New Compact Dual-Band Circularly Polarized Universal RFID Reader Antenna Using Ramped Convergence Particle Swarm Optimization

Salehin Kibria, Mohammad Tariqul Islam, *Senior Member, IEEE*, and Baharuddin Yatim

***Abstract*—A new ramped convergence particle swarm optimization (RCPSO) algorithm to design radio frequency identification (RFID) reader antenna for gain optimization is presented in this paper. The algorithm breaks down the optimization problem by considering only a subset of dimensions at a time, hence overcoming curse of dimensionality. It uses a multi-start approach that alleviates premature convergence. It applies heterogeneous boundary conditions to errant particles. In this paper, the effectiveness of using RCPSO for RFID reader antenna design will be investigated by a number of iterations required to achieve optimum solution along with the quality of solution. RCPSO is built specifically for antenna design. For the microstrip antenna, a significant bandwidth improvement is achieved and the overall antenna dimensions are kept practically the same. The circular gain improves by a significant 2 dBiC over super high frequency (SHF).**

***Index Terms*—Circular-polarization, optimization, ramped convergence particle swarm optimization (RCPSO), reader antenna, radio frequency identification (RFID).**

I. Introduction

RFID technology is used as an industry staple for short-range communication for applications like inventory management and supply chain monitoring [1]–[8]. Hence there has been a worldwide thrust to improve on RFID technology. Particle swarm optimization (PSO) was first presented in the mid-nineties [9]. Numerous applications have been found since the algorithm's inception like antenna design [10]. In [10], an extensive analysis on PSO is conducted for various benchmark functions and problems. It illustrates the techniques for handling particles that wander out of the search space. It establishes the "invisible wall technique" to be the best of the lot but fails to explain why. In this paper, some fundamental axioms were inferred from [10] about these walls' performances, and a hybrid implementation was concocted. RFID reader antennae require high gain, compactness, and low axial ratio. These result in higher read ranges, alleviating any constraint on tag orientation and ease of mounting on portable devices. Microstrip antennae have a low profile and are compact enough to be placed on mobile communication units [11]. Further, edge-fed microstrip antenna can be fabricated on the system printed circuit board itself. Microstrip antennae suffer inherently from low gain and narrow bandwidth. It may thus be interpreted as an optimization problem to design a microstrip RFID reader antenna.

Ramped convergence PSO, or RCPSO, is practically free of prejudice regarding the antenna or its properties [12]. While the underlying phenomena of patch antennae are understood, it is hard to extend them to complex geometric shapes and parametric analyses. Thus, RCPSO implements a multi-start algorithm as premature convergence is a key drawback with PSO. It has been named ramped convergence PSO, or RCPSO. It breaks down the search space to a two- or three-dimensional space and applies a rapid convergence PSO to it. The process is repeated for the next set of dimensions in the optimization problem.

In [13], a 200 mm by 200 mm by 20 mm multilayer multi-patch antenna with an intricate feeding technique is presented. It achieves significantly high gain of 5.3–7.3 dBiC and 6.7–7.6 dBiC for the ultra high frequency (UHF) and SHF bands, respectively. It has a complex feeding structure and is rather bulky. This size makes it too large to be fitted onto handheld devices. Such devices usually implement planar antennae for compactness.

The study conducted in [14] shows the implementation of RCPSO to optimize planner dual-frequency RFID reader antenna. The initial design was optimized to maximize the linear gain at the UHF and SHF bands. RFID applications require circular polarization, but the antenna proposed in [14] does not achieve optimum circular polarization characteristics. The simulated gains presented in [14] were 2.9 dBi and 5.5 dBi.

In this paper, the performance of the RCPSO algorithm is evaluated by comparing the optimized RFID reader antenna with the initial design in terms of circular polarization gain. Conventional optimization techniques like classical PSO and genetic algorithm are prone to premature convergence and curse of dimensionality. There are other algorithms available that overcome these problems by increasing the algorithm complexity. The additional complexity results in difficulty in

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S. Kibria and B. Yatim are with the Center for Space Science (ANGKASA), Universiti Kebangsaan Malaysia, Bangi, Selangor D. E. 43600, Malaysia (e-mail: sakib2005@yahoo.com; baha@ukm.my).

M. T. Islam was with the Center for Space Science (ANGKASA), Universiti Kebangsaan Malaysia, Bangi, Selangor D. E. 43600, Malaysia. He is now with the Department of Electrical, Electronic and Systems Engineering (JKEES), Universiti Kebangsaan Malaysia (e-mail: titareq@gmail.com).

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