Optimization of UHF RFID Tag Antennas Using a Genetic Algorithm

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Abstract – An UHF (860~960MHz) RFID tag antenna is optimized and designed using a genetic algorithm (GA). The tag antenna impedance should be matched to the conjugate of the impedance of the tag IC Chip. The chip impedance has real and capacitive imaginary parts due to the parasitic capacitance of the RFID chip. A GA linked with a commercially available antenna simulation program optimizes the UHF 860~960 MHz tag antenna to match a commercially available RFID chip. This method shows that any RFID antenna can be designed for any commercial RFID chip with any impedance.

Keywords: RFID Tag Antenna, Genetic Algorithm

1 Introduction

An RFID system consists of a reader, a transponder (tag) and a computer connected to the reader. A transponder consists of an antenna and an RFID IC chip. The reader has an antenna. The reader transmits modulated electromagnetic field, which powers up the tag while it sends the data to the tag. The RFID IC micro chip is attached to the feeding point of the tag antenna [1-2]. The passive tag receives all the required energy from the RF energy of the carrier signal of the reader. The tag sends a coded signal back to the reader using the tag antenna at UHF frequencies based on backscattering method. The tag antenna reflects back a part of the energy received from the reader. References [3-5] introduce a method to power up the tag. The method uses a rectifying Schottky detector diode circuit that converts microwave energy into DC. The rectified or DC part of the energy is used to power up the electronics in a passive tag chip. Various shapes of UHF RFID antennas are introduced [6-14]. Meander line antenna [6], folded dipole [7], inverted F [8] and folded strip line of RFID antennas are introduced [9]. References [10-11] introduce electromagnetic band gap (EBG) antennas for RFID tag and reader antennas. An EBG antenna is attached to metal objects. A dual-polarized C band (5.8GHz) RFID antenna is shown in [12]. Dual polarized high gain 2x2 arrays for 5.8GHz and 2.4GHz bands are introduced. The two elements are receiving antennas and the other two are transmitting antennas. Two Wilkinson power dividers are used for the receiving and transmitting antennas [13]. Beam-scanning with low side-lobe pattern used for RFID reader antennas is shown in [14]. Dipole, crossed dipole with Dual polarization, fractal crossed dipole, and spire antenna with circular polarization are introduced in [15]. Various antenna types and polarizations matched to RFID chip impedances are introduced [16].

Genetic algorithm (GA) was introduced by Holland in 1975, and have been applied to many optimization problems, such as optimum mechanical part design, image processing, filter design, control, digital signal processing, artificial intelligence, electromagnetics, communication network design and many others [17]-[21]. Miniaturized Meander-line using a GA was introduced in [6]. A GA has been used to minimize the size of a biocompatible microstrip antenna [17]. Reference [18] introduces the optimization a wideband corrugated multi-sectional conical horn antenna using a GA. GAs are used to maximize the mainbeam radiation and minimize sidelobe levels. 3DFA (three-dimension fishbone antenna) has been designed automatically from GA and found high gain and good matched impedance [20]. In [21] the design of a ultra wide band (UWB) linked GA with FDTD is introduced. This antenna operates from 3.3 to 10.55Ghz, has a 7.25Ghz (104.7%) bandwidth with VSWR, less than 2. As we know, antenna bandwidth, efficiency and size are the qualitative tradeoffs. Reference [22] shows that optimized values of these can be found using GA in the design of electrically small wire antenna.

A genetic algorithm has been applied to design an RFID antenna. The impedance of a tag antenna should match to the conjugate of the impedance of an RFID IC Chip. The chip impedance has real and capacitive imaginary parts due to the parasitic capacitance of the RFID chip. The different impedance values of commercially available RFID chips are matched to the impedance of antenna. This paper shows a RFID tag antenna matched with the complex chip impedance of a RFID chip using a GA.

