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Research Paper

Power Amplifier Linearization Using Digital Pre-Distortion Techniques Based On Memory Polynomial Model and Estimated By Self Organizing Migrating Algorithm

Harjinder Singh[#1], Amandeep Singh Sappal[#2]
[#1]*Department of Electronics and Communication Engineering, Punjabi University, Patiala, India*
[#2]*Department of Electronics and Communication Engineering, Punjabi University, Patiala, India*

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ABSTRACT: *To gratify the requirements of modern wireless communication, linearization of power amplifier (PA) becomes a foremost research field. Several linearization techniques have been introduced time to time. Digital pre-distortion linearization technique is the best linearization technique from other linearization techniques. In this paper, modified memory polynomial function is used to model PA and digital pre-distorter. Self organizing migrating algorithm (SOMA) is applied to estimate the coefficients of the PA and digital pre-distorter models. The coefficients of PA and DPD are optimized iteratively in order to minimize the output PSD around the pre specified frequency. The simulation results for Worldwide Interoperability of Microwave Access (WiMAX) 10 MHz PA system shows the extraction solution achieves excellent linearization accuracy. The adjacent channel leakage ratio (ACLR), error vector magnitude (EVM) and number coefficients of the PA and digital predistorter are calculated of the proposed memory polynomial model. Improvement in ACLR (dB) and EVM (dB) shows the correctness of the proposed technique.*

Keywords: *Digital predistorter, memory effects, memory polynomial, non-linearity, power amplifier, self organizing migrating algorithm and WiMAX*

I. INTRODUCTION

PA is a key component of the communication system and its approach to achieve the highest possible power efficiency under linearity requirements [1,5]. In order to improve the PA's efficiency and nonlinearity, some highly efficient linearization techniques are used. The classification of linearization techniques is uncertain but these techniques can be classified into the following categories [2-4]. Boot up bias linearization technique, dynamic bias linearization technique, feedback linearization techniques (baseband envelope feedback linearization technique, polar loop modulation feedback linearization technique, cartesian loop modulation feedback linearization technique), envelope elimination and restoration linearization technique, feedforward linearization technique, linear amplification using non linear components (LINC) linearization technique and digital Pre-distortion (DPD) [5,12-14]. Among all of these existing linearization techniques, DPD linearization techniques has become the most popular linearization technique for its good performance. Digital pre-distorter can be modeled by look up table (LUT), Volterra series and memory polynomial. LUT is based on stored PA data in tabular form so it increases the complexity. To compensate for the strong nonlinearity, higher memory polynomial order, longer memory depth and more samplings are required [15-17]. Volterra series suffered from the problem, the number of model coefficients rapidly increase with the increase of polynomial order and memory depth. Memory polynomial model is simplified version of Volterra series model. Hence modified memory polynomial model is used in proposed work. In this work, the achievability of PA memory polynomial behavioral models is analyzed by using SOMA. SOMA estimates the model coefficients from the view of probability [5,18-20]. The performance of the proposed method is verified by simulations for WiMAX system. This paper is organized as follows; First section introduction, in section II memory polynomial function, section III introduce the SOMA, simulation results are in section IV and the conclusion is presented in last section.

Memory Polynomial Function

The memory polynomial expression implemented in the proposed work is given for the output is given as [3,5,11];

$$y_{MP}(n)=\sum_{k=0}^{K-1}\sum_{l=0}^{L-1}c_{l,k}x\left(n-l\right)\left|x\left(n-l\right)\right|^{k} \quad (1)$$

where the signals $x(n)$ and $y_{MP}(n)$ are the complex baseband input and output waveforms, respectively, and $c_{l,k}$ represents the model's coefficients. L represents memory length and K is the order of non-linearity. The output of a PA and DPD modeledusing memory polynomial model can be written in vector form as [5,18]

$$y_{MP}(n)=\mathbf{u}(n)\mathbf{c} \quad (2)$$

Estimation of the coefficients $c_{l,k}$ can be carried out by considering the solution of equation 5.1 as solution of linear equation;

