM distortion.

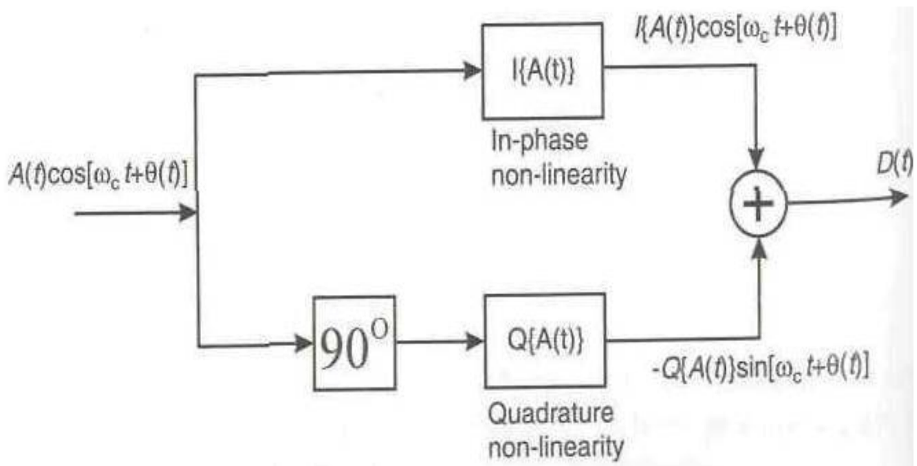


Figure 2. Cartesian form of envelope nonlinearity for AM/AM and AM/PM.

nonlinearity is given by Minkoff (1984) as:

$$D(t) = f(A)\cos[2\pi f_c t+\theta+g(A)] \quad \text{(ii)}$$

where f (A) describes AM/AM characteristics of the nonlinearity and g(A) describes its AM/PM conversion.

Work by Minkoff (1982, 1984) has shown that =n (i) and =n (ii) can be applied to modulated signals as well as to a single CW carrier. Thus:

$$C(t) = A(t)\cos[2\pi f_c t+\theta(t)]$$

where A (t) describes the envelope modulations present on carrier.

In regard to the memory-less model defined by Equation (i), the time instant on the right-hand side of the equation may be later than that on the left; the difference is equivalent to a group delay that is perfectly flat across the whole frequency band. The model can characterize envelope nonlinearities and can be used to describe the in band distortion of a signal containing some form of envelope variation. A block diagram of this form of envelope variation is shown in Figure 1.

In real systems there will be a finite group delay, inclusive of the propagation delay, and in many cases it would not be perfectly flat and thus represents a memory effect, which is large or small depending on the contributing factors. However, a perfectly flat group delay has no distortion effect in itself and so, in modeling, the delay can be set to zero, implying that the output at any instant is dependent only on the input at that same instant.

Cartesian form of memory-less nonlinear model

This model can be constructed from two nonlinear amplitude models I{A(t)} and Q{A(t)}.This model has an advantage that it avoids the potential complexity of AM/PM model. The distorted o/p from a bandpass memory-less nonlinearity may be expanded to give:

$$D(t)=f\{A(t)\}\cos[g\{A(t)\}]\cos[2\pi f_c t+\theta(t)] \quad \text{(iii)(Kuo, 1973)}$$

$$f\{A(t)\}\sin[g\{A(t)\}]\sin[2\pi f_c t+\theta(t)] \quad \text{(iv)(Larkin, 1991)}$$

This may be expressed in Quadrature components as:

$$D(t)=I\{A(t)\}\cos[2\pi f_c t+\theta(t)]-Q\{A(t)\}\sin[2\pi f_c t+\theta(t)]$$

where $I\{A(t)\}=f\{A(t)\}\cos[g\{A(t)\}]$ and $Q\{A(t)\}=f\{A(t)\}\sin[g\{A(t)\}]$

The Cartesian form of envelope non linearity for both AM/AM and AM/PM distortion can be represented diagrammatically as shown in Figure 2. The difference between the polar and quadrature descriptions is largely an algorithmic implementation difference. The IMPs within the zonal band may be limited by using graphed in dB backoff values (that is, IBO and OBO), which are relative to the input and output 'saturation' powers, corresponding here to the powers at the 1 dB compression point.

