3. Posterirori Minimization for Pre-Error Inclusion Linearizer of 5G-HPA

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ABSTRACT

The Number of Android Mobile (Voice, Mobile Data, Internet) users getting increased year by year, But there is a major scarcity of operating frequency for the users. Even though many spectral efficient techniques like OFDMA and NOMA are introduced to manage the spectral scarcity. The real time interference problems due to harmonics still exist. With the introduction of 5G Mobile Communication there is an exponential increase of radiations from communication equipment (BTS, Mobiles) due to massive MIMO antennas, mixers, H-PA (High-Power-Amplifier). To reduce the above effects, a modified V-LMS linearizer has been introduced instead of the conventional nonlinear filter methods (N-LMS, RLS). V-LMS not only estimates the gain error (priori) of the HPA, but also introduces very low additive error (posteriori). The proposed has been executed through the 64-QAM nonlinear modulated signal with amplifier operating at 1.89 GHz to 2.32 GHz.

Keywords— *H-PA-High Power Amplifier, V-LMS-Variable Least Mean Square, N-LMS-Normalized Least Mean Square, RLS-Regressive Least Square*

INTRODUCTION

The H-PA has been used in almost all the transmitter equipments for improving the power of the nonlinear modulated signals. Since the amplifier behaves as nonlinear device, the output signal is introduced with the harmonics (Even Order) and Intermodulates (Odd Order). The newly introduced intermodulates in adjacent band of the desired signal is hard to eliminate where as the harmonics can be eliminated using a simple 1st order Low Pass Filter (LPF) or Band Pass Filter (BPF).

The intermodulates which represent the odd order of the amplifier output is very adjacent to the message signal. This unwanted output is introduced due to the varying gain value of the amplifier. Since it is adjacent to the message signal the odd intermodulates create interference sideband distortion and self-heating effect of the device. The sideband distortion cannot be negated but it can be minimized. To minimize the distortion, pre-error inclusion method is well renowned and wide implemented.

In Pre-error inclusion method the various adaptive filters have been used to estimate the gain error of the poweramplifiers. In this work, the performance of various adaptive filters (N-LMS, RLS, V-LMS) has been analyzed which is a part of pre error inclusion linearizer module of PA. The proposed method (V-LMS) has been only examined for the High-PA type i.e for the saleh model.

The same analysis will be implemented for other PA nonlinear models like hyperbolic tangent, cubic polynomial, Ghorbhani and Rapp model. The work has been executed by considering the amplitude distortion value as α=4 and phase distortion value as β=2. A generic model has been given below,

$$H(z) = \frac{\alpha z^{\gamma}}{(1+\beta z^2)^n} \qquad (1)$$

where γ =1,2,3 and n=1,2. Here the error has been estimated as generalized Cartesian form instead of polar format (AM-AM and AM-PM). In Previous models, the signal has been converted into Cartesian to polar form and each error(Phase and amplitude) has been estimated, but in our proposed method the signal has been estimated as generic Cartesian form.

ADAPTIVE ERROR ESTIMATION MODEL

A. N-LMS MODEL

The N-LMS nonlinear filter model estimates the error from top to bottom structure using the Widrow-Hoff function. In this non-linear adaptive method of error estimation(Mean-Square-Error-MSE), it estimates the huge error using the filter tapes. After a number iteration the error has been fully minimized. The N-LMS estimation error time totally depends upon the step size of the filter function μ which varies between 0 and 1. If the μ value is close to 1, the error estimation speed is fast, but the priori error can not be quantified correctly. Similarly, when the μ value is close to 0, the error estimation speed will be very slow, but the priori error has been quantified.

This conventional filter model has more number of filter tapes which increases the computational complexity and introduces the posteriori error for initial set of iteration upto 20k to 50k samples. So this method further introduces a new additive distortion to the signal. Even though there is a tradeoff done between estimation speed and μ value, the posteriori error inclusion has been considered as a major disadvantage for utilizing N-LMS during error estimation process.

B. RLS MODEL

The RLS Adaptive filter method totally depends upon the forgetting factor. Unlike the N-LMS, RLS method will use the forgetting factor with reduced number of filter tapes. The model estimates only 3^{rd} order and 5^{th} order intermodulate distortion which is very adjacent to the signal. The estimated speed of the filter is normal as well as it quantifies the first 2 orders of the odd intermodulates.

The forgetting factor fails to keep the error in a constant suppressive mode. The filter introduces occasional high posteriori error variations which lead to the non stability of gain error which may spoil the power amplifier. To overcome this issue a new modified method using improved RLS algorithm increases the computational complexity of the gain error estimation.

