Chapter 17

An Innovation Applied to the Simulation of RFID Environments as Used in the Logistics

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This chapter presents the results of experimental research for the development of an innovative product designated as the software for the Simulation of Radio Frequency Identification (RFID) Environments, or RFID-Env. This apparatus is designed for use by professionals in computer systems and plant engineering who are engaged in the research and development of RFID systems as applied to the management and operation of logistic supply chains. The RFID-Env makes it possible to simulate on computer screens a complete RFID environment by processing user data on the technical and physical characteristics of real or virtual RFID environments. Information output can include descriptions of the performance to be expected from a given configuration and detailed reports as to whether that particular configuration will succeed in reading all the RFID tags flowing through a defined system. In arriving at these results, the RFID-Env considers the anti-collision communication protocols utilized by the tags, the quantity of tags to be read in a given period, the temperature at the location, the distance between the tags and reader antennas, and the velocity of exposure of the tags to readers. The software required for these results is built into the RFID-Env and includes a library of communication protocols (ACPL, or Anti-Collision Protocol Library) covering the four RFID International Standard Organization (ISO) standards most frequently used (ISO 18000-6) in the market.

Keywords: Radio Frequency Identification (RFID); simulation of RFID environments; anti-collision algorithms to electronic tags; ISO 18000-6 standards; EPCGlobal Gon2 standard.

1. Introduction

The industry's major challenge in logistic chains is the need to constantly optimize processes to produce goods or services as quickly and efficiently as possible, at the right place and precisely as desired by clients (Rosa, 2006). Nowadays, the variety of products offered in the marketplace adds to the complexity of managing the flow of information along the productive supply chain and obliges manufacturers to introduce new technologies to facilitate logistical operations (Ngai *et al.*, 2005). Radio Frequency Identification (RFID) is attracting attention and interest from industrial and commercial enterprises because the system has the potential to simplify the process and improve the efficiency of automatic product identification (Prado *et al.*, 2006).

Brock (2008) states that the principal component of RFID technology is the intelligent ticket or tag, which is affixed to the product. The information electronically written on the tag is read by electromagnetic radiation and passed to a radio transmitter, where a radio frequency (RF) carrier transmits the data wirelessly to a distant receiver (reader) capable of interpreting and registering the information (Ygal *et al.*, 2006).

Prado *et al.* (2006) consider that the RFID system is made up of basically three elements, which are (i) the tickets or tags; (ii) the electromagnetic and data readers, and (iii) a series of computer programs. Brock (2008) agrees with this, adding that the operation of the RFID system depends on an electronic ticket that is affixed to each product and has a unique digital identity. This identity is known as the product code or Electronic Product Code (EPC). When the tag is interrogated by the external electronic reader, the data recorded in the ticket's memory are recovered and transmitted. This memory consists of an integrated circuit or microchip and has the capacity to store a great deal of information such as, amongst others, (i) the electronic code of that particular product; (ii) the product reference number; (iii) the respective production data; (iv) delivery date; (v) validity period; and (vi) information on the supplier (Atkinson, 2004).

The RFID technology can be utilized in many different ways and the field of its application is growing exponentially (Brock, 2008). Among the improvements that the system can provide in logistical operations, Prado *et al.* (2006) emphasize (i) greater availability of products; (ii) better profit margins due to cost reduction; (iii) improved worker operational efficiency; (iv) reduction in inventory losses; (v) reduction in stock levels; (vi) reduced technical assistance costs; and (vii) better industrial or commercial layouts of the installations.

Ygal *et al.* (2006) agree and state that if conventional business processes are compared with those RFID technology, the new technology's impact will be seen, principally at the strategic level. Effects include (i) the development of new business models; (ii) the integration of activities; and (iii) the reengineering and automation of the older processes, thereby facilitating B2B commerce.

However, in spite of the many promising applications of RFID technology in the supply chain, various technological difficulties prevent the large-scale use of this system (Prado *et al.*, 2006). The technology has functional problems that have been widely discussed by the software developers and production engineers and which have required constant research to develop technological improvements. These problems are (i) "collisions" caused by simultaneous communication of the readouts of two or more tickets; (ii) electromagnetic interference; (iii) insufficient range of the RF carriers; (iv) difficulties in finding the ideal positioning; and (v) the number of antennas required for the electronic readers (Cheng and Jin, 2007; Hassan and Chatterjee, 2006; Myung and Lee, 2006).

Considering these problems, this article presents the results of experimental research conducted to obtain data for the development of an innovative product: the Software for Simulation of RFID Environments (RFID-Env). This product is designed for use by developers of computer system applications and research and development (R&D) engineers working on RFID problems and makes it possible to simulate a complete RFID environment away from the factory floor.

