# PSO-Based Optimization Of Sigma-Delta Modulator For Wireless Transreceivers

***Manuscripts***

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## Abstract

Over-sampling sigma-delta analog-to digital converters (ADCs) are one of the key building blocks of state of the art wireless transceivers. Delta-sigma (ΔΣ; or sigma-delta, ΣΔ) modulation is a method for encoding analog signals into digital signals or higher-resolution digital signals into lower-resolution digital signals. The conversion is done using error feedback, where the difference between the two signals is measured and used to improve the conversion. The low-resolution signal typically changes more quickly than the high-resolution signal and it can be filtered to recover the high-resolution signal with little or no loss of fidelity.

The proposed structure has pso - based optimization of $4^{th}$ order sigma-delta modulators for wireless transceivers. The aim of this paper is the identification of the best coefficients suitable for the proposed topology in order to achieve the desired signal-to-noise ratio.GA-based search engine is a stochastic search method which can find the optimum solution within the given constraints. In sigma-delta (ΣΔ) modulator design, GA can be effectively used to optimize the scaling coefficients in order to achieve the desired signal-to-noise ratio. By comparing PSO and GA results the signal to noise ratio in PSO is greater than in GA.

**Keywords:** Genetic Algorithm, PSO, Sigma Delta, Wireless LAN, Analog to Digital Converter.

## Introduction

Now days the world is becoming more and more digital due to the development of digital computing and signal processing. Digital circuits are less sensitive to the disturbances and more robust compared to the analog counterparts. In addition, the digital circuits are easier to integrate on a chip to realize complicated functions. Nevertheless, the signals we are dealing with naturally are analog: voice, image, etc . As a consequence, an interface between analog and digital world is a must to convert an analog signal into a digital signal which we usually refer as analog-to digital convert (ADC). Therefore the ADCs become increasingly the bottleneck in many signal processing systems. Any improvement in the field of the ADCs always leads to system improvements.

There are mainly two classes of ADCs, distinguished according to the ratio of the sampling frequency *fs* and the signal bandwidth fB

[1] Nyquist rate ADCs: fs = 2fB; the flash, the interpolating, the folding, the algorithmic, the successive approximation register (SAR), the pipelined ADCs belong to Nyquist rate ADC.

[2]Oversampling ADCs: fs equals multiple (>2) fB; The sigma- delta, error feedback ADC belong to this class.

## 1.Modulator Architecture

This Section explores tradeoffs among the wide variety of ΣΔ modulator architectures that can be used to implementation ΣΔ A/D converter suitable for low power and high integration WLAN standard receiver. The search for an optimal wideband ΣΔ topology has been performed by varying the order L, the oversampling ratio M and the number of bits B in the quantizer.

Sigma-Delta ADCs or ΣΔADCs are based on the principle that the input signal is oversampled and the quantization noise is shaped and later removed by digital filters. A more efficient way is to shape the quantization noise up to higher frequency, i.e. less quantization noise remains in the band of interest while higher at the out of band. Therefore, the number of bits in the loop can be less than that in a Nyquist ADC.A system that can do this is known as a sigma-delta modulator.

A sigma-delta modulator has three important components.

- A loop filter *H*(*z*)
- An internal quantizer
- A feedback digital-to-analog converter (DAC)

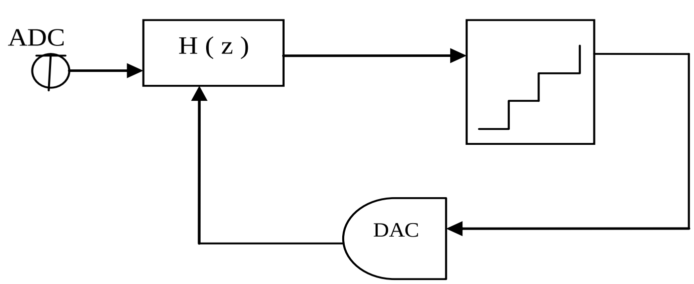


Fig.1.1 sigma-delta modulator components

### 1.1Figures

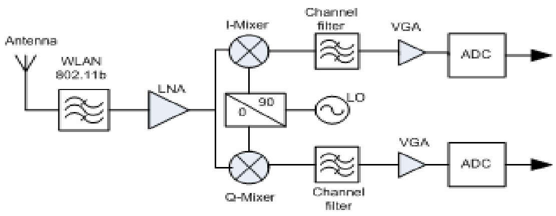


*Fig.1.2 Zero-IF Receiver Architecture.*

### 1.2Tables

*Table1.1Comparison of gain coefficients with and without GA*

| | *Coeffieients* | *Peak SNR* | *Peak SNDR* |
|---|---|---|---|
| *Without GA* | *g1=0.5,g2=0.5,g3=4,g4=4* | *60dB* | *55.9dB* |
| *With GA* | *g1=0.325,g2=0.7646, g3=4.023,g4=6.1538* | *66dB* | *61dB* |

## 2. GA-Based Coefficient Optimization

### *2.1 Genetic Algorithm*

GAs are search and optimization algorithms based on the mechanics of natural selection and natural genetics[7]. They make use of structured but randomized information exchange and concept of the survival of the fittest. The algorithm starts with an initial population which consists of a collection of chromosomes i.e. possible solutions coded in the form of strings.