$$\mathbf{A}x=\mathbf{B} \quad (3)$$

The coefficients of PA and DPD model are estimated by SOMA

Self Organizing Migrating Algorithm

SOMA belongs to a member of the family of swarm intelligence algorithms which mimics the competitive-cooperative behaviour of a pack of intelligent agents. This algorithm is based on effective combination of exploration and exploitation. During last two decades, SOMA has been used by numerous researchers for solving diverse tasks [7-9]. SOMA has very fast convergence rate, it based on a population of individuals in loops called migration loops. In each migration loop, the population is evaluated, and the solution with the highest fitness becomes the chef. Apart from the chef, in one migration loop, all individuals will traverse the input space in the direction of the chef. An individual will travel a certain path length towards the chef in n steps of defined length. If the $path\ length>1$, then the individual will overshoot the chef. Flow chart of SOMA process is given in Figure 1.

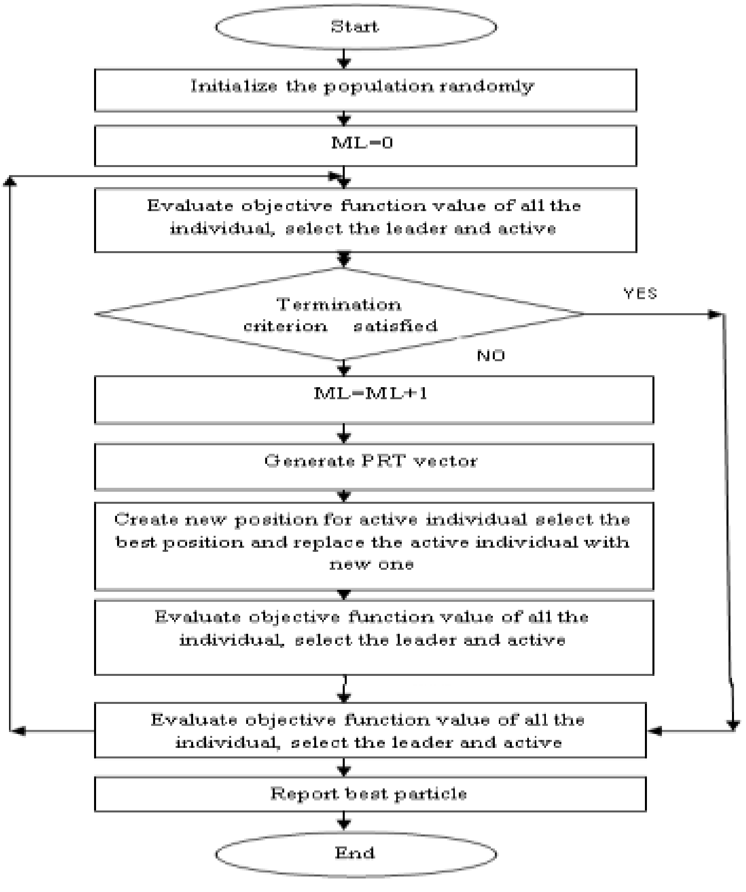

Figure 1: Flow chart of SOMA process

The main parameters used in SOMA are described as follows [11]:

Pop Size: defines the number of individuals in the population.

Dimension: represents the number of parameters of individual.

Path Length (PL): determines in what distance from the chef the actual individual will stop his movement.

Step (t): the granularity with which the search space is sampled.

Perturbation (PRT): determines whether an individual will travel directly towards the Chef, or not.

Migrations (ML): represents the number of migration loops or iterations.

In SOMA, the mutation is replaced by the perturbation and it depends on the perturbation vector. For each individual's parameter, the algorithm generates a random number $\left(rnd_j\right)$ from the interval [0,1] as the following expression.

```
if $rnd_j < PRT$, then
    $PRTVector_j = 1;$
else
    $PRTVector_j = 0;$
end if
```

Then, the following expression is used.

$$x_{i,j}^{MLnew} = x_{i,j,start}^{ML} + \left(x_{L,j}^{ML} - x_{i,j,start}^{ML}\right).t.PRTVector_j \tag{5.7}$$

where, $t \in [0,\ by\ step\ to,\ PL]$, $x_{i,j}^{MLnew}$ is the new positions of an individual, $x_{i,j,start}^{ML}$ is the positions of active individual, $x_{L,j}^{ML}$ is the positions of chef