The remainder of the article is organized in the following manner: Section 2 presents the methodology and the procedures used in the research while Section 3 describes the proposed system and an experimental-simulated application. Section 4 demonstrates the results obtained by describing the physical parameters considered in the system and the kind of environments that can be simulated, such as "conveyor mode" or "portal mode". Finally, (iv) Section 5 lists the conclusions of our study.

2. Methodology

Software development is classified as R&D and involves the realization of scientific and technological advances in a systematic manner (OCDE, 2007). Our research was of an experimental nature and resulted in the construction of a prototype. A prototype is defined by OCDE (2007) as an original model that includes all the technical characteristics and functions of the new product.

2.1. *Methodological Procedures*

The development of the RFID-Env was based on high-level abstract models and can represent all the parameters, enabling the developer to configure tests in the way best suited to the environment to be simulated. The software includes a library of communication protocols called the Anti-Collision Protocol Library (ACPL) that covers the four International Standard Organization (ISO) standards for the area (ISO 18000-6), which are (i) ALOHA LST; (ii) ALOHA FST; (iii) Btree, and (iv) Random Slotted (Q Algorithm). In addition, the protocol library has a copy of Calculated Q, which is an improved edition of Random Slotted, the most recent version of the ISO standards. The software was written in the Java programming language and the developer can readily extend coverage by using new communication protocols. Proper operation of the RFID-Env was confirmed by operation under various test conditions with the different protocols proposed by the ISO.

Efforts to use RFID in the control of supply chains and consumer goods have been mostly directed at Ultra High Frequency (UHF) passive tags (ISO 18000-6) (Borrielo, 2005; Curtin *et al.*, 2007; Hassan and Chatterjee, 2006; Weinstein, 2006). This is due to their size, their reading capacity at distances of about 5 m, and the ability to control their reading area by adjusting the antennas direction and the interrogator's configuration. For this reason, our development concentrated on the physical characteristics and anti-collision algorithms used in these tickets.

In the simulated environment developed, we considered the anti-collision communication protocol impressed on the tickets, the quantity of tickets to be read in a specified time, the ambient temperature, the distance between the tickets and the reading antennas, and the speed at which the tickets passed by the readers. To use RFID-Env, the operator merely has to enter the physical and technical characteristics of the RFID environment, and the simulator will generate reports predicting whether all the tickets will be read correctly for that particular configuration.

2.2. *The Proposed System*

2.2.1. *Description*

When the RFID-Env software simulates the reading of ISO 18000-6 standard type A, B, and C tickets and their respective anti-collision communication protocols, it respects the manner in which these devices work — there are processes involving interrogator operation and others related to ticket functioning. Some few processes were implemented specifically for the simulation, such as the process that generates the unique code identifier, or Unique Identifier (UID), on each ticket. In a typical real-life system, the tickets already have a UID value at the moment that the protocols are executed, whereas in RFID-Env a random number generator produces initial simulated UID numbers and allocates to each ticket the corresponding simulated UID value. This can vary between 16 bits (in the ISO 18000-6 C) and 64 bits (in the ISO 18000-6 B) (ISO/IEC 18000-6 2006a,b).

During the process of identifying the tickets, the protocol may use only a portion of the data contained in the memory on the ticket. In the ISO 18000-6 A (2006a), a Sub-Identifier (SUID) of 40 bits is transmitted. However, in the ISO 18000-6 B (2006b), the whole UID of 64 bits is sent, and in the ISO 18000-6 C a random value of 16 bits called the RNI6 is sent out exclusively for the anti-collision process.

The work environment of the RFID-Env is divided into three windows: Simulator, Single Mode and Portal Mode. On the initial screen (see Fig. 1), the user specifies which anti-collision protocol he/she wishes to use in testing a number of tickets in an environment. Depending on the protocol selected, he provides some specific parameters, such as the starting sizes of the frames in ALOHA-type protocols utilized by the ISO 18000-6 A and C standards. The user may also select the total number of

Figure 1. Initial window of RFID-Env and selection of the type of environment.

executions (to facilitate the generation of statistical averages of the results) and the format of the printout (which is generated by an ACIII file).

On the initial screen, one can select the Advanced Simulation option, where the user can select a system operational mode simulate: Single Mode or Portal Mode.

If the user only wants to test if the algorithms are functioning, this option may be ignored together with the respective tabs. But for tests where the physical characteristics of the ticket (for example, whether the material of the ticket base is plastic or wood) and environmental variations (such as the quantity of the readers and antennas, the speed of the passage of the tickets in front of the antennas, and temperature) are to be considered, the user must in this case select either the Single or Portal Mode. Figure 2 shows the Portal Mode screen after the user has selected Advanced Simulation, and the options corresponding to this mode.

Figure 2. Portal Mode screen of RFID-Env.

