Available Online at http://www.recentscientific.com

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 7, Issue, 11, pp. 14303-14306, November, 2016

International Journal of Recent Scientific Research

Research Article

COMBINATION OF NEURAL NETWORK AND GENETIC ALGORITHM FOR RADIO FEREQUENCY POWER AMPLIFIER MODELING

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ARTICLE INFO

Article History:

Received 16th August, 2016
Received in revised form 25th September, 2016
Accepted 23rd October, 2016
Published online 28th November, 2016

Key Words:

Hybrid Genetic Algorithm- Neural Network -Power Amplifier.

ABSTRACT

This paper proposes a power amplifier behavior modeling based on neural network. This power amplifier uses genetic algorithm to find the suitable weights and number of neurons. In this paper a real valued time delay neural network has been trained and optimized with hybrid genetic algorithm. This neural network is used as a pre distorter and model a radio frequency power amplifier. The simulations show that the training is done with higher speed and sufficient linearity. Result shows that hybrid genetic algorithm can do with more speed than back propagation. The performance of the amplifier is optimized for input signals with frequencies in a range of radio frequency. The neural network is used as pre distorter of power amplifier and showed 9 db improvement in linearity in response to a wide band signal.

INTRODUCTION

Power amplifiers (PA) are vital to enable the rapid growth of wireless communication systems, and they are evolving under the dual pressures of providing improved efficiency and improved linearity. Power amplifier is a critical nonlinear module in various radio frequency communication systems [1].

PA is usually biased near saturation point to work more efficiently and therefore in such systems the battery has more life. But paradoxically PAs are more nonlinear when is used near saturation point. Thus they cause tradeoff between distort adjacent and alternate channels. Fortunately, linearization techniques have been used to allow PA to be operated at higher power with minimal adjacent channel power ratio (ACPR) [2]. There are three main techniques to linearism PA in the field today: Feedback, Feed forward and Pre distortion (PD). 3G communication systems use signals with a bandwidth near 5-10MHz. This wideband signal at gigahertz frequency made using of feedback almost impossible. Nowadays PAs are predominately linearized by some form of digital pre distortion or feed forward. There has been growing interest in linearization by digital pre distortion (DPD). Compared to feed forward, designs based on digital pre-distortion are showing higher efficiency at lower cost, and with recent advances in DSP processors technology, digital pre distortion can now support signal bandwidths in excess of 20 MHz [3].

Early using of DPD had employed a look-up table. Then, these big look-up tables are estimated with polynomials. If we want to have a better model and more effective linearization, we need a higher order polynomial; but finding the coefficients was become very harder. As we know, neural networks can effectively map a system with high degree of nonlinearity. Thus they are applicable to model the inverse characteristics of the PA response and recently have been used as pre distorters [4-6]. There are also remained problems: most neural networks pre distorters are modeled using Multi-Layer Perceptron (MLP), in which the number of hidden neurons increases with the amount of needed improvement and moreover, it is hard to extract structured knowledge in either finding the weights or the configuration of the system [7-10].

In this paper, we present a mathematical form of neural network and use genetic algorithm (GA) to find the suitable weights and number of neurons. Genetic algorithms are optimization techniques that use natural selection and recombination to generate new sample points in a search space. These algorithms are well-suited to nonlinear optimization problems and converge well even on complicated non-convex cost functions[11-12].

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The paper is organized as follows. Section 1 is an introduction. Section 2 presents linearization fundamentals and defines the PA model used in the simulations. The genetic algorithm is presented in Section 3 along with performance results. A summary of results is given in Section 4 and conclusion is given in section 5.

Pre distortion with Neural Networks

Pre distortion Fundamentals

We can see the basis of pre distortion in Fig. 1. The main concept is that the signal is distorted in the way that the inverse transfer function of nonlinear PA has been achieved. The result is that the whole system became linear. Transfer function of PA:

$$V_{out} = f\ V_{in}$$
$$V_{out}(desired) = A(V_{in}) \qquad (1)$$

Transfer function of pre distorter:

$$V_{in} = g(V_{out}) \rightarrow V_{out} = f(g(V_{in})) \rightarrow g = f^{-1} \qquad (2)$$

We can choose the normalized output of main PA as the input of pre distorter to produce inverse transfer function of a nonlinear PA response.

Neural Network

Many topologies of ANNs were reported in the literature for the modeling of different types of circuits and systems that exhibit different kinds of linear and nonlinear behaviors. The ANN that proposed in [4] has been chosen to model a 3G PA. It used real weights and can well model memory effects. The term memory effects refer to the bandwidth-dependent nonlinear effects often present in PAs. These encompass envelope memory effects and frequency memory effects. Spectral regrowth asymmetry in the adjacent and alternate channels indicates the presence of memory effects and is commonly referred to as IMD imbalance [1]. In genetic algorithm only some parameters are changed if another structure is used for ANN. As a specific ANN, the time-delay neural network has been used to learn and represent dynamic systems. It was successfully utilized in signal processing, speech recognition, system identification, and control to solve the temporal processing problems [5], [6]. The ANN is shown in Fig. 2. To training this ANN we firstly need to represent it with mathematical equations as below:

