Meander-line Antenna Design for UHF RFID Tag Using a Genetic Algorithm

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Abstract— In this paper, a simple planar meander-line tag antenna for RFID application at UHF band designed and optimized using genetic algorithms (GA). The meander-line tag antenna dimensions were optimized and evaluated using GA in collaboration with NEC-2 source code. Configuration of optimal antenna with excellent impedance value at 900 MHz frequency band was found within the maximum generation. The simulated input impedance of the GA-optimised tag antenna has shown good agreement with the targeted impedance value. Moreover, the capabilities of GA are shown as an efficient optimisation tool for selecting globally optimal parameters to be used in simulations with an electromagnetic antenna design code, seeking convergence to designated specifications.

1. INTRODUCTION

In recent years Radio Frequency Identification (RFID) has become very popular in many commercial applications such as access control, animal tracking, security, and toll collection, because of its ability to track moving objects and its low-cost implementation [1, 2]. A typical RFID system is always made up of two components, including the tags (transponders) and readers (interrogators). A tag comprises an antenna and an application-specific integrated circuit (ASIC, or microchip) that is given a unique electronic product code. The antennas, as a key part of the system, enable the tag or reader to send and receive the signals. Readers are devices that read tags, and they equipped with antennas, a transceiver, and a processor (server with software system). The tag antenna design is quite challenging. This is because tag antenna is required directly connected to the tag IC, whose input impedance always presents capacitive reactance in nature. It means that the reactance part of tag antenna has to be designed and optimised to be complex conjugate impedance of tag IC in order to realize the maximum transmission using RF power induced from the antenna tag.

In this paper, an approach of using Genetic Algorithm (GA) in cooperation with an electromagnetic simulator was adopted to design and optimise the RFID tag antenna for UHF band. The benefit of applying GA is that it provides fast, accurate and reliable solutions for antenna structures. Genetic algorithm driver [3], written in Fortran, was adopted in this work in conjunction with the industry-standard NEC-2 Fortran source code [4], which was used to evaluate the randomly generated antenna samples. A meander-line antenna configuration was proposed in this study in order to achieve a tag design with compact size at UHF band. A Higgs IC [5], designed to follow EPCglobal Class-1 Gen-2 specification, was selected for the tag IC, input impedance of which was found to be $(12.2 - j135)\,\Omega$ at 900 MHz.

2. GENETIC ALGORITHM

Genetic algorithms are stochastic search procedures orchestrated by natural genetics, selection and evolution. They are modelled on Darwinian concepts of natural evolution thus making them more inspiring during use [6]. After it's first introduction in 1960's by J. Holland, it has become an efficient tool for search, optimization and machine learning, but in the pre-GA era, concepts of it had been looming and applied in game playing and pattern recognition [7]. Over the recent years, it has proven to be a promising technique for different optimizations, designs and control applications.

An approach of using GA in cooperation with an electromagnetic simulator has been introduced for antenna designs and has become increasingly popular recently [8]. For example, GA have been employed to design wire antennas [9, 10] and microstrip antennas [11]. The benefit of applying GA is that they provide fast, accurate and reliable solutions for antenna structures. Genetic algorithm driver [3], written in Fortran, was adopted in this work in conjunction with the industry-standard NEC-2 Fortran source code [4], which was used to evaluate the randomly generated antenna samples.

Several antenna designs using GA in authors' previous study [12, 13] has shown that the GA was successfully proved as an efficient optimizer tool that can be adopted and used to search and find the quicker solutions for complex antenna design geometries.

A flow chart to represent the easiest way in which the GA optimizer coordinates its functions is represented in Fig. 1. The algorithm randomly initiates its population and converts the parameters of the initiated individuals into a file in a card format which can be called by NEC-2 to determine the performance of these individuals. The results from NEC-2 are fed again to the GA engine to evaluate individual fitness if the maximum value is obtained for convergence, if otherwise the whole process is repeated until optimal results are produced.