As soon as the user inputs the number of tickets present in the environment, the UID generation process is executed and a unique code is attributed to each ticket the virtual environment. The environment generated in the RAM memory and the five principle stages of the simulation process are illustrated in Fig. 3.

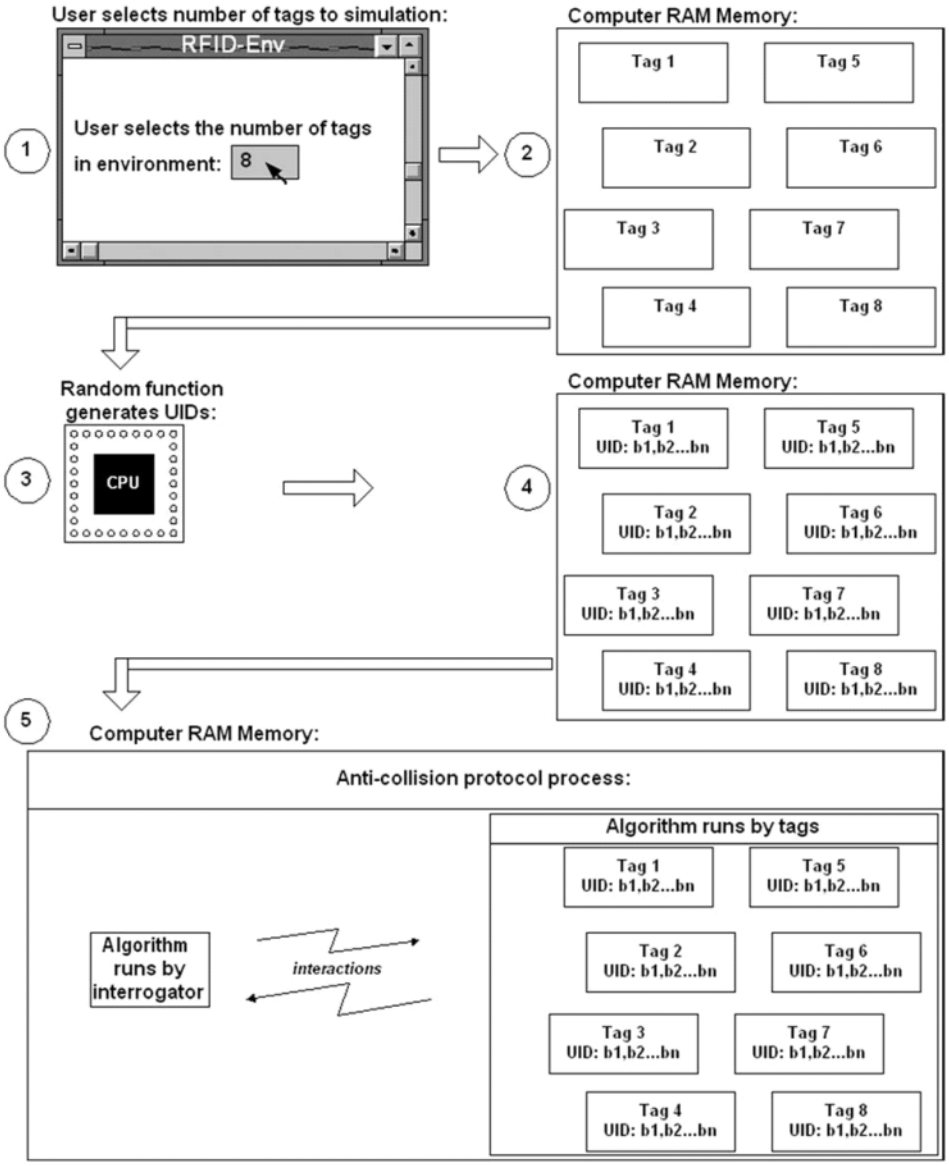

Figure 3. Simulation environment and the initial stages of RFID-Env operation.

When execution starts, the user is requested to input the number of tickets to be simulated (see Stage 1 in Fig. 3). With this information, the software creates a slot in the memory where values will be stored for each ticket (Stage 2). When this is complete, the process of generating the UID for the tickets commences (Stages 3 and 4). At Stage 5, the process that runs the specific algorithm of the anti-collision protocol to be simulated is initiated and begins to interact with the tickets. The interrogator process starts up simultaneously.

2.2.2. *Experimental operation*

Having obtained the inputs on the type and quantity of the RFID sensors, the system realizes a simple simulation of reading the tickets by using the anti-collision protocols. As an example, we will demonstrate the report of a simulation of reading 10 tickets using the ISO 18000-6 B (Btree Anti-Collision Protocol) standard. The algorithm utilized by the Btree is significantly different from its ALOHA counterparts in that it does not include the concept of the communication frame size, or the round size (ISO/IEC 18000-6, 2006a).