$$\begin{matrix} \vartheta_{11} & \vartheta_{12} \dots \dots \vartheta_{1p} \\ \vartheta_{21} & \vartheta_{22} \dots \dots \vartheta_{2p} \\ \dots & \dots \\ \vartheta_{k1} & \vartheta_{k2} \dots \dots \vartheta_{kp} \end{matrix} \cdot \begin{matrix} I_{in}\ n \\ I_{in}\ n-1 \\ \dots \dots \\ I_{in}\ n-p \end{matrix} + \begin{matrix} \omega_{11} & \omega_{12} \dots \dots \omega_{1p} \\ \omega_{21} & \omega_{22} \dots \dots \omega_{2p} \\ \dots & \dots \\ \omega_{k1} & \omega_{k2} \dots \dots \omega_{kp} \end{matrix} \cdot \begin{matrix} Q_{in}\ n \\ Q_{in}\ n-1 \\ \dots \dots \\ Q_{in}\ n-p \end{matrix} + \begin{matrix} b_1^1 \\ b_2^1 \\ \dots \dots \\ b_k^1 \end{matrix} = \begin{matrix} net_1^1\ n \\ net_2^1\ n \\ \dots \dots \\ net_k^1\ n \end{matrix} \qquad (3)$$

$$\begin{matrix} I_{out}\ n \\ Q_{out}\ n \end{matrix} = \begin{matrix} b_1^2 & \omega_{11}^2 & \omega_{12}^2 \dots \dots \omega_{1m}^2 \\ b_2^2 & \omega_{21}^2 & \omega_{22}^2 \dots \dots \omega_{2m}^2 \end{matrix} \cdot f \begin{matrix} net_1^1\ n \\ net_2^1\ n \\ \dots \dots \\ net_k^1\ n \end{matrix} \qquad (4)$$

$$f\ x = \frac{1-e^{-2x}}{1+e^{2x}} = tg\Box(x) \qquad (5)$$

Our mission here is to find the matrices members. Firstly we need a set of inputs and outputs of a nonlinear PA to make the equations. For this work, the MATLAB model of PA is modified and used to produce inputs and outputs. This model and amplifier AM/AM and AM/PM characteristics are shown in Fig. 3-5.

Genetic Algorithm

To have better results hybrid GA is used. A hybrid GA combines the power of the GA with the speed of a local optimizer. The GA excels at gravitating toward the global minimum. It is not especially fast at finding the minimum when in a locally quadratic region. Thus the GA finds the region of the optimum, and then the local optimizer takes over to find the minimum [8]. For local optimizer Nelder-Mead simplex method is used [7]. Nelder-Mead act is very simple and easy to implement. Optimization is done in two phases. In phase 1, the unknown matrix in equation (2) is determined. Also the needed input data for phase 2 is produced. Then in phase 2 the two unknown matrices is found simultaneously. Bias matrix in equation (1) is generated randomly in first generation and not changed in other generations. After some generations if there is no improvement in results Nelder-Mead method try to find a new good result and improve the cost. All weights in ANN is choose in range [-0.5 0.5] and cost function for both phases is the average of sum of squared errors.

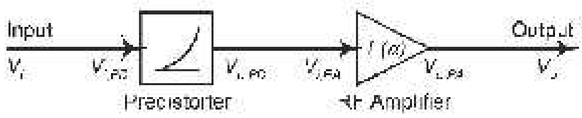
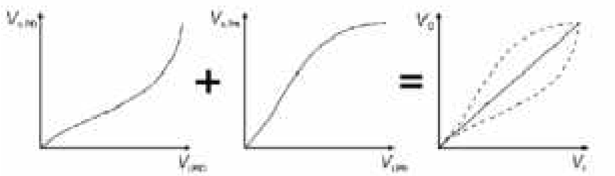


Fig. 1 The main idea of pre distortion



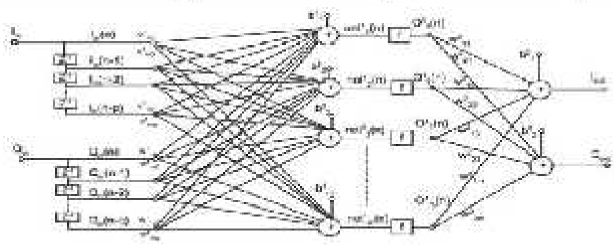


Fig. 2 Neural network structure

In every generation almost half of population is removed and replaced by mating of good members. Mating method is here tournament of 4 or 5. Mutation rate is 0.25 for phase 1 and 0.29

for phase 2. Below are two snapshots from the results of desired output (blue) and trained ANN (magenta). At least about 16000 point is needed for good result.