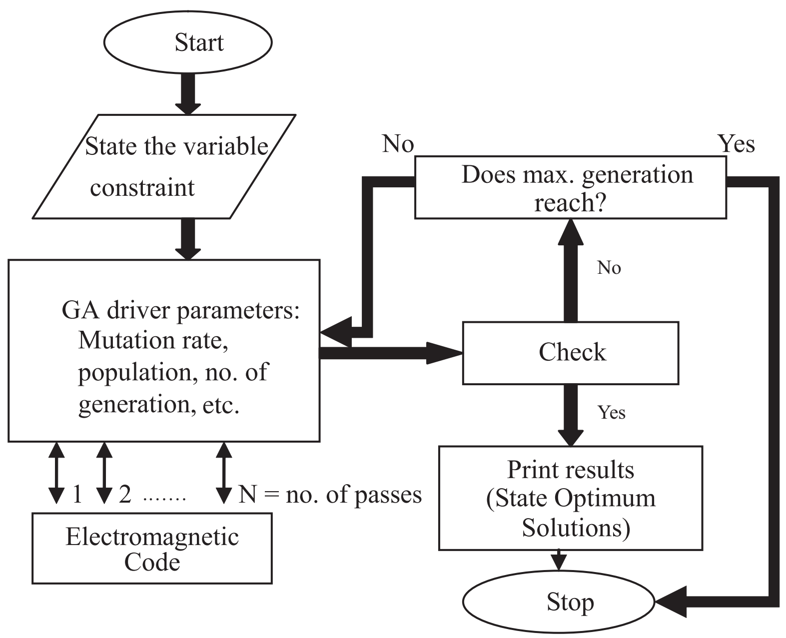

Figure 1: Flow chart of the genetic algorithm adopted in this study.

3. SIMULATION RESULTS AND DISCUSSION

A meander-line antenna configuration, as shown in Fig. 2, was proposed in this study in order to achieve a tag design with compact size at UHF band. Moreover, a paralleled meander line arrangement was used to enhance the impedance bandwidth for the proposed design. A Higgs IC [5], designed to follow EPCglobal Class-1 Gen-2 specification, was selected for the tag IC, input impedance of which was found to be $(12.2 - j135)\,\Omega$ at 900 MHz.

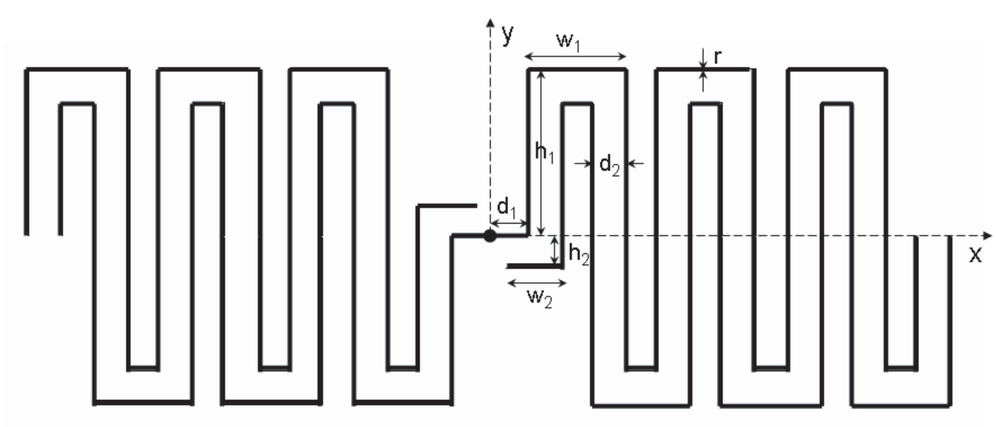

Figure 2: The new RFID antenna tag model.