The computational steps of SOMA are given as follows [11]:

Step 1: generate initial population;

Step 2: evaluate all individuals in the population;

Step 3: generate PRT vector for all individuals;

Step 4: sort all of them;

Step 5: select the best fitness individual as chef and worst as active;

Step 6: for active individual, new positions are created using equation 5.7. Then the best position is selected and replaces the active individual by the new one;

Step 7: if termination criterion is satisfied stop else go to step 2;

Step 8: report the best individual as the optimal solution.

Simulation Results

This section illustrates the results obtained by using SOMA. To validate the performance of the SOMA, the PA and DPD was modeled using the memory polynomial model given by equation 4.23. All the characteristics of proposed algorithms for PA and DPD have been measured by sweeping value of memory length L between 1 to 5 and the nonlinearity order K between 2 to 7 in memory polynomial.

PA modeling

Figure 2 and figure 3 shows the AM-AM characteristics and the AM-PM characteristics respectively of actual PA and proposed SOMA PA model, the characteristics curve of proposed SOMA PA model is tried to follow the characteristics of actual PA. This shows the accuracy of the modeling in terms of AM-AM and AM-PM characteristics.

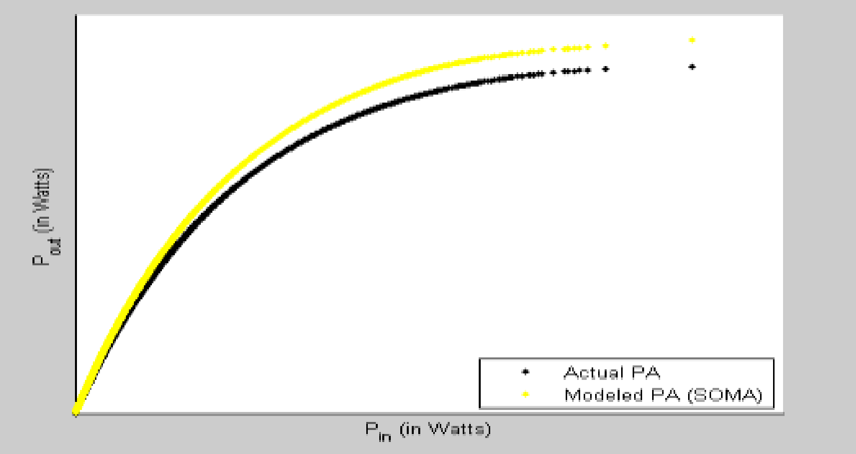

Figure 2: AM-AM characteristics for actual PA and proposed SOMA PA model

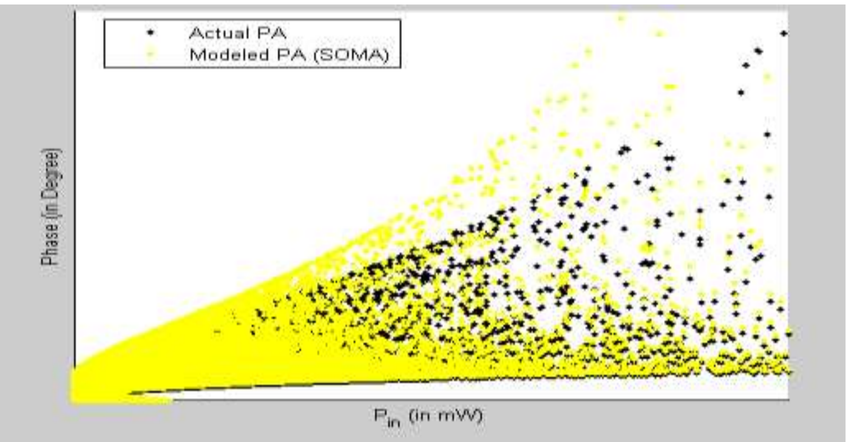

Figure 3: AM-PM characteristics for actual PA and proposed SOMA PA model

Figure 4 shows the power spectral density diagram of actual PA and proposed SOMA PA model, due to PA memory and non-linear effects, the spectrum of output signal has expanded.

