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Fuzzy Logic Based Digital Pre-distorter to Linearize Power Amplifier for QAM Signals

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Abstract — **The development of wireless communication products is surprisingly rapid. The RF power amplifier (PA); an important element in transmitter units of communication systems and is expected to provide a suitable output power at a very good gain with high efficiency. But the nonlinearity of PA is not acceptable; this paper presents a fuzzy based digital pre-distortion technique to linearize the characteristics of power amplifier.**

Keywords — **Power Amplifier, Digital Pre-distorter, Fuzzy-Logic, Neural Network.**

I. Introduction

A digital communication system has to fulfil the basic requirements of linearity and signal to noise ratio (SNR); desired for the modulation scheme. The overall linearity of a wireless system is mainly dependent on Power Amplifier (PA) used in the transmitter, because designing a PA with a required power output is not as challenging as to keep its characteristic linear throughout its operating range, that is why most of Power Amplifiers used in transmitters shows nonlinearity when driven to saturation and at back off power they are quite linear. This feature of a typical PA prevents use of higher order QAM, because when a typical RF-PA driven with higher order M-QAM it has to operate in saturation region to maintain the desired SNR for the M-QAM. Hence better bandwidth utilization, higher data rate and power efficient communication system design is possible if the PA used in the transmitter is linear, which can be operated at high efficiency as well and allow use of higher order M-QAM for information transmission. Since power amplifier used in wireless transmitters process (amplifies) radio frequency signal. Most of RF-PA shows nonlinearity when driven to saturation that is why we can't use higher order M-QAM scheme because that may forces the PA to operate in nonlinear region in order to maintain the desired SNR. Therefore to use higher order M-QAM technique we have to use linear PA which we don't have actually. However if PA used in the transmitter, can be linearize the problem will be resolved. This paper present such a linearization technique so the basic wireless communication block diagram include an additional block known as Digital Pre-distortion in the transmitting chain before the PA.

II. Digital Pre-Distortion

The digital Pre-distortion (DPD) technique relies on an exact inverse Pre-distorter element placed before the PA as shown in figure below:

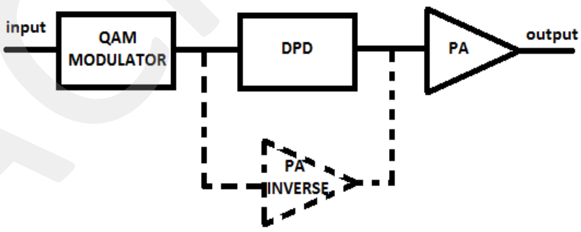

Figure1: Basic Structure of DPD in system

The signal at the output M-QAM modulator is given by

$$S_{in}(n) = \left[I_{in}(n) + jQ_{in}(n) \right]$$

The output of the power amplifier (PA) $S_{PA}(n)$ should be replica of the modulator output $S_{in}(n)$ but actually PA does not amplify linearly all M-QAM signals. Therefore to make PA output linear $S_{in}(n)$ is first applied to DPD as input to obtain the inverse model of PA with target given by

$$S_{PA}^{-1}(n) = \frac{S_{in}(n)}{S_{PA}(n)}$$

Now with $S_{PA}^{-1}(n)$ as input, PA output is almost replica of the M-QAM modulator output, $S_{in}(n)$.

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This is how DPD compensates for nonlinearity of the PA.

III. Fuzzy Based DPD

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic they can have varying values, where binary sets have two-valued logic, true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.

In past an Artificial Neural Network Based DPD scheme has been proposed where $S_{PA}^{-1}(n)$ target and modulator output $S_{in}(n)$ as input to the ANN is trained to mimic the inverse characteristic of PA by suitable training algorithm to achieve predefined goal; mean square error (MSE) and after that its output becomes almost equal to $S_{PA}^{-1}(n)$.
We here proposing a much simplified fuzzy logic based DPD which will inverse the output of modulator to and this will be the input for PA so that PA output now is almost replica of the M-QAM modulator output, $S_{in}(n)$.