Table 1 presents the GA input parameters in which the possible range of parameters magnitudes were shown. There are seven parameters used to define the proposed tag antenna, including a matching circuit (i.e., parameters w_2 and h_2). For this optimisation, real-valued GA chromosomes were used. The optimisation of input impedance of the proposed tag antenna at 900 MHz band is considered inside the GA cost function. The randomly generated antenna configurations were evaluated for maximum fitness using a cost function. The computation time consumed for each of the erratically generated antenna samples only took a few seconds, according to the different combination of length, width and height of the patch antenna selected for comprising the antenna configuration. This was achieved by using a PC: 2.8 Pentium IV of 1 GB RAM.

Table 1: Summary of GA input parameters, antenna variables and best solutions.

GA parameters	GA-optimised RFID passive tag antenna	
	Parameters (m)	Optimal (m)
	Feeding wire length (d_1) (0.0025–0.0025)	0.0025
No. of population size = 4,	Spacing between wires (d_2) (0.001–0.003)	0.00222
No. of parameters = 7,	Outer wire width (w_1) (0.006–0.01)	0.00651
Probability of mutation = 0.02,	Matching wire width (w_2) (0.0015–0.0055)	0.00372
Maximum generation = 250,	Outer wire height (h_1) (0.005–0.015)	0.01110
No. of possibilities = 32768,	Matching wire height (h_2) (0.001–0.003)	0.00214
	Wire radius (r) (0.0002–0.0002)	0.0002

The geometry configuration of the optimal antenna was found within the maximum generations and the best solutions are listed in Table 1. It is notable the overall dimension ($l \times w$) of the optimal tag antenna is 62×22 mm. The obtained input impedance of the optimal tag antenna was found to be $(10.5+j135.2)\,\Omega$. For validation, the performance of the GA-optimised tag antenna was evaluated and validated with another commercial EM simulator and simulated results of the antenna input impedance from 800 MHz to 1000 MHz was analysed and presented in Fig. 3. Moreover, comparison of the simulated return loss of the GA-optimised RFID tag antenna was shown in Fig. 4. As can be seen, the optimal tag antenna features wide impedance bandwidth with respect to the tag IC impedance and enables to fully cover the allocated UHF frequency band for RFID application from 860 MHz to 960 MHz. Radiation patterns of the proposed tag antenna were also investigated. The radiation patterns in the zx plane and zy plane at 900 MHz were studied and the corresponding normalised results were presented in Fig. 5. As can be see, the optimal antenna has a dipole-like pattern, as expected. The maximum antenna gain was found to about 1.5 dB. The results are encouraging for practical implementation of this tag antenna.

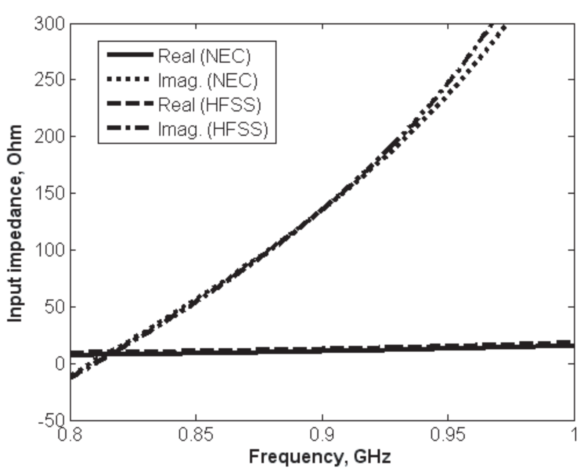

Figure 3: Simulated input impedance of the optimal RFID tag antenna.