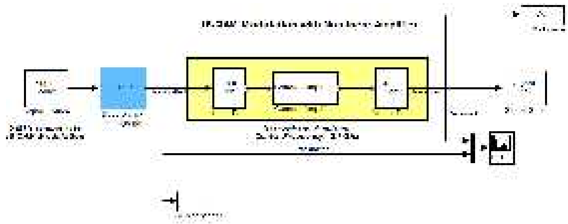


Fig. 3 The model of nonlinear amplifier

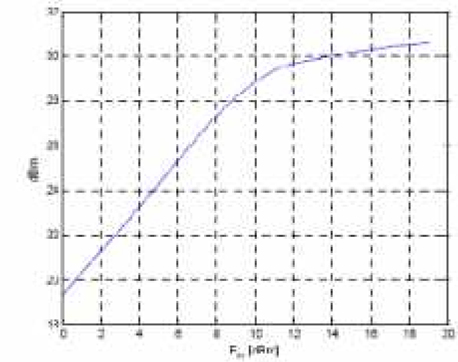


Fig. 4 AM/AM characteristics

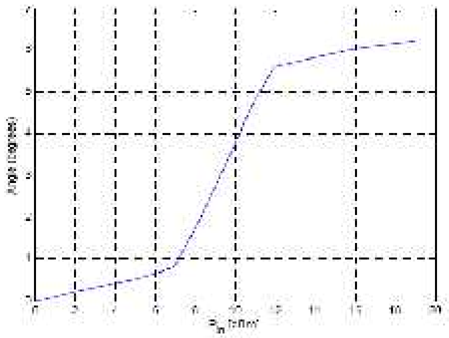


Fig. 5 AM/PM characteristics

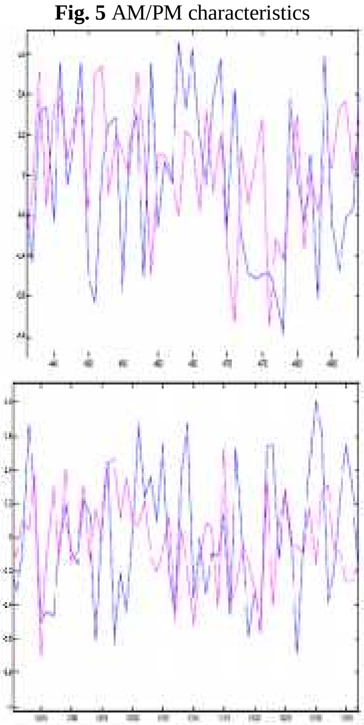


Fig. 6a,b Two snapshots from trained neural Network.

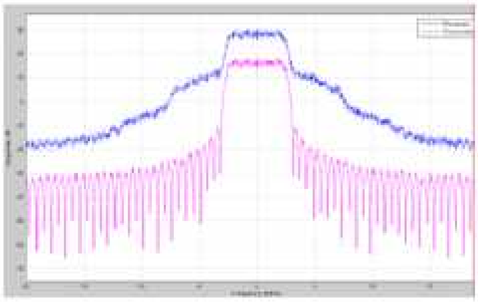


Fig. 7 system response without linearizer

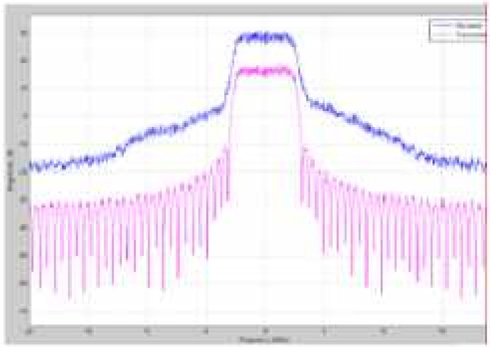


Fig. 8 system response with predistorter (linearizer)

RESULTS

After training the ANN and use the two best results to PA model we can see about 9db improvement in ACPR. Input of system is 16QAM signal with bandwidth of 5MHz and center frequency of 2.1GHz. It is a good example of wideband signal. The asymmetry that has been seen in two sides of output of PA is relating to memory effects. In the training of NN fewer epochs were needed in comparison with what reported in [4]. Also the effect of changing tap delays and number of neurons can easily be seen. Our simulation showed 14 neurons and 3 tap delays for real input and 2 tap delays for imaginary input. In this report hybrid genetic algorithm is used to optimize a real valued time delay neural network and find its related weights. It was shown that hybrid GA can do with more speed than BP. The NN is used as pre distorter of power amplifier and showed 9 db improvement in linearity in response to a wideband signal.

CONCLUSION

We have accomplished our work on using genetic algorithms to train neural networks. We have demonstrated a real-world application of a genetic algorithm to design of power amplifier. In the held of neural networks, we use introduced a new type of training algorithm base on back propagation algorithm. To have better results hybrid GA is used. A hybrid GA combines the power of the GA with the speed of a local optimizer. The GA excels at gravitating toward the global minimum. The existence of genetic algorithms for training could aid in the development of other types of neural networks.

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How to cite this article:

Alireza Rezaee.2016, Combination of Neural Network and Genetic Algorithm for Radio Ferequency Power Amplifier Modeling, India. *Int J Recent Sci Res.* 7(11), pp. 14303-14306.