Approximate forms of memory-less nonlinear model

A number of simpler models involving more analytical functions may

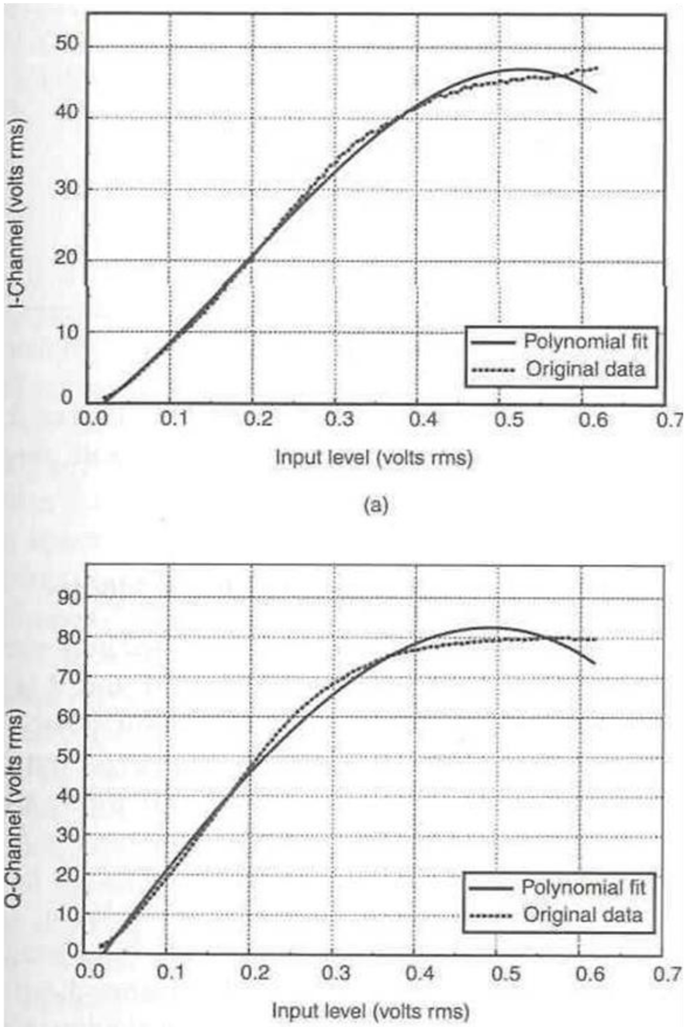


Figure 3. Cartesian form of envelope characteristics for a Class C amplifier.

be used to improve speed at the expense of model accuracy.

Saleh functions

Saleh functions (Saleh, 1981, 1982) are a simple method of approximating a nonlinear characteristic in either polar or Cartesian form. These functions have subsequently been applied to the problem of predistortion linearization of TWT amplifiers and the prediction of carrier to intermodulation ratios for multicarrier and Gaussian input signals. The basic concept of Saleh functions is to approximate the AM/AM and AM/PM characteristics of nonlinearity. These functions provide an accurate, yet simple, model for a bandpass memory-less nonlinearity. The Cartesian form of envelope characteristics for class C amplifier are shown in Figure 3.

Modified Saleh functions

Applying the Saleh model directly to SSPA devices can lead to problems. This may particularly arise with the AM–PM characteristic when the shape differs from those obtained for TWTAs, which generally are positive throughout and have a shape not too different from the AM–AM characteristic. This would explain the similarity of the models for TWTAs. The main difference is that the LDMOS characteristic has an inflection point and a negative-going curve that takes on zero and negative values with increasing input power. This causes optimization problems that result in ill-defined α and β parameters. Introducing a phase shift into the measurements (so that all AM– PM values are positive), an approach that is part of the new ‘modified Saleh’ model presented, does not solve the problem. The variability of the transfer characteristics of SSPAs, especially of the AM–PM characteristics, thus suggests a reconsideration of the Saleh model. Modifying the general Saleh model (Cripps, 2006) by the addition of two new parameters, an exponent γ and a phase shift ε, yields the generalized form for the ‘modified Saleh’ model;

$$z(r) = \alpha r\eta/(1 + \beta r\gamma)v - \varepsilon$$

For a given set of values (η, v, γ and ε), optimum values for (α, β) can be extracted from a measurement data set (z(r), r) of either the AM–AM or the AM–PM characteristics.

Taylor series

The concept involves describing the distorted output of the system D (t) in the form of Taylor series (Kuo, 1973; Larkin, 1991)of the input, v_{in} (t):

$$D(t) = \sum_{n=1}^{\infty} a_n v_{in}^{n}(t) \qquad (v)$$

where a_n is constant.

This form of model has the advantage that the relative level of each order of distortion is clear from its coefficient a_i and the level of each IMD product may therefore be calculated. It is useful for systems which contain few orders of distortion. A standard Taylor series as described by =n 5 will only characterize AM/AM distortion. If significant AM/PM distortion exists within a nonlinear device then a complex power series must be used:

$$D(t) = \sum_{n=1}^{\infty} (x_n + jy_n) a_n v_{in}^{n}(t) \qquad \text{(vi)(Saleh, 1982)}$$

An alternative is the use of two series, one representing the I characteristic and other representing the Q characteristic which is effectively a splitting of the terms in =n 6 and results in model of the form as shown in Figure 4.