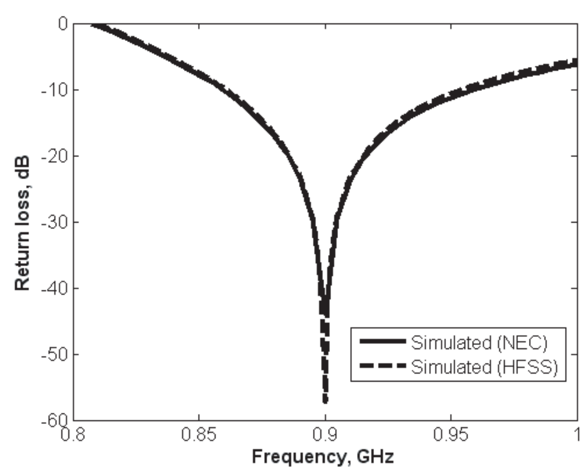

Figure 4: Comparison of return loss for the optimal RFID tag antenna.

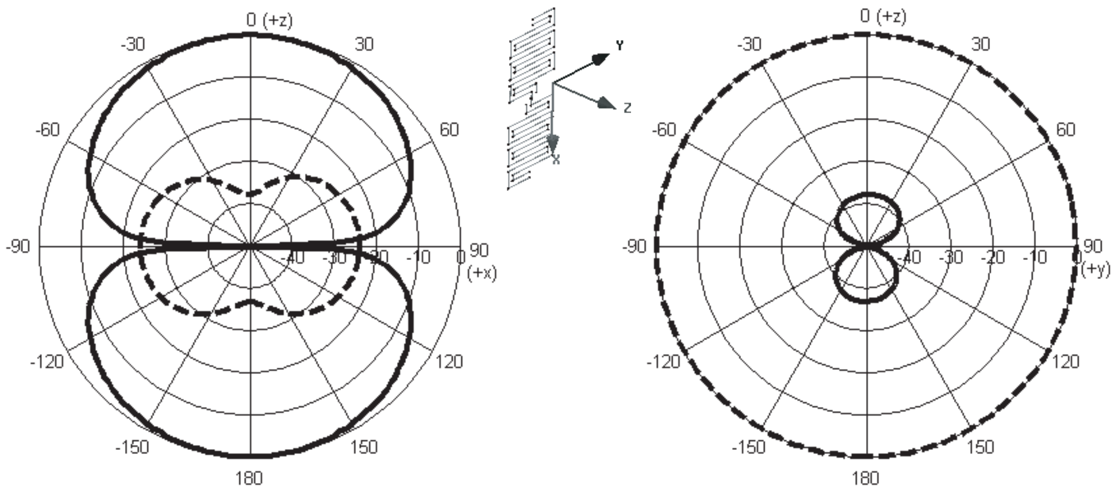

Figure 5: Radiation patterns of the proposed GA-optimized tag antenna for 900 MHz at: (left) zx plane; (right) zy plane; '—' measured E_θ and '- - - -' measured E_ϕ.

4. CONCLUSIONS

A novel design for the design and optimisation of RFID tag antennas with linear polarisation by use of genetic algorithms has been presented. A FORTRAN code genetic algorithm driver was adopted in this work in conjunction with the industry-standard NEC-2 FORTRAN source code, which was used to evaluate the randomly generated antenna samples. The results of the optimum designs of the proposed antennas exhibit good input impedance matching as required by the RFID IC. The presented examples show the capability of the proposed program in antenna design using GA and the results are encouraging for practical implementation of this tag antenna for UHF RFID applications.

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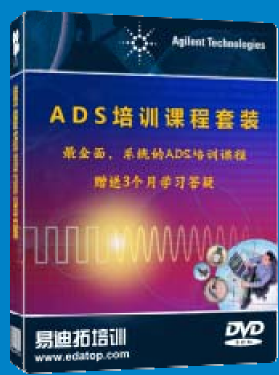

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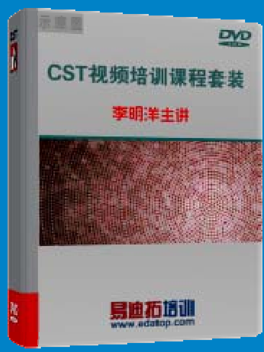

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