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EVM & ACP ANALYSIS OF LMS FILTER FOR SALEH MODEL PA LINEARIZATION IN DIFFERENT PHASE SHIFT KEYING MODULATIONS

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ABSTRACT

The Power Amplifier plays the major role in boosting the message signal strength. The Memoryless non linearity nature of the Power amplifier varies according to its output power function. The nature of the amplifier can be difined by diffrent models. By this factor, PA has been classified in to diffrent types. Here we choosed Saleh model PA which is best suited for TWT type amplifers. To linearize the PA, Pre-distortion is one of the method used. Here we are going to use NLMS algorithm in Predistorter and evaluates its error estimating capability for saleh power amplifier model using diffrent Phase shift key modulation methods like BPSK, QPSK, 8-PSK,16-QAM. We measured ACP and EVM for the above modulations using Matlab software.

Keywords: *NLMS- Normalized Least Mean Square, PA- Power Amplfier, QAM- Quadrature Ampliture Modulation, BPSK- Binary Phase Shift Keying, QPSK- Quadrature Phase Shift Keying, PSK- Phase Shift Keying, TWT- Travelling Wave Tube, ACP – Adjacent Channel Power EVM – Error Vector Magnitude.*

1. INTRODUCTION

The Power amplifier plays a major role in modern digital communication system. Especially TWT types PA are used in Mobile Base Tran receiver Station, Satellite Transponders etc. Saleh Model is the best suitable mathematical model to explain the work function of TWT Amplifiers. Since we are using Spectral efficient modulation for the above applications. We are not bother about the power efficiency of the signal. When these spectral efficient Modulated signals are given as input, PA introduces harmonics and inter-modulation distortion which are known as Memoryless Non Linearity's. It can be clearly explained by [15] voltera series.

$$H_0 = a_1H_i + a_2H_i^2 + a_3H_i^3 + a_4H_i^4 + a_5H_i^5 + \ldots\ldots \quad (1)$$

$$H_i = H\cos\omega_1 t + H\cos\omega_2 t \quad (2)$$

Where H_i & H_0 are desired input and output signal and in the equation (1) explains the non linear nature of PA the odd power series are the inter-modulation distortion the even power series are the harmonics which is nothing but replica of the desired signal. A simple Band pass filter

Can be used to remove the Harmonics but to remove

Inter-modulation distortion is a biggest challenge since it is very adjacent to the tone signal. Especially IM3 which cause the self heating effect for the PA, which results in the Inter Carrier Interference and also the life time of the amplifier is reduced. To overcome these problems, there are three methods of linearization techniques are available 1. Feed Back Method 2.Feed Forward Method 3.Predistortion Method. In power Amplifier memory less non linear modeling there are several methods are available. Ghorbani model is the best suitable for designing of the solid state power amplifier but Ghorbani model is not giving the exact non linearity of TWT power

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amplifier. Saleh model is the best suitable model for RF microwave amplifier of TWT model.

We are going to brief the problem statement, related work and glimpse of our contribution in section 2. In section 3 we will brief about our work. We discussed the simulation results in section 4 and our final conclusion in section 5.

2. PROBLEM STATEMENT & RELATED WORK

In this section we designed the Predistorter and describe the problem statement and review related work.

2.1 Problem Statement

As specified in Section 1 there are some severe issues arises due to the Non linearity of the Power Amplifiers.

(1) There is no problem in removing the Harmonics distortion, but removing the Intermodulates is the huge task. If a two tone signal with frequency f_1 and f_2 is given as input to PA then IM3 arises at $2f_2 – f_1$ and $2f_1 – f_2$ in the output which is very adjacent to the desired signal.

(2) So there is increase of ACP which is the resultant of introduction of IM3 which cause inter carrier interference. This will affect the entire communication system setup.

(3) The Error vector Magnitude of the signal is also high when comparing the input signal and the non linear output. This results in the self heating effect of the amplifier which will reduce its working capability and its life term.

2.2 Related Work

In [1] Leulescu *et al.* done the linearization work using predistortion method using digital method. The linearization analysis done using the Digital filters (weiner). But they didn't discussed about the Spectral modulation used. They analyzed the output power and linearized power only. They didn't discussed ACP which is the main factor.