PROPOSED V-LMS METHOD

The proposed V-LMS algorithm is working on the concept of variable step size to reduce the computation complexity. For each iteration the step size will be varied, so new step size will be found as,

$$\mu(n+1) = \alpha\mu(n) + \gamma\rho_2(n) \qquad (2)$$

where $\mu_{min} < \mu(n+1) < \mu_{max}$ & $0 < \alpha < 1$ and $\gamma > 0$ which are represented as varying parameters utilized from Aboulnasr's algorithm. As the variable step-size, modeled with time changing correlated signals and successive errors. The impulse samples are noted as p(n) and its future response will be derived as follows,

$$p(n+1) = \big(1 - \beta(n)\big)p(n) + \beta(n)e(n)e(n-1) \qquad (3)$$

The future response with time varying and averaged data has been found with β(n) as error signal. So from the error response, the future value will be derived as follows,

$$\beta(n+1) = \eta\beta(n) + \lambda_{e2}(n) \qquad (4)$$

where $\beta_{min} < \beta(n+1) < \beta_{max}$ and $0 < \eta < 1$ and $\lambda > 0$ are the parameters influencing the error power signal. It has been found that β(n) is variable between 0 and 1. So the maximum value of the error will be less than 1. The modification of the step size of the conventional model will give good error tracking capability with convergence. The equation 2.8 gives the solution for the additive error, misadjustment which has been called as posteriori error. Around 6 to 8 parameters has been utilized for the error estimation process. The upper bound of the step size will be represented as μmax in N-LMS. The value of the maximum step-size has to be chosen carefully such that it should not increase the complexity in step-size and the actual correct convergence. The upper value totally depends on the experimental values and it is not like the minimum step size which will be chosen as a rough approximate value.

$\mu_{max} = s2\mu T(n)u(n)$ where $0 < s < 1$ is the measuring factor for scaling.

The V-LMS algorithm does not have constant μ, so it adjusts the error estimation speed as needed. It has introduced a minimal posteriori error range with constant suppression of gain error for all the orders of the intermodulates. The performance of the V-LMS has been compared with conventional N-LMS and RLS method using gain error vector magnitude analysis.

COMPARATIVE ANALYSIS AND RESULTS

The Linearizer has been designed for the purpose of reducing the harmonic distortion of Saleh-TWT based 5G-HPA. In the previous model, N-LMS and RLS used to estimate the priori error by comparing with the input signal and feedback down converted signal. The same will be now carried out by V-LMS algorithm which also reduces the posteriori noise effect of conventional model and quantization memory effects of 2D-ML-LUT. Similarly the V–LMS error estimator reduces the computational complexity with minimum priori error estimation time. To validate 5G-HPA performance, Peak, RMS and 95th percentile EVM has been estimated according to the standards

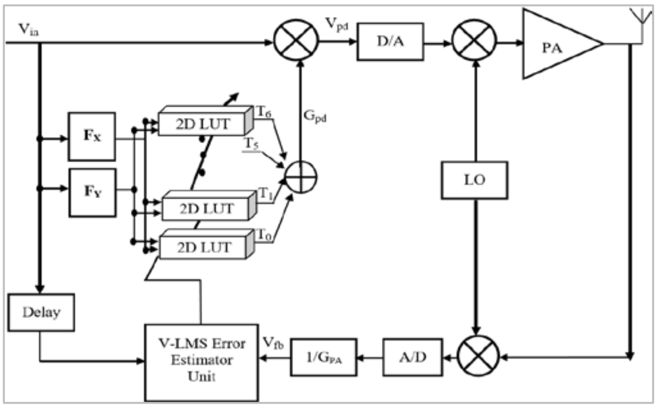

Figure 3-1 roposed Pre-Error Inclusion V-LMS Linearizer

A. RMS-EVM ANALYSIS

The model has been implemented mathematically in Matlab environment with α = 4 and β = 2 of the saleh 5G-HPA. The constant step size μ=0.23 (NLMS), forgetting factor =0.18. The prori estimation is done in Cartesian mode.