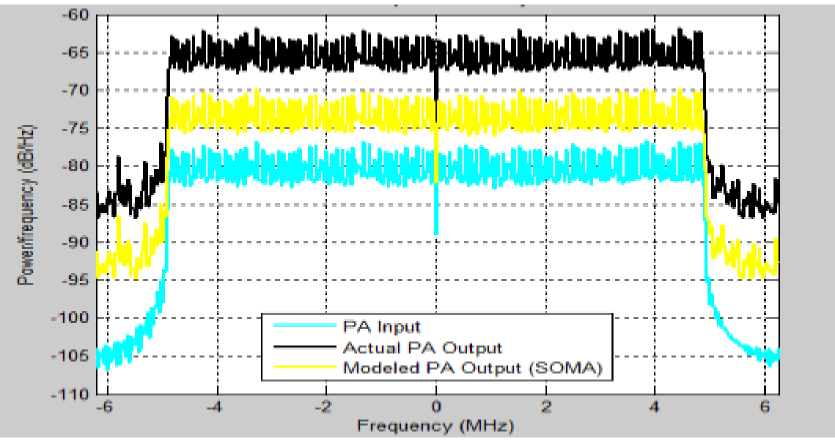

Figure 4: Power spectral density of actual and proposed SOMA PA model

The performance of proposed SOMA PA model based on ACLR (dB), EVM (dB), memory length and non linear order can be inferred from table 1. The ACLRs of actual PA are Lower Channel 2 (53.17), Lower Channel 1 (28.28), Upper Channel 1 (29.04) and Upper Channel 2 (54.01). The ACLRs of modeled PA using SOMA are Lower Channel 2 (58.02), Lower Channel 1 (30.26), Upper Channel 1 (31.18) and Upper Channel 2 (56.20).

Table 1: Measurements of actual PA and proposed SOMA modeled PA

Type	**Adjacent Channel Leakage Ratio (dB)**				**Error Vector Magnitude (dB)**	**Memor y length**	**Non linear order**
	Lower Channel 2	**Lower Channel 1**	**Upper Channel 1**	**Upper Channel**			
Actual PA	53.17	28.28	29.04	54.01	-24.28	-	-
SOMA PA	58.02	30.26	31.18	56.20	-26.23	3	7

From table 1, it has been concluded that all ACLRs of SOMA modelled PA have closer to the ACLRs of actual PA. For SOMA PA model, the values of memory length L and the nonlinearity order K are 3and 7 respectively so, the no of coefficients are 21 in SOMA PA model. The EVM of actual PA and SOMA are -24.28 and -26.23 respectively, so the EVM of SOMA PA model (-24.26) is also closer to EVM of actual PA (-24.28).

DPD modeling

Figure 5 shows the inverse AM-AM characteristics of actual PA and proposed SOMA DPD model. The characteristics curves of proposed SOMA modeled digital predistorter is tried to follow the inverse characteristics of actual PA, this shows the accuracy of the modeled SOMA digital predistorter.

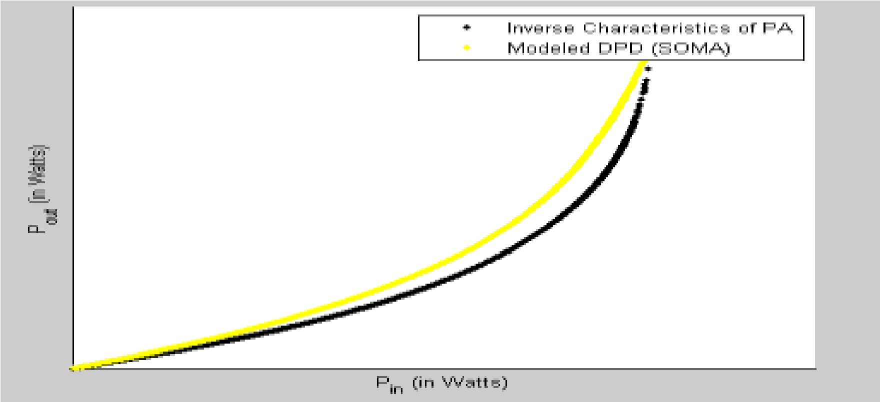

Figure 5: AM-AM characteristics for proposed SOMA PA model and inverse AM-AM characteristics of actual PA

Figure 6 shows the power spectral density diagram of actual PA and digital predistorters of proposed SOMA, due to PA memory and non-linear effects, the spectrum of output signal has expanded.