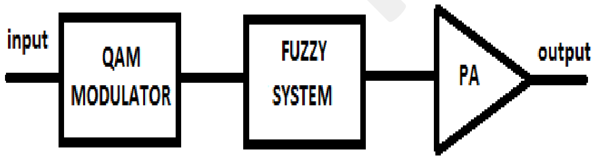

Figure2: Fuzzy Based DPD System

Since fuzzy systems have simple implementation over the hardware then the neural networks, this method can be much effective.

IV. Simulation and Results

Matlab/Simulink R2009b is used to implement the program and simulation. System is developed for M = 8,16,32 and 64 QAM modulation. Also our fuzzy system is compared with previous neural network based system:

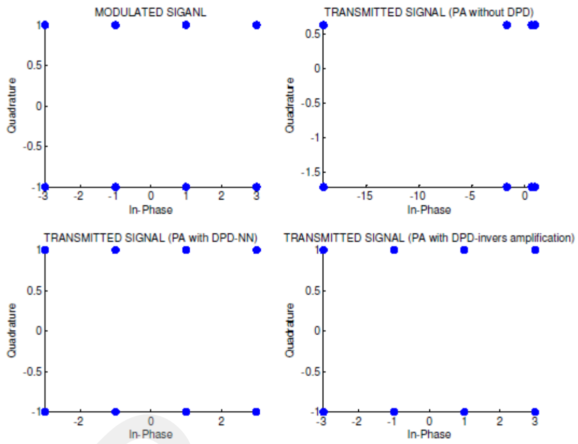

Figure3: Constellation for M=8

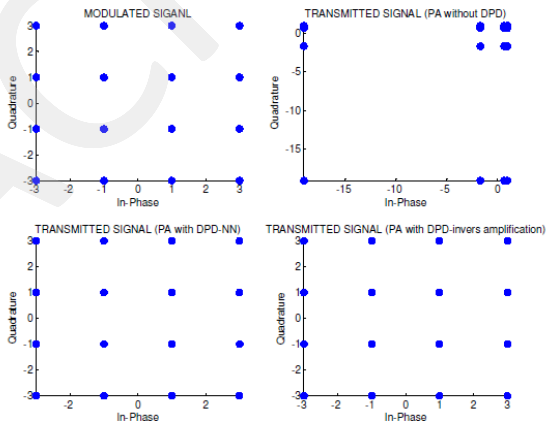

Figure4: Constellation for M=16

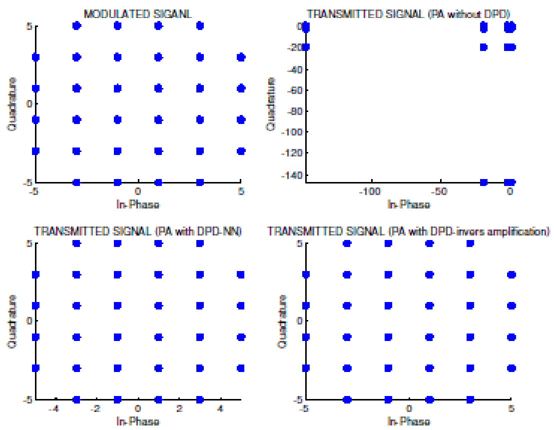

Figure5: Constellation for M=32

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Table below showing number of correctly received symbols for M = 8, 16 and 32:

M	Number of Transmitted Symbols	Number of Transmitted Symbols without DPD	Number of Transmitted Symbols with NN-DPD	Number of Transmitted Symbols with FUZZY DPD
8	10001	7550	10001	10001
16	10001	5618	10001	10001
32	10001	3080	10001	10001

V. CONCLUSION

This work has carried out to model and analyze the performance of Fuzzy Logic based digital pre distorter to linearize a nonlinear power amplifier for M-QAM signals. When performance of digital pre distorter based linearised power amplifier is analyzed in presence of AWGN for various M-QAM signals the SNR requirements are found in close agreement with the theoretical SNR requirement for the M-QAM signals. This shows that linearization achieved by digital Pre-distorter modeling of prototype non linear power amplifier is approximately equivalent to an ideal linear power amplifier.

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