RESULTS AND DISCUSSION

The equivalent memory-less characteristics of an LDMOS High-power PA is shown (Pasricha and Sharma, 2008) in Figure 5. These were extracted from measurements of an input and corresponding amplified output 3G (third generation) WCDMA signal.

Figure 6 depict the measurements that were taken on a three-stage class-AB PA with a Motorola 90W MRF 18090A LDMOS transistor in the final stage and having the following nominal characteristics: a frequency range1.93 to 1.96 GHz, maximum output power 48 dBm, 36 dB gain and a 1 dB output compression point of 53d Bm. The measurement setup allowed for an RF bandwidth of 35 MHz to be captured, within which a signal-to-noise ratio (SNR) of approximately 60 dB was achieved.

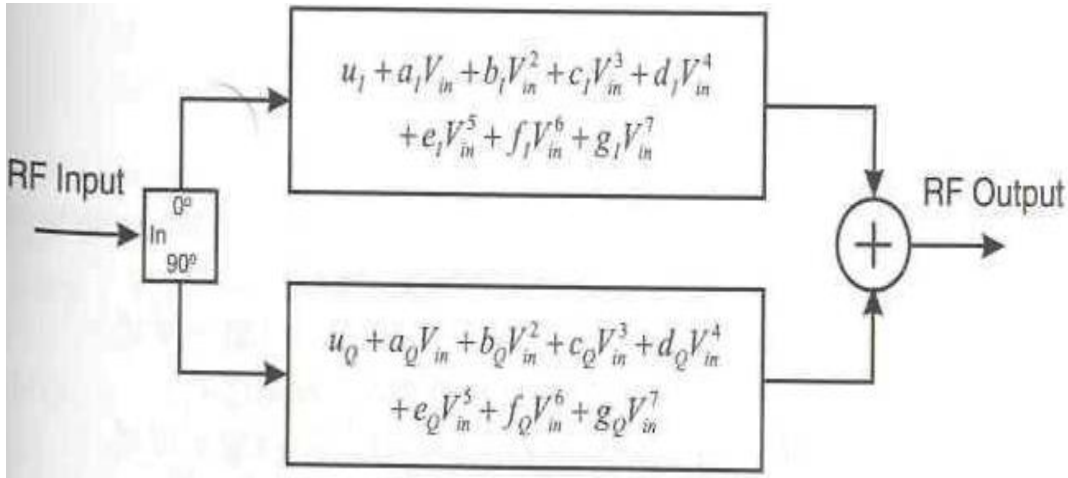
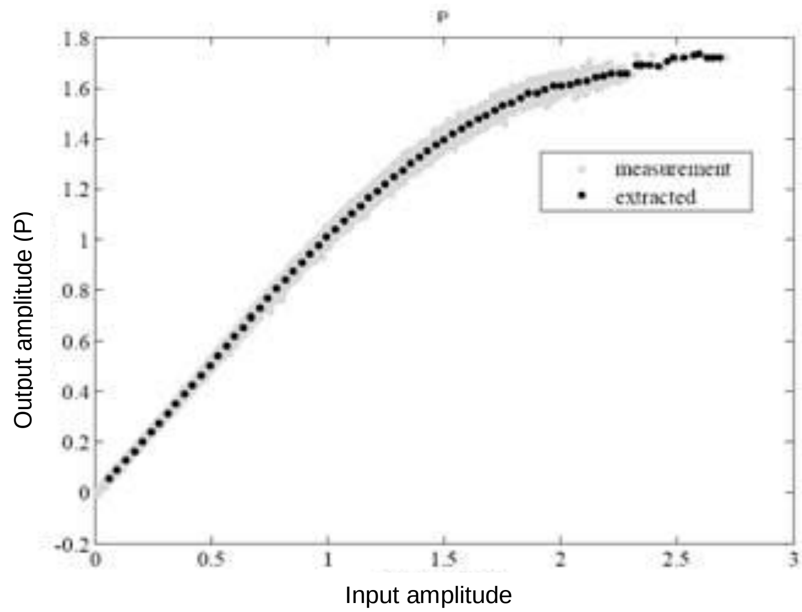
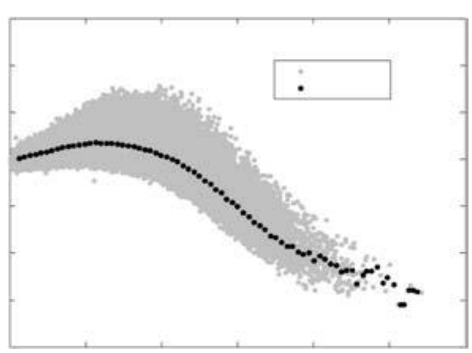


Figure 4. Diagramatic representation of power series



a



b

Figure 5. (a) The WCDMA signal measurements (grey); (b) extracted equivalent Memory-less quadrature characteristics (black dots) of an LDMOS PA: (a) in-phase component P and (b) quadrature component Q (for a PA at 5 dB IBO).

