Closed-Loop Digital Pre-Distortion for Power Amplifier Linearization using Genetic Algorithms

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Abstract

This presentation continues our investigation of genetic pre-distortion algorithms to power amplifier linearization. In previous work, we reported simulation results of an adaptive algorithm that requires only a measure of out-of-band emissions. Compared to traditional algorithms that require wideband feedback, the proposed algorithm is implemented using narrowband feedback, affording a large cost savings in ADC components. This presentation describes the implementation of the genetic algorithm to a laboratory power amplifier and describes linearization results in terms of adjacent and alternate channel leakage ratio and efficiency improvement.
Digital Pre-Distortion

ISL5239 Feedback Architecture

Multi-carrier Baseband IQ Samples

ISL5239 Pre-Distortion Linearizer

DAC → LPF → Power Amp

LO

ADC → LPF → X

DSP

RF Signal

Block Level Architecture and the Genetic Algorithm

Predistorter and power amplifier cascade input/output diagram:

\[ v_i(t) \xrightarrow{f(\cdot)} v_d(t) \xrightarrow{g(\cdot)} v_o(t) \]

Where,

\[ v_o(t) = g \left( |f \left( \left| v_i(t) \right|^2 \right)/v_i(t) \right|^2 \right) f \left( \left| v_i(t) \right|^2 \right) v_i(t) \]

The genetic algorithm creates PD functions that are in the form of:

\[ \hat{f}(\left| v_i(t) \right|^2) = \hat{f}_\alpha \left( \left| v_i(t) \right|^2 \right) e^{jf\phi(\left| v_i(t) \right|^2)} \]
Genetic Algorithm Polynomials

Where amplitude correction is governed through the genetic algorithm by:

\[ f_a(\|v_A(t)\|^2) = (\bar{A}_\Omega + \tilde{A}_\Omega ) + (\bar{B}_\Omega + \tilde{B}_\Omega )|v_A(t)|^2 + (\bar{C}_\Omega + \tilde{C}_\Omega )|v_A(t)|^4 + (\bar{D}_\Omega + \tilde{D}_\Omega )|v_A(t)|^6 \]

And phase correction is governed by:

\[ f_\phi(\|v_\phi(t)\|^2) = (\bar{B}_\Phi + \tilde{B}_\Phi )|v_\phi(t)|^2 + (\bar{C}_\Phi + \tilde{C}_\Phi )|v_\phi(t)|^4 + (\bar{D}_\Phi + \tilde{D}_\Phi )|v_\phi(t)|^6 \]

Genetic Algorithm Process

1. Generate random population of N members.
2. Evaluate the fitness of each member in the population and sort.
3. Generate new population.
   a) Elitism. Select best K members of the current population.
   b) Non-elitism.
      i. Selection. Identify parents by stochastic sampling with replacement.
      ii. Crossover. Apply uniform crossover.
      iii. Mutation.
4. Return to step 2 and repeat for a new population.
Genetic Algorithm Process

Genetic algorithm process showing two iterations, the process is repeated over 20 iterations for our laboratory implementation.

Narrowband Feedback Implementation

The local oscillator is set such that the three-carrier CDMA2000 waveform is centralized at 880MHz.

The narrowband data is collected through the spectrum analyzer and used by the PC to optimize the genetic algorithm solution.
Simulation Results

- The average adjacent and alternate power (ACP) from the genetic algorithm improves from the initial iteration, the average results show an improvement of 9dB.
- The genetic algorithm solution is able to achieve approximately 15dB of ACP.

Conclusions

- The application of genetic algorithms to PA linearization is a new approach to adaptive digital predistortion using narrowband feedback.
- The solution offers high performance and is an attractive alternative to the more expensive feedforward and wideband feedback techniques.