Applied Mathematics and Computation 258 (2015) 436–453

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

Clustered-gravitational search algorithm and its application in parameter optimization of a low noise amplifier

Masumeh Shams [a,*], Esmat Rashedi [a], Ahmad Hakimi [b]

[a] Electrical Engineering Department, Graduate University of Advanced technology, P.O. Box 76315-117, Kerman, Iran
[b] Electrical Engineering Department, Shahid Bahonar University, P.O. Box 76169-133, Kerman, Iran

ARTICLE INFO

Keywords:
Optimization
Gravitational search algorithm
Clustered-GSA
Multi-objective problems
Low noise amplifier

ABSTRACT

Gravitational search algorithm (GSA) is a recent introduced algorithm which is inspired by law of gravity and mass interactions. In this paper, a novel version of GSA, named Clustered-GSA, is proposed to reduce complexity and computation of the standard GSA. This algorithm is originated from calculating central mass of a system in nature and improves the ability of GSA by reducing the number of objective function evaluations. Clustered-GSA is evaluated on two sets of standard benchmark functions and the results are compared with several heuristic algorithms and a deterministic optimization algorithm. Experimental results show that by using Clustered-GSA, better results are achieved with lower complexity. Moreover, the proposed algorithm is used to optimize the parameters of a Low Noise Amplifier (LNA) in order to achieve the required specifications. LNA is the first stage in a receiver after the antenna. The main performance characteristics of receivers are dictated by the LNA performance. It is necessary to study, design, and optimize all the elements included in the structure, simultaneously. The comparative results show the efficiency of the proposed algorithm.

1. Introduction

Optimization plays an important role on both industrial application and the scientific research. During the past decade, significant progresses on tackling optimization problems have been viewed and different kinds of methods have been employed to handle optimization problems. Generally, optimization methods can be divided into two groups: deterministic methods and meta-heuristic methods. Various mathematical programming methods such as linear programming, nonlinear programming, quadratic programming, and Direct (DIviding RECTangles) algorithm have been proposed [1–3]. These methods are classical optimization methods which usually use gradient information to search the solution space near an initial starting point. Furthermore, in these methods, the problem should be defined in a continuous space, while many optimization problems such as engineering problems are defined in discrete spaces [2]. Prohibited zones, side limits, and non-smooth or non-convex objective functions are some other considerations in optimization problems which cannot be solved by the traditional mathematical programming methods [2,4]. Moreover, in complicated problems, deterministic methods does not provide satisfactory solutions [5,6].

As an alternative to the conventional mathematical approaches, the meta-heuristic optimization techniques have been utilized to obtain global or near-global optimum solutions [4]. These methods are consisted of a group of search agents that

* Corresponding author.
E-mail address: Shams910702@yahoo.com (M. Shams).

http://dx.doi.org/10.1016/j.amc.2015.02.020
0096-3003/

explore the feasible region in the search space based on both randomization and some specified rules usually inspired by natural phenomena laws [2]. These approximation methods employ probabilistic transition rules instead of deterministic ones and alleviate the need for the derivatives of the objective function and constraints used for mathematical optimization methods. These methods are quite suitable for global searches and offer good (near-optimal) solutions in an affordable time [4].

Some of the most famous heuristic algorithms are Genetic Algorithm [7], Simulated Annealing (SA; [8]), Ant Colony Search Algorithm (ACSA; [9]), Particle Swarm Optimization (PSO; [10]), gravitational search algorithm (GSA; [5]), etc.

These optimization algorithms have optimized different engineering designed problems such as control problems, power system problems, and electrical engineering problems. Ref [11] has considered an applied problem of analysis and the security of stability of systems with an uncertainty. In [12], the problem of global tuning of fuzzy power-system stabilizers (FPSSs) present in a multi-machine power system has been considered. One of the popular optimization problems in electrical engineering is LNA parameter optimization which is brought into focus in [13–26].

LNA stands for low noise amplifier. It is the first stage in a receiver after the antenna and determines the overall system sensitivity [27]. The LNA design has several common goals such as enough gain, low noise figure, good matching, high linearity, and/or low power. Due to the trade-off between these goals, LNA designing is a multi-objective problem and forces designers to optimize the conflicting parameters. Also, complicated and approximate relations make the designing difficult and time-consuming. Hence, the designers must rely on their own knowledge and experiment different parameters to obtain desirable results [14]. Furthermore, the main performance characteristics of receivers are dictated by the LNA performance. So, the LNA should be considered as a whole rather than a single block and all the elements included in the structure must be studied, designed and optimized, simultaneously.

Without an automated synthesis methodology, LNA design suffers from long time design, complex design process, high production cost and pressing need of skilled designers [25,28]. This challenge motivates us to use a combination of high quality Computer Aided Design (CAD) tools and an efficient multi-objective optimization algorithm to design a LNA.

In this paper, the power of gravitational search algorithm (GSA) is assessed in LNA parameter optimization. To improve the efficiency of the GSA and reduce the computation complexity, a new version of GSA, named Clustered-GSA (CGSA), is introduced. Next, the proposed algorithm is used to optimize the parameter setting for a low noise amplifier in order to achieve the required specifications in terms of S-parameters (S_{21}, S_{11}, S_{22}, and S_{12}) and the minimum noise figure (NF_{min}).

The structure of the paper is as follows: Section 2 reviews the related works in LNA optimization. In Section 3, key concepts of Clustered-GSA are discussed. Section 4 introduces the proposed method for parameter optimization of a LNA using CAD tool. The performance evaluation of the proposed algorithm, the comparative results for benchmark functions and the LNA optimization results are in Section 5. Finally, the paper is concluded in Section 6.

2. LNA optimization using heuristic search algorithms

Recently, several articles have been reported in LNA parameter optimization using heuristic search algorithms and Computer-Aided Design (CAD) tools [13–26]. Some heuristic search algorithms used in these studies are Genetic algorithm (GA), Simulated Annealing (SA), Particle swarm optimization (PSO), and modified versions of these algorithms. The CAD tool used for LNA optimization is usually the combination of a heuristic algorithm and a simulator. Up to the author's knowledge, there are two types of CAD tools used to optimize the LNA design. One of them is the combination of a heuristic search algorithm usually implemented in MATLAB and Agilent Advanced Design System (ADS) as circuit simulator [15–26]. Although, ADS consists of various built-in optimizers, it is difficult to incorporate external developed optimizers into the ADS system. Owing to software incompatibility between MATLAB and the ADS, the evolutionary search is conducted offline [16]. The second CAD

Table 1
Previous works in LNA optimization using heuristic search algorithms and simulators.

Article	Heuristic search algorithm	Simulator
[15]	GA, SA, LM[2]	ADS
[16]	IGA[a]	ADS
[17]	Layered encoding structure using combination of GA and PSO	ADS
[18]	GA	ADS
[19]	MOPSO-CD[b]and NSGA-II[c]	ADS
[20]	PSO	_
[21]	Combination of GA and multi objective PSO (programmed in C++ software)	ADS
[14]	GA, LM	Hspice
[22]	Modified genetic algorithm and PSO	Hspice RF
[23]	Genetic algorithm and Multi-Objective PSO	Hspice RF
[24]	Multi objective genetic algorithm	Hspice RF
[25]	NSGA-II	Hspice RF
[26]	Pareto-based multi-objective genetic algorithm	Hspice RF

[a] Interactive genetic algorithm.
[b] Multi-Objective Optimization algorithm PSO incorporating the mechanism of the crowding distance technique.
[c] Non-dominated sorting genetic algorithm.