Automatic Optimization of Single-Chip UHF RFID Tags

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Abstract

The automatic optimization is presented of the passive RF part of RFID, with special attention to single-chip UHF tags, and to the novel concept of RFID grids. The presented approach employs an optimization based on the Genetic Algorithm, and an efficient electromagnetic problem parameterization and novel solution strategy. A practical application example shows increase in overall performance.

Keywords: Genetic Algorithm, RFID, Tag Antenna, Method of Moments

1. Introduction

The Radio-Frequency Identification Technology (RFID) for object tracking¹ is rapidly evolving towards the “Internet of Things”²-³: the convergence of a number of research fields (identification, real-time localization, sensor networks, pervasive computing, applications and systems based on RFID) that enable the Internet to get into the real world of physical objects interacting with web services.

The challenges to the design of the current- and next-generation RFID have spurred a significant research over the past few years, and the availability of low-cost chips has prompted the study of UHF tags with single or multi-chips built-in.

In this context, electromagnetic (EM) theory has recently renovated antenna and radiation concepts into expanding the capabilities of RFID. As an interesting example, there is a research work on RFID grid paradigm recently published¹.

2. Tag Functional Optimization

Recent realizations of single- and multi-chip and grid types of tags have shown the need for optimizing the EM properties of the passive part of the tag, also for performance robustness. Along this line, we have made an effort to design this passive part via automatic optimization, yet keeping the information on the chip(s) directly in the process (linear behavior considered, as usual). Antenna optimization has been a constant effort in the last years, and we employ here the approach devised in⁴, which explored the combination of genetic algorithm (GA) and method of moments (MoM). This approach is especially useful for electrically small antennas, and since it mainly considered multi-port structures, however, re-configurability is well suited for the present endeavor as well.

The passive part (metallization) of the multi-chip tag is automatically designed to optimize the global parameters introduced and discussed in⁴, rather than individual radiation or impedance matching, which is a novel approach. The global parameter is named embedded realized gain and it closely integrates parameters like impedance matching, gain and polarization factor into a single parameter.

In this contribution, the optimization of embedded gain for single-chip UHF RFID-tag antenna is emphasized. Consistency checks against previous partial optimization of tags⁵ have been preliminarily carried out. The obtained results show detailed structure, as often with automatic optimization, and efforts were done to keep complexity within fabrication process requirement. Due to the fact that in our work GA usually generates non intuitive output...
structures, which brings inconvenience for fabrication, there was made a trial to mitigate the structural complexity of the individuals by means of imposing constraints within the optimizer and examining the structure after optimization, assuming that the performance of the output structures should not degrade too much. One output structure was fabricated and measured; comparisons were then made between the measured and simulated results to verify the feasibility of our approach.

3. Single-Port UHF RFID-tag Antenna

In research paper1, authors introduce the concept “grid”, which represents a generally coupled multitude of UHF tags, including standalone tags in close mutual proximity as well as tags with a multiplicity of embedded RFID microchip transponders able to achieve advanced capabilities such as redundancy and sensing; also it has been fully investigated as an EM interconnected system. In the following research work, the initial formation of grid, i.e., a tag with single-chip has been discussed; this tag might be handled as a single-port antenna. Considering the design of RFID tag antenna, dipole-like antenna is always preferred as an excellent choice due to some important factors such as simplicity, light weight, and low-cost. A prototype of a single-port tag antenna working in UHF band (840-960 MHz) is presented in Figure 1, which is derived from6. We would like to optimize this single-port RFID tag antenna such that it can be applied for monitoring the luggage in airports, with the help of a small piece of shape memory alloy.

4. An Optimization Example

As it can be seen from Figure 1, the single-port antenna made up of two major parts: the blue part is always unchanged during the GA optimization while the green part (which is divided into small squares) will experience modifications, providing the possibility of generating the desired structure. In this specific example, the antenna structure with optimal embedded realized gain is desired, which means that antenna has an optimal performance regarding reading range.

The optimization goes in a pixel-scale way, i.e., each individual generated by GA is obtained by means of taking away some corresponding squares from the prototype. The result is plotted in Figure 2, and lines are represented in a following way: the blue line is the result in7, and the red line is the result obtained after our optimization, and it can be observed clearly that significant improvement has been achieved. More complicated optimization problems including the increase of number of ports and observation angles can be extended from this simple case.

Next figure represents the convergence curve of fitness value versus number of generations is presented. A similar EM characteristics analysis is applied to the final design in7, whose fitness value is found to be around 20 after computation. However, in our case, we just run the code for 10 generations. From Figure 3, we can see that the GA can evolve towards much smaller fitness value, hence better structures; the monotonically decreasing feature of the curve is due to the introduction of elitism, which ensures that the smallest fitness value in the next generation will be no larger than the corresponding value in the previous generation.

![Figure 1](image1.png)  **Figure 1.** Prototype of RFID-tag optimization.

![Figure 2](image2.png)  **Figure 2.** Embedded realized gain (G) comparison.
5. Conclusion

Optimization of single-port UHF RFID tag antenna is proposed in this research work, focusing on novel developed concept of RFID Grid, which includes the embedded realized gain concepts along with other innovative metrics. GA combined with MoMIs employed as the optimization approach. In the test optimization example a significant performance improvement has been achieved comparing to previous result.

6. References