In [2] Zhang Peng *et al.* has done the linearization of the PA by Look Up Table method using quadrature non linear model. Here also they analyzed how to design the AM-AM distortion (Amplitude Distortion) and AM-PM distortion (Phase Distortion). They discussed only for the quadrature type modulation(QAM) only.

In [3], [4], [5] swaminathan *et al.* they discussed well about the ACP analysis of SSPA in different phase shift keying methods. But they didn't discussed about the EVM analysis for the SSPA and they didn't compared the results with other methods.and the other Existing methods like feed forward and feedback method..

3. ANALYSIS AND MODELING USING PREDISTORTION METHOD

To reduce the [4] IM3 distortion Pre-distortion method is one of the effective method used. By giving the input as H (n) to the PA the output will come as Y (n) which is non linear in nature .Here the Harmonics and inter modulates are introduced. The equation is given as

$$H(n).F(n) = Y(n) \quad \text{(Non Linear Output)} \quad (3)$$

Now the Y(n) will be given loop back and it will be compared with the input signal H (n) with a slight delay [3] and the error will be estimated using the pre-distorter. Here we used NLMS which is one of the fastest adaptive algorithms to estimate the error. Then estimated error e(n) is will be pre-distorted with the input H(n) and produce a pre-distortion function Z(n) . here Z(n) is designed in such a way that it will linearize Y(n). The Predistorter function will be given as input to PA to get the linear Y(n). The above process will be explain following equation.

$$H(n).e(n) = Z(n) \text{(Pre-distorter output)} \quad (4)$$

$$Z(n).\ F(n) = Y(n) \text{ or } H_{out} \quad (5)$$
(Linearized output)

The main advantage of using NLMS Pre-distorter instead of feed forward and feed back linearizer is highly cost effective and simple

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model. Feed forward and feedback types are costly and also made up of complex algorithm. Even though in feed forward spectral efficiency will be improved at its maximum but in Pre-distortion method both power and spectral efficiency is improved. Due to the low power back off the power efficiency can't be improved drastically in feed forward method.

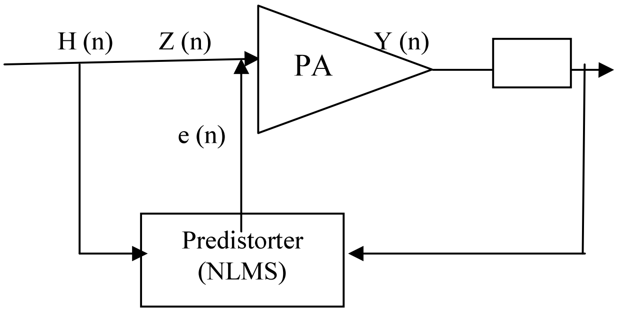

Fig.1. Predistortion Linearization Process For Saleh Model PA

3.1 IM3 DISTORTION & ESTIMATION

The two tone input signal will be given as input and non linear output will be taken. The harmonics signal will be removed. i.e. output signal equation after the band pass filter is given below

$$T(n) \text{ or } H_{out} = \left\{ a_1H_i + \frac{9}{4}a_3H_i^3 + \frac{25}{4}a_5H_i^5 \right\} \cos(\omega_{1,2}t) \qquad (6)$$

From the above equation NLMS will estimates the Inter modulates. Here we shown estimated IM3 equation from the voltera series which plays a significant role in rising the ACP level of the signal.

$$H_{IM3} = \left\{ \frac{3}{4}a_3H_i^3 + \frac{25}{8}a_5H_i^5 \right\} \cos(2\omega_{1,2} - \omega_{2,1}) \qquad (7)$$

The equation (7) tells how close the IM3 is with the tone signal. The LMS filter which will estimate not only IM3 but also other intermodulates plays the important role in the Pre distortion part. This Non stationary filter quickly estimates the error and send it for the Pre-distortion Process to the input signal H(n).

IM5 is the next important distortion need to be estimated but we don't concentrate on this distortion. Since it is somewhat farther away from the tone signal.