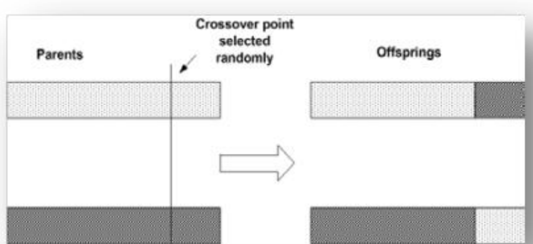


Fig.2.1Single-point crossover process

The chromosome which produces the minimum error function value represents the best solution. The chromosomes which represent the better solutions are selected using roulette wheel selection technique. Genetic operators like crossover, mutation , elitism etc. are applied over the selected chromosomes .As a result a new set of chromosome is produced.

This process is repeated until a fit solution appears. In essence, a population of chromosomes is always available to get the desired result. Occasionally a new part is added to a chromosome to make it more robust. Genetic algorithms exploit past to extrapolate new search points to provide improved performance.

The steps involved in the process of optimization using GA there are two general schemes for coding the solutions: (i) binary coding (ii) decimal coding. In our work, binary coding has been used where 0s and 1s are used to form a chromosome of length l depending on the precision needed. The next step, called pairing, consists of selecting the chromosomes that will pair together to reproduce the offsprings. This is done by using roulette wheel selection technique. These pairs will be used for reproduction. Reproduction ensures that chromosomes with higher fitness will have a higher probability of reproduction than chromosomes with lower fitness. Reproduction is the application of crossover, mutation and elitism operators over the selected chromosomes.

Mutation rate (MR) is set to a very low value. A high MR introduces high diversity but might cause instability However, a very low MR makes it difficult for the GA to find a global optimal solution. In addition to crossover and mutation the best chromosome present in a particular generation is passed on to the next generation so that it will not be lost until the next best arrives. In this way the stability of the GA is improved. A fitness function or objective function has to be obtained to evaluate the performance of the chromosomes and compare their performance. In the design of sigma-delta modulator we need to optimize the coefficients for a maximum signal-to-noise ratio (SNR). Hence the fitness function is formulated as

$$\text{fitness} = (1/\text{Error})$$

where

$$\text{Error} = \text{Desired SNR} - \text{Obtained SNR}$$

After evaluating the fitness function, fitness values will be assigned to each chromosome. If the best fit chromosome has arrived, the GA can be stopped and the coefficient values can be decoded. Otherwise the chromosomes are sent back to the selection module and the whole procedure is repeated again until the best arrives or the maximum number of generation set is reached. It is to be noted that the number of chromosomes should not be very small or very high.

### 3. Simulation Results

A fourth-order sigma-delta feed forward topology has been chosen as the first design example in which simulations were performed for both using ideal and real integrator blocksAt the end of the 20th generation,the optimum values of the coefficients were obtained as g1 = 0.325, g2 = 0.7646, g3 = 4.023, g4 = 6.1538. After 20 generations, the optimum value

IJERT

ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

for g1 was found to be 0.325 for which the peak SNDR was 64 dB. Table1.1 shows that there is almost a 6dB increase or 1-bit resolution in both SNR and SNDR after using GA-based optimization technique.

**Simulation Parameters**

Fs (Hz) =11289600, Ts(s)=8.857710e008,
Fin (Hz) =11714.0625
BW (Hz) =22050, OSR=256,
Npoints=16384, tsim(sec) =0.001
Nperiods=17.000, SNR (dB) =59.831,
Simulation time =0.509 min

Simulations were performed using an OSR of 256 for a bandwidth of 22.05 MHz. Fig.3.1shows the modulator output spectrum for a 11714.0625(Hz)input signal. As shown in Fig.3.2, the peak SNR achieved was found to be 60.8 dB with a finite dc gain of 60 dB, slew rate of at least 200$V/\mu s$ and a gain-bandwith product of 350 MHZ.

