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REGULAR PAPER

Design of load-ended spiral antennas for RFID UHF passive tags using improved artificial bee colony algorithm

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ABSTRACT

In this paper, new planar spiral antennas for passive RFID tag application at UHF band are designed and optimized using a new artificial bee colony (ABC) algorithm. We apply the improved ABC (I-ABC), which is an improved version of the original ABC algorithm. The I-ABC introduces the best-so-far solution, inertia weight and acceleration coefficients to modify the search process. The optimization goals are antenna size minimization, gain maximization and conjugate matching. The antenna dimensions were optimized and evaluated using I-ABC in conjunction with commercial EM software. We compare the I-ABC with the original ABC algorithm. The obtained results show that both algorithms are powerful optimizers that can be efficiently applied to tag antenna design problems. I-ABC produces better results than the original ABC algorithm in terms of solution accuracy and success rate. RFID tags with dimensions less than 3 cm, maximum gain that reaches the value of 1.46 dBi and read distance more than 10 m were among those obtained by the algorithm.

1. Introduction

The radiofrequency identification (RFID) technology is known for more than two decades but has been used extensively as far as in the last decade. Nowadays the RFID technology providing automated wireless identification and tracking capability and being more robust than the barcode system, has shown a commercial worldwide deployment following frequency allocation in the UHF band, ranging from 860 MHz to 950 MHz. An ordinary RFID system comprises of at least, a reader (interrogator) with a reader antenna [1,2], tags (transponders) which are microchips combined with an antenna in a compact package, a host computer and middleware including software and data base. Tag antennas are crucial elements for the good performance of an RFID network. The basic task of a tag antenna designer is to obtain high efficiency and effective impedance matching to IC chips with typically capacitive reactance [3–6].

These antenna requirements are essential to optimize the RFID system power performance, especially for passive configurations where the only energy source is the incoming reader energy. The antenna designer is confronted with two major problems. The first is the antenna miniaturization, which opposes to the desired attribute of relatively high gain and the second is the fact that the tag antenna has to be conjugate matched to the capacitive reactance of the IC. The first of these problems could be solved by selecting the shape of the printed structure in a way that it would be improvable with respect to its size. The second problem could be solved by changing the geometrical parameters of the antenna via the ordinary trial and error method or by employing an algorithm of optimization.

Various geometrical configurations have been employed for the design of antennas of this kind and have been proved effective in giving to them the required characteristics of operation. In the present work, the spiral shaped antenna printed on a dielectric slab was selected because this geometry has the attribute to fill the space it occupies. Thus, it has small size and at the same time has long length that is capable of resonating at small frequencies. Moreover, this configuration has several geometrical parameters, which could assist the optimization algorithm to find a good solution. In addition to these parameters a novel one was selected with intend to be employed at the effort to minimize the antenna's size and to conjugate match it with the IC. We consider that the spiral is not open-ended, as it is usually found in the literature, but load-ended. The load layout parameters are additional geometrical parameters that also contribute to the design process.

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Several RFID design cases can be found in the literature [7–12]. Most of these use a trial and error procedure for selecting the antenna geometry. Evolutionary algorithms (EAs) are suitable optimization tools for solving the above-described design problem. Genetic algorithms (GA) and ant colony optimization (ACO) have been applied successfully to RFID antenna design [13–15]. The artificial bee colony (ABC) algorithm [16] models the foraging behavior of honey bee swarm. The ABC algorithm has been applied successfully to RFID tag design [17]. In this paper, we extend our earlier work [17–19]. We apply a recently proposed ABC variant, the Improved ABC (I-ABC) [20] to load-ended spiral antennas design. The I-ABC introduces the best-so-far solution, inertia weight and acceleration coefficients to modify the search process. To best of the authors' knowledge, this is the first time that the I-ABC algorithm is applied to an electromagnetics design problem. We compare the I-ABC with the original ABC algorithm on two design cases using two different objective functions. The results show that I-ABC outperforms the original ABC algorithm.