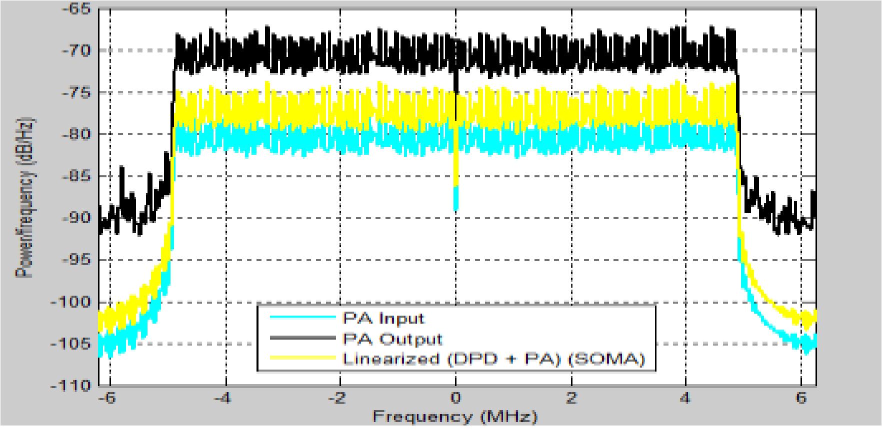

Figure 6: Power spectral density of actual and modelled PA, modelled (DPD+PA) using proposed SOMA

The performance comparison of the proposed SOMA digital predistorters based on ACLR (dB), EVM (dB), memory length and non linear order can be inferred from table 2. The ACLRs of modeled digital predistorter using SOMA are Lower Channel 2 (78.06), Lower Channel 1 (52.19), Upper Channel 1 (53.05) and Upper Channel 2 (79.27). The ACLRs of actual PA are Lower Channel 2 (53.17), Lower Channel 1 (28.28), Upper Channel 1 (29.04) and Upper Channel 2 (54.01).

Table 2: DPD Performance Metrics using using proposed SOMA modeled DPD

Type	**Adjacent Channel Leakage Ratio (dB)**				**Error Vector Magnitude (dB)**	**Memory length**	**Non linear order**
	Lower Channel 2	**Lower Channel 1**	**Upper Channel 1**	**Upper Channel 2**			
Actual PA	53.17	28.28	29.04	54.01	-24.28	-	-
SOMA DPD	78.06	52.19	53.05	79.27	-28.25	4	7

From table 2, it has been concluded that the improvement in all ACLRs (Lower Channel 2 (24.89dB), Lower Channel 1 (23.91dB), Upper Channel 1 (24.01dB) and Upper Channel 2 (25.26dB)) of SOMA digital predistorter with respect to the actual PA all ACLRs. For SOMA DPD model, the values of memory length L and the nonlinearity order K are 4 and 7 respectively so, the no of coefficients are 28 in SOMA DPD model. The EVM of actual PA and SOMA PA model are -24.28 and -28.25 respectively, so the EVM (-3.97 dB) of SOMA DPD model has been improved with respect to the EVM of actual PA (24.28).

II. CONCLUSION

The PA and DPD model measurement results based on a SOMA optimization algorithm shows the sovereignty of algorithm. The performance of proposed algorithm was tested on a wideband radio frequency power amplifier working for a 10 MHz WiMAX communication system. The PA results show the ACLR and EVM of modeled PA are very close to the actual PA, this shows the accuracy of proposed PA model. The DPD results concluded that approximately 24dB improvement in ACLR and EVM has also improved. The number of coefficients PA and DPD models are also less in proposed technique.

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