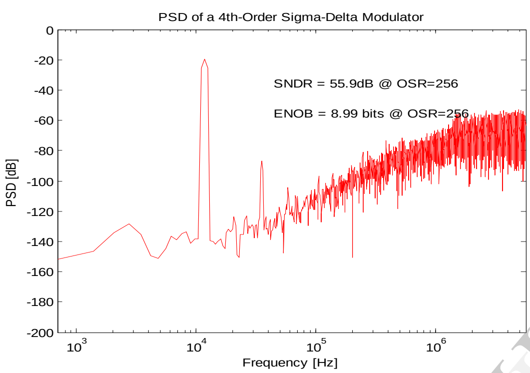


Fig.3.1 PSD of a 4th-Order Sigma-Delta Modulator

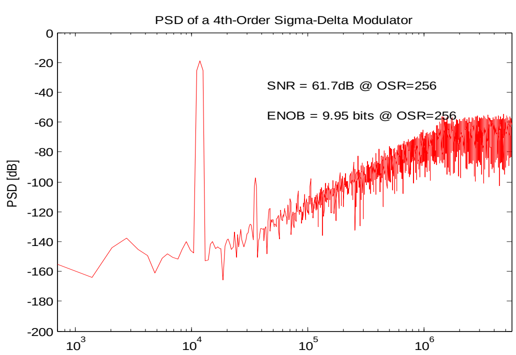


Fig3.2 Modulator output spectrum for WLAN with GA

Fig.3.3 presents the simulated SNDR versus input signal amplitude for WLAN. Simulation results show a peak SNDR of 55.9 dB @ -6dBFS without using GA and 61 dB @ -4dBFS after optimizing the coefficients using GA in the WLAN mode.

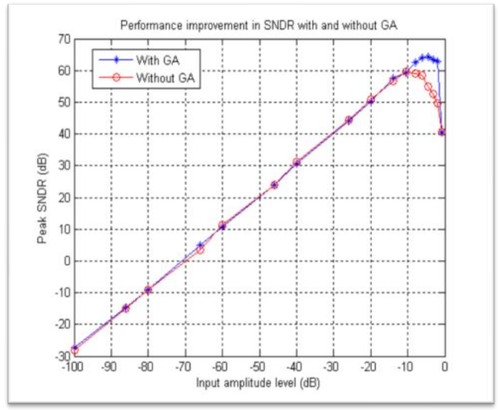


Fig3.3 SNDR versus input signal amplitude with and GA

## *4. Particle Swarm Optimization*

PSO is originally attributed to Kennedy, Eberhart and Shi and was first intended for simulating social behaviour,as a stylized representation of the movement of organisms in a bird flock orfish school. The algorithm was simplified and it was observed to be performing optimization.

A basic variant of the PSO algorithm works by having a population (called a swarm) of candidate solutions (called particles). These particles are moved around in the search-space according to a few simple formulae. The movements of the particles are guided by their own best known position in the search-space as well as the entire swarm's best known position. When improved positions are being discovered these will then come to guide the movements of the swarm. The process is repeated and by doing so it is hoped, but not guaranteed, that a satisfactory solution will eventually be discovered.

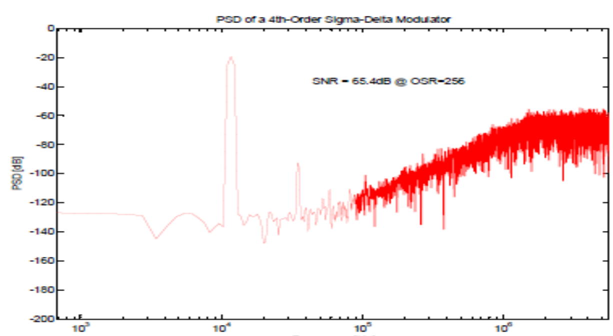


Fig3.4 Modulator output spectrum for WLAN with PSO

IJERT

ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

## *5. Conclusions*

A GA-based search engine is developed for the quick and easy design of sigma-delta modulators. The genetic algorithm based search engine can effectively search for solutions with different characteristics and enables tradeoffs between different design considerations. It has been successfully used to improve the performance of a 2-2 cascaded feed forward sigma-delta ADC which is proposed for WLAN applications. The coefficients were optimized using GA which results in extended dynamic range. Design examples and numerical results demonstrate the effectiveness of our proposed method. By comparing PSO and GA results the signal to noise ratio in PSO is greater than in GA.

### 1. Equations

1. $OSR = fs/2Fb$

2. $Y(z) = H(z)/1 + H(z).X(z) + 1/1 + H(z).Q(z)$
$= STF(z).X(z) + NTF(z).Q(z)$

where $STF(z)$ and $NTF(z)$ is the signal transfer function (STF) and noise transfer function (NTF), respectively.

3. $SNR[dB] = 10 log10(SNR) = 6.02N + 1.76(dB)$

Hence the $SNR[dB]$ is increased by 6 dB for every additional bit in a data converter.

4. $ENOB$ = SNDR[db]-1.76/60.2

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