2. Artificial bee colony algorithm

The ABC algorithm models and simulates the honey bee behavior in food foraging. In ABC algorithm, a potential solution to the optimization problem is represented by the position of a food source while the nectar amount of a food source corresponds to the quality (objective function fitness) of the associated solution. For population-based optimization algorithms, both exploration and exploitation are necessary. The exploration refers to the ability to investigate the various unknown regions in the solution space to discover the global optimum, while, the exploitation refers to the ability to apply the knowledge of the previous good solutions to find better solutions [10].

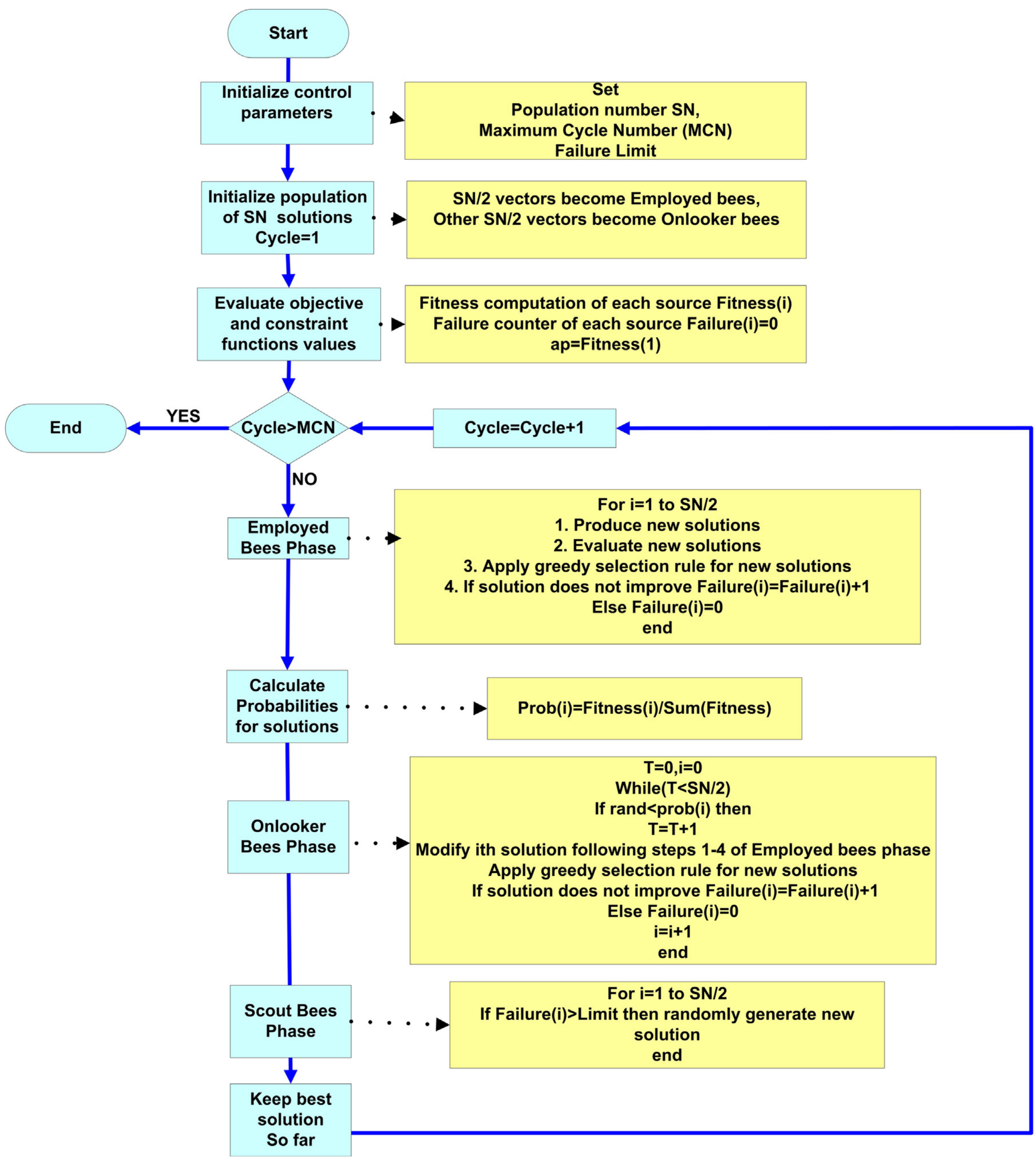

Fig. 1. I-ABC flowchart.