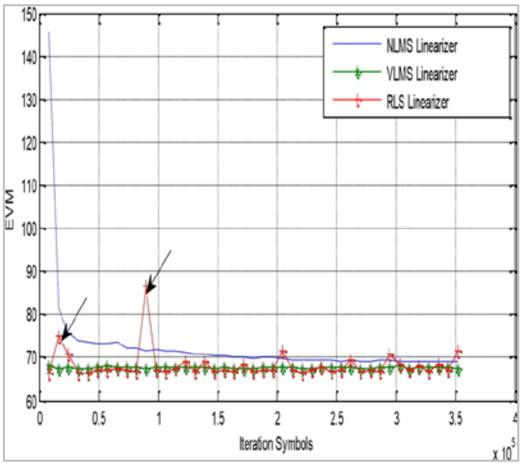

Figure 3-2 RMS-EVM analysis (V-LMS vs N-LMS & RLS)

Around 0.35 million of iteration sampled symbols has been taken to estimate the RMS-EVM. In figure 3-1 shows that initially the conventional N-LMS has a huge unnatural error of around 140-150 which means the N-LMS priori estimator added the posteriori error which was later reduced to the normal level after 0.15 million of iterations. Both RLS and V-LMS has a same priori error level of (65-70). However, it is evident from figure 3-2 that RLS failed to keep the constant gain error with the inconsistent estimation process.

B. PEAK EVM ANALYSIS

In figure 3-3 the 0.35 million of iteration symbols, random EVM peak values have been estimated for saleh-5G-H-PA, and all nonlinear error estimators. The peak EVM measurement also confirms the inconsistency of RLS method which has many high inconsistent tall peaks. There is a chance to the H-PA failure due to these inconsistent tall peaks introduced by the RLS error estimator. V-LMS once again perform consistently educes both the priori and further not introduce any posteriori distortion.

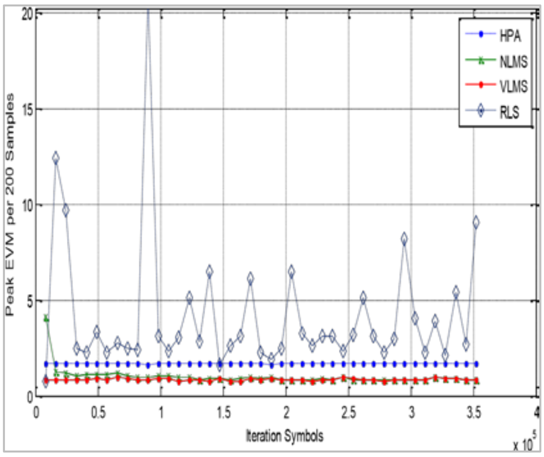

Figure 3-3 Peak EVM analysis (V-LMS vs N-LMS & RLS)

C. 95TH PERCENTILE EVM ANALYSIS

Once again like the RMS-EVM, in 95th percentile EVM also the N-LMS error estimator has an unnatural error initially, but later it has a consistent error compression. Unlike in earlier two EVM analysis, RLS has a consistent gain error suppression and inline with V-LMS.

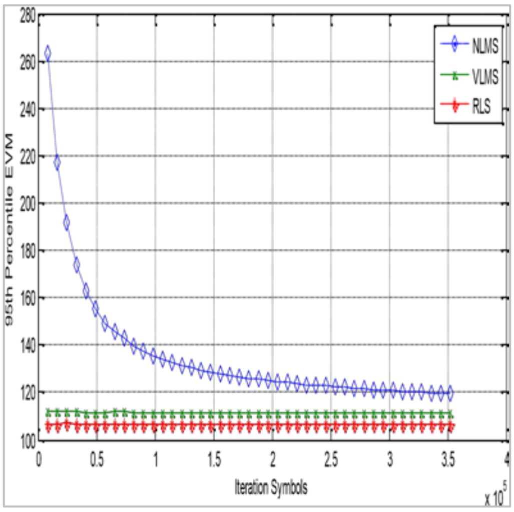

Figure 3-4 95th percentile EVM analysis (V-LMS vs N-LMS & RLS)

CONCLUSION

As per the 5G Communication 3GPP standards the RMS, Peak and 95th percentile EVM should not exceed 10%, 30% and 15% of the mobile station in worst case. N-LMS exceed all these limits for the initial 0.15 million of iteration later it comes under this level. RLS cannot able to maintain the error consistently and introduces tall gain posteriori peaks. In all these three analysis only V–LMS linearizer has a consistent error suppression performance and in line with the worst case EVM values. The worst case EVM values are listed at various intervals has been tabulated below in Table 3-1.

Table 3-1 EVM ANALYSIS FOR 5G-3GPP STANDARDS

Error Estimator	**EVM Analysis**		
	RMS-EVM	***Peak EVM***	***95th Percentile EVM***
N-LMS	8.33% (Initial 0.15 million Symbols 48%)	26.43% (Initial 0.15 million Symbols 52%)	13.5% (Initial 0.15 million Symbols 45%)
RLS	7.52% (Inconsistent short, tall posteriori peaks 33%)	32.12% (Inconsistent short, tall posteriori peaks 67%)	8.21% (Consistent)
V-LMS	7.56% (Consistent)	23.33% (Consistent)	9% (Consistent)

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