2 Method of Analysis and Evaluation

This paper shows a new design method for RFID Tag antenna using a GA. An RFID passive tag consists of a tag chip and an antenna [1]. According to ISO18000-6, the UHF RFID frequency band is from 860Mhz to 960Mhz. Since the center frequency of the UHF band is 910Mhz. An RFID chip EM4223 manufactured by EM Microelectonic, Inc. was used. The chip impedance is 19-282j at 910MHz. A simulation using the Finite-difference time-domain (FDTD) method is linked to a GA. The evaluations of the antennas are done in FDTD. The optimized results were then double checked with HFSS program. The objective of this work was to design a RFID tag antenna in the UHF RFID band with the lowest return loss value at fc=910MHz. The optimization technique required a cost function. In the cost of the evaluated antennas, the GA optimizes the return loss value |S11| of the antennas. Each chromosome of the GA is composed of genes described as a sequence of binary bits containing parameters to be optimized. The total number of the chromosome bits is the total number of antenna pieces that will be used to design the tag antenna as shown in Figure 1. Each piece of the antenna is located at a specified position. In Figure 1, the GA recognizes '0' as non-metal piece and '1' as a metal piece.

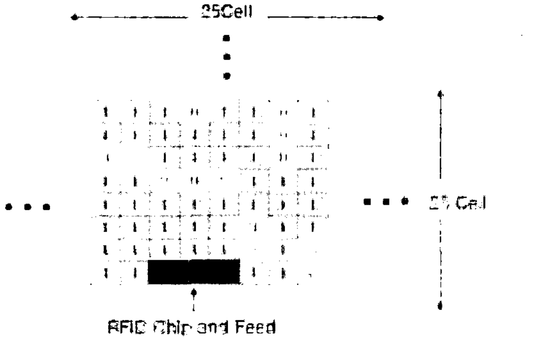

Figure 1. An antenna model represented by a chromosome array of 1's and 0's

3 RFID Antenna and Result

Figure 2 is the first optimized design of the GA antenna. The total number of piece is 625 (25 *25 array). The size of the piece in an antenna structure is 2*2mm. Therefore the total size of this antenna is 50*50mm. This size satisfies one of the standards size required by Wal-Mart, which is 2 inches by 2 inches. As shown in Figure 3, the bandwidth is about 440Mhz, This means that it can cover the whole UHF band (860~960MHz). But it doesn't have a uniform radiation pattern due to the non-symmetric current distribution. Thus, the second design has a symmetrical shape antenna as in Figure 4 to have a symmetric radiation pattern. The location of the tag chip is at the center of the antenna. This antenna has horizontally and vertically symmetrical structures as shown in Figure 4. The GA only controls and optimizes the 1/4 number of the cells since rest of 3/4 parts are symmetric of the 1/4 parts. The total numbers of bits to control are 156 (13*12 array).

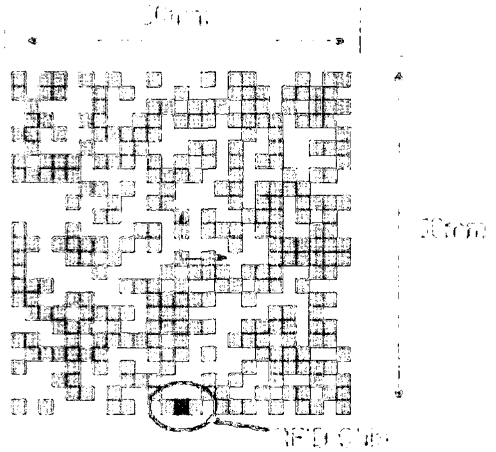

Figure 2. The GA antenna design, 625 chromosomes (25*25 array).

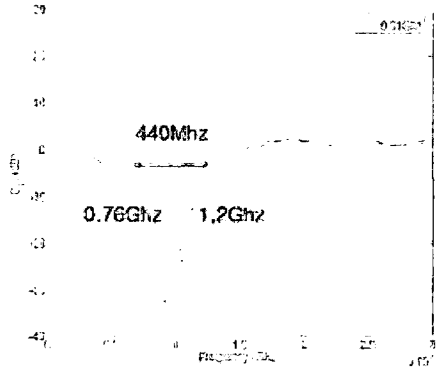

Figure 3. The return loss of the design in Figure 2.