3.2 Normalized LMS Algorithm

The two important parameters in this adaptive filter are filter order '*p*' & step size 'μ'. These two factors play a major role in making the LMS as a fastest adaptive filter and accurately estimating the error. If we increase the value of the step size the error estimating capability may varies. Here we estimated the error with fixed 'μ'.

$$H_i(n) = [H_i(n), H_i(n-1), \ldots\ldots H_i(n-p-1)]^T \qquad (8)$$

Here the error e(n) can be estimated using the NLMS algorithm

$$e(n) = d(n) - \hat{h}(n)\,H_i(n) \qquad (9) \qquad (11)$$

Where $\hat{h}$ (n) is the adaptive transfer function of the adaptive Normalized LMS filter. The transfer function is designed by the filter order and its step size. Using the above equation (11) the error is estimated and pre-distorter will invert the error signal and distort the two tone signal input which is the input signal of the Saleh type PA.

3.3 Saleh Power Amplifier Model

Each power amplifier has been mathematically modeled according to its output power, the range of frequency it works and also material used to manufacture it. Here RF Microwave TWT type amplifiers are modeled by Saleh model which describes the amplitude distortion (AM-AM) and phase distortion (AM-PM).
Here α and β are the Coeffecients. We set the α and β value as [2,1] respectively.

$$H_{AM/AM} = \frac{\alpha * H_i}{1 + \beta * H_i^2} \qquad (10)$$

$$H_{AM/PM} = \frac{\alpha * H_i^2}{1 + \beta * H_i^2} \qquad (11)$$

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4. SIMULATION RESULTS

The first output show below in the Fig. 2. is the linearized and non linearized output for BPSK Modulation technique. Here the ACP has been reduced upto 18dB.

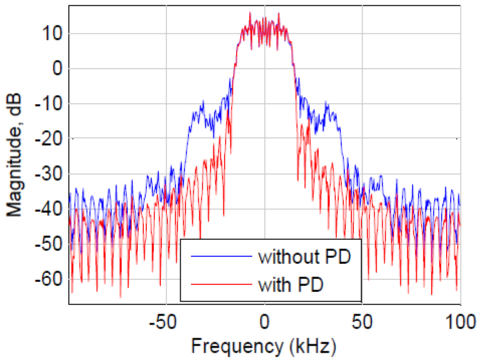

Fig.2. LMS Linearization Performance For BPSK Modulation

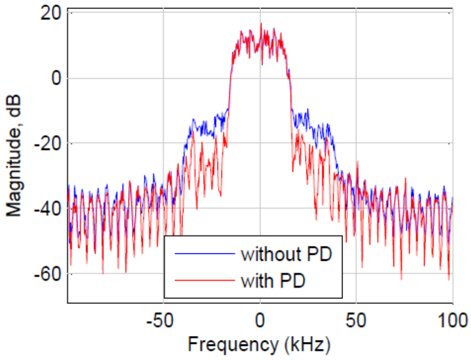

Fig.3. LMS Linearization Performance For 8-PSK Modulation

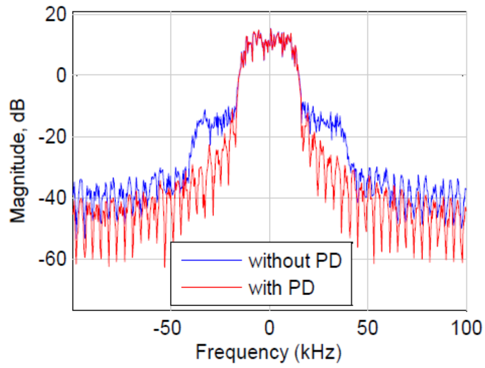

Fig.4. LMS Linearization Performance For QPSK Modulation

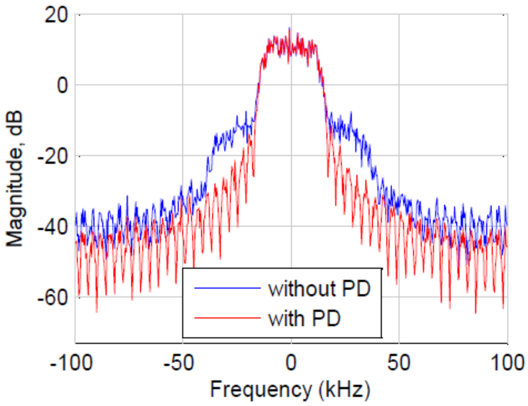

Fig.5. LMS Linearization Performance For 16-QAM Modulation

Table 1:. Linearization Performance In Different Modulation Techniques For Saleh Model Power Amplifer