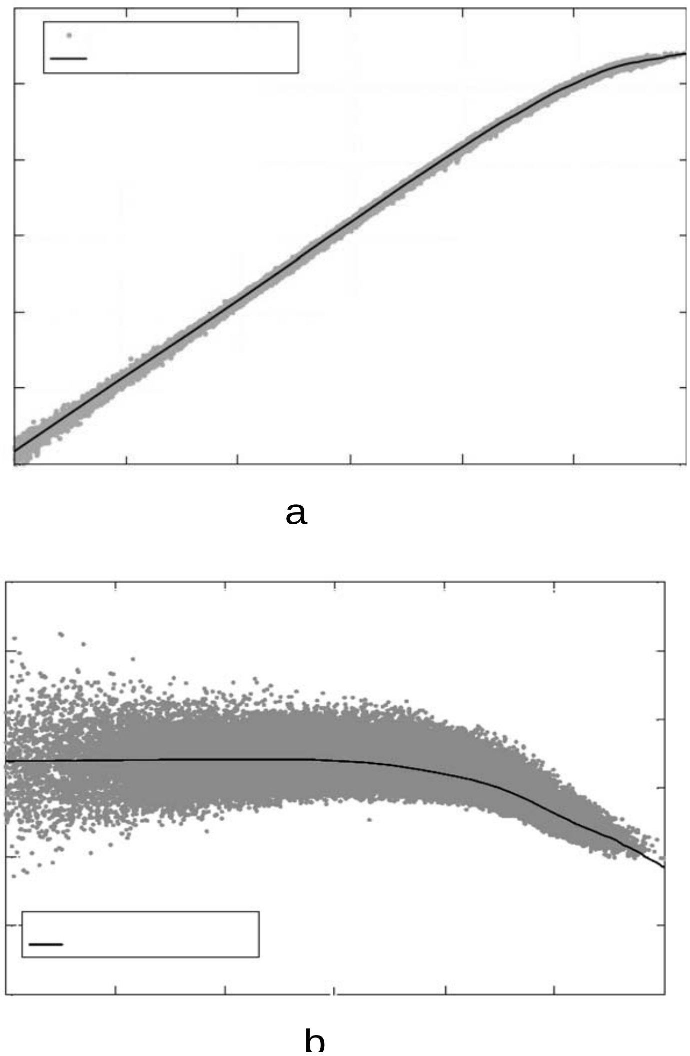


Figure 6. The LDMOS PA polar (a) AM–AM and (b) AM–PM measurements on the amplification of a WCDMA signal (at 5 dB IBO) and the extracted equivalent memoryless characteristics (Graphs of output amplitude with respect to input amplitude).

Conclusion

The design of memory-less nonlinear model to linearize power amplifiers was considered. The model assumes that power amplifiers have no memory effects, that is, it has no knowledge of past events and hence the present output signal is only a function of present input signal. The main advantage is the simplification of the model as they do not need to model even order nonlinearities.

REFERENCES

Cripps S (2006). RF Power amplifier for wireless Communication,2nd edition, Boston, Artech House.

Kuo Y (1973). Noise loading analysis of a memoryless nonlinearity characterized by a Taylor series of Finite order. IEEE Trans. Instrum. Meas., l. IM-22: 246-249.

Larkin R (1991). Multiple signal intermodulation and stability considerations in the use of linear repeaters. Prov. IEEE 41st Vehic. Technol. Conf., St. Louis, Missouri, USA, pp. 747-752.

Minkoff JB (1982). Intermodulation noise in solid-state power amplifiers for wideband signal transmission. Prov. A1AA 9th Communication Satellite System Conference.

Minkoff JB (1984). Wideband operation of nonlinear solid-state power amplifiers-comparisons of calculations and measurements. Bell. Syst. Technol. J., 63(2): 231-248.

Pasricha R, Sharma S (2008). Digital Predistortion in WCDMA power Amplifier using embedded processor. ICGST Int. J. Program. Dev. Circuits Syst., 3: 1-10.

Saleh AAM (1981). Frequency-Independent and frequency-dependent nonlinear models of TWT amplifiers. IEEE Trans. Commun. COM, 29: 1715-1720.

Saleh AAM (1982). Intermodulation analysis of FDMA satellite systems employing compensated and uncompensated TWT's. IEEE Trans. Communications. 30(5): 1233-1242.