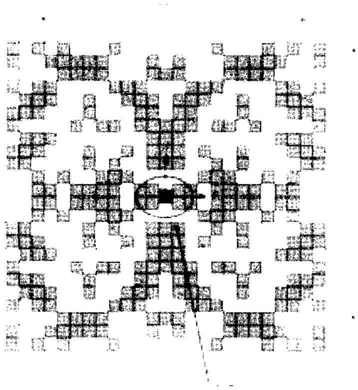

Figure 4. The symmetrical GA antenna, 156 chromosomes (13*12 array).

Figure 5 shows the return loss of the antenna design shown in Figure 4. The bandwidth is about 360Mhz which also covers the whole UHF band (860~960MHz). The problem with this design is that it is too difficult to manufacture even though it has a symmetric radiation pattern. It requires to be simpler design as Figure 6.

The 144 bits of 12 x 12 cell array are used, and the size of one grid is increased to 4x4 mm. Similar to the design of the antenna shown in Figure 5, the GA only controls and optimizes the first of 1/4 of the total antenna and the other three sections are designed symmetrically around the feed point. As shown in Figure 7, the bandwidth is about 340Mhz, this antenna can also cover the whole UHF band.

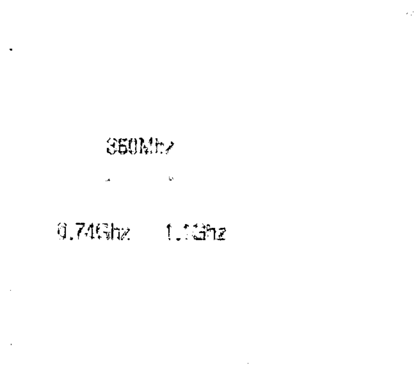

Figure 5. The return loss graph of the symmetrical GA antenna.

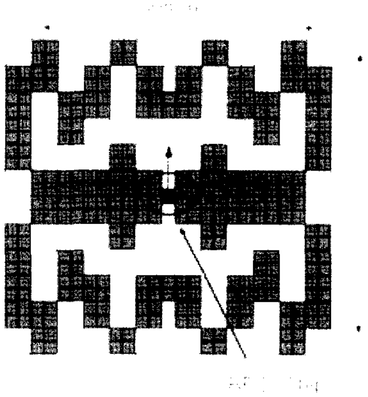

Figure 6. The simple symmetrical GA antenna, 42 chromosomes (6*7 array).

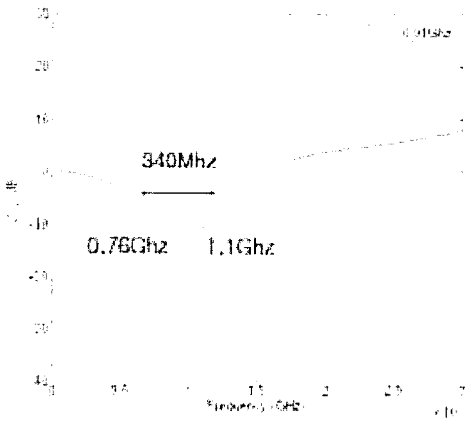

Figure 7. The return loss graph of the simple symmetrical GA antenna.

The optimized antennas shown in Figures 4 and 6 have deep S11 at the center frequency and wide bandwidth. The last design with larger cell has better manufacturability since it has a simpler structure than the design shown in Figure 4.

4 Conclustions

A GA is linked with an antenna evaluation software and it optimizes the design. Few RFID tag antennas with lower than -30dB return loss and wider than 340MHz bandwidth have been optimized successfully using a GA for EM4223 RFID chip, which has impedance of the 19-282j at 910MHz. The size of antenna has been specified as 50x50mm. The performance of the optimized design is also verified with other antenna evaluation program. It shows the same results as FDTD program.

First random 25x25 array of cells (2x2mm) are optimized with non-symmetric structure. The second design as shown in Figure 4 has symmetric structure with 2x2mm cell size. The 3rd optimized design as shown in Figure 6 has the simpler structure than the second optimized design as shown in Figure 4 since it has larger cell size as 4x4mm. Two different cell sizes have been tried to have an optimized RFID tag antenna with simpler structure. The 1/4 of the total number of cells are 144, which is enough to optimize the tag antenna. The cell size is 4x4mm and the symmetrically structured.

For the future work, a simpler structure of tag antenna with larger cell size than 4x4mm can be researched to create omni-directional radiation pattern.

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