Linearization Methods	Modulation Equation	Bandwidth	Modulation	ACP Before Linearization	ACP After Linearization
Feedback (Existing Method)	-	-	-	-12dB	-18dB
Feed forward (Existing Method)	-	-	-	-12dB	-42dB
Predistortion	$X\sin(\omega_a t)\sin(\omega_c t)$ $X=\pm 0.22$	$F_b/4$	16-QAM	-12dB	-40dB
	$X\sin(\omega_a t)\sin(\omega_c t)$ $X=\pm 1.307$	$F_b/3$	8-PSK	-15dB	-23dB

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$\sin(\omega_a t)\sin(\omega_c t)$	$F_b/2$	QPSK	-15dB	-38dB
$\sin(\omega_a t)\sin(\omega_c t)$	F_b	BPSK	-11dB	-29dB

In the second following output shows the linearized and non-linearized output for 8-PSK Modulation. The ACP level in this Modulation is reduced only around 5-8dB. In the above modulation the error estimation performance of the filter is found to be poor. In Fig.4. and Fig.5. We showed the Linearized and Non linearized output of the Quadrature Modulations (QPSK & 16-QAM) which shows the error estimation process follows a similar pattern. For QPSK the ACP is reduced upto 23-24dB and for 16-QAM the ACP is reduced upto 24-26dB. Now the above results are compared with the previous implemented results of the Feedback and Feed forward method. These output values of existing feedback and feed forward are taken from data sheets. In the above analyzed results the linearization performance of LMS for 16-QAM is almost resembles the performance of the feed forward method. As already told even though the feed forward performance is better the system is bulkier. The error estimation process is also not fast. Here the predistortion method is used as the alternative method. The predistortion methods can be implemented by many ways. Here we implemented new predistorter method using NLMS filter.

4.1 Error Vector Magnitude

The Error vector magnitude analysis is an important analysis in the field communication. The EVM results will tell how far your orginal signal is get distorted when comparing with the actual signal. Here the orginal signal is the two tone input signal and the actual signal is Linearized signal. The EVM performance of the LMS filter for the different Phase shift keying methods is shown below

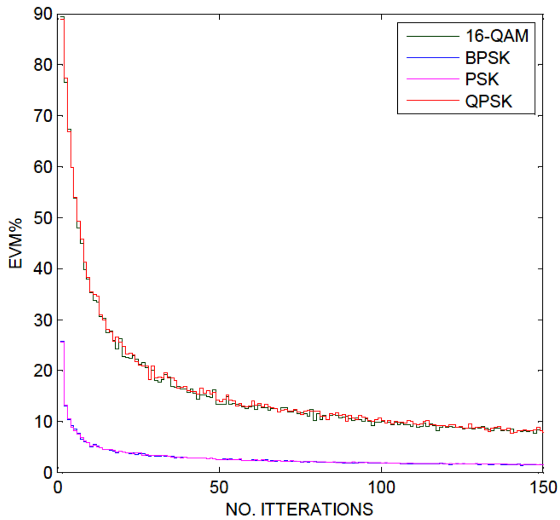

Fig.6. EVM Performance Of The LMS For The 16-QAM, QPSK, 8-PSK And BPSK

In the above result for quadrature modulation its start with high EVM and get reduced to minimum error with minimum iterations. For BPSK and 8-PSK its start with moderate EVM and reduced to very low value. It shows that as the spectral efficiency of the Phase shift keying (from BPSK to 16-QAM)increases the intial EVM values is also higher. All the above results are taken using Matlab software.

5. CONCLUSION

The LMS Filter plays a major role in the error estimation process of the signal. Predistortion method is simple comparing the other existing methods and also it can able achieve good linearization by reducing ACP around 26dB for Quadrature modulations (16-QAM & QPSK) which is used in the modern day communication system. So it results in the improvement of the power of the signal and the BER at the receiver end may be reduced.

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