In the other three ISO protocols, the dimensions for the initial round sizes are required, but the Btree approach has the advantage of eliminating this necessity. While the algorithms utilized by the ISO 18000-6 A LST and FST standards return very poor performances when reading more than 256 tickets (this is the maximum round tree size), the Btree does not suffer from this limitation (ISO/IEC 18000-6, 2006a,b; Shih *et al.*, 2006). On the other hand, the Btree utilizes a concept where the first iterations of the algorithm — that is, the first communications between the tickets and the reader — tend to generate many collisions, as can be seen in the RFID-Env utilization example presented below.

However, when the number of tickets to be simulated is provided manually, the RFID-Env executes the algorithms and generates the outputs and totals in the final simulation results at the end of the report. (See Fig. 4).

By analyzing the outputs generated by RFID-Env as shown in Fig. 4, the algorithm utilized by Btree can be better understood. In the first iteration, the 10 tickets in the environment try to transmit their information, causing collisions among the signals directed to the readers that impede the reading.

Normally, the first reaction of all the tickets after a failed first attempt to communicate is to randomly select a value of 0 or 1. The tickets that receive a 1 at this time increase their slot counter and may try to re-transmit when this counter contains 0 once again.

Those tickets that get a zero do not increase their counters and continue to have an opportunity to transmit their data at the next process iteration. If more than one ticket gets a 0 (such as in the second iteration in Fig. 4), these tickets must once again draw for a 1 or 0. Those tickets that already have a 1 in the counter (the other three tickets in the environment) must again increase the value by one more unit.

```
-----------------|BTREE|----------------
--Iteration #1, Tags that replied:
E0E069FEC02185EC20 | E0B4909015F4627A76
E08C1013BF9FCB2BAE | E059592730460AF424
E0BB6B2EA85B402E70 | E0D49AC0DD20AEE2E7
E041E50008FC2F6965 | E096E4892AAEA7DCF9
E03783A6E0D9449A7D | E0A77048EDBEF83434
--Iteration #2, Tags that replied:
E059592730460AF424 | E0BB6B2EA85B402E70
E0D49AC0DD20AEE2E7 | E041E50008FC2F6965
E096E4892AAEA7DCF9 | E03783A6E0D9449A7D
E0A77048EDBEF83434
--Iteration #3, Tags that replied:
E041E50008FC2F6965 | E03783A6E0D9449A7D
E0A77048EDBEF83434
--Iteration #4, Tags that replied:
E0A77048EDBEF83434
--Iteration #5, Tags that replied:
E041E50008FC2F6965 | E03783A6E0D9449A7D
                     ...
--Iteration #11, Tags that replied:
No tag replied
                     ...
--Iteration #27, Tags that replied:
E08C1013BF9FCB2BAE
---------- Performance Report ---------
Tags: 10
Iterations: 27
Iterations with tag collision: 13
Iterations with no tag reply: 4
```

Figure 4. Report of execution of the Btree protocol, with 13 collisions, 4 empty slots, and a total of 27 slots utilized for communication of 10 RFID tickets.

These steps are repeated until only one ticket has a 0 and all the others a 1 — which happens in the example at iteration #4.

The many collisions taking plane in the first iterations of the Btree algorithm is typical of this protocol. While the iterations proceed, the ticket counters increase and little by little, the transmissions normalize. At the bottom of Fig. 4, the Performance Report shows that 27 iterations between all tickets and readers were necessary for the 10 tickets to succeed in transmitting their data. 13 iterations (slots) were occupied with collisions, and 4 slots remained vacant because no ticket had a zero in its counter when these iterations took place.

3. Results

3.1. *Physical Parameters Consider by the RFID-Env System*

This section presents the physical parameters considered by RFID-Env, the way they are analyzed and the influence of these parameters on the final results of the simulations.

3.1.1. *Maximum reach for reading, velocity, and total exposition time*

The maximum distance for proper reading of the ticket varies because of the following principal factors: (i) the rapidity of the ticket's passage (ii) the material onto which the ticket antenna is mounted; and (iii) the presence of magnetic and physical interference the environment. On average, the UHF tickets can operate at distances of 5 m between the ticket and the interrogator antenna, but the average may vary between 3.65 and 10.66 m, depending on the frequency of operation and the ticket material (Cheng and Jin, 2007; Friedrich, 2005; INTERMEC, 2007).

The RFID-Env system considers these values in the following manner: given the average read reach distance of the tickets and the moving speed of the ticketed product, we can calculate how long each ticket is exposed to the interrogator. From the values of reading speeds found in the references in ISO/IEC 18000-6 (ISO/IEC 18000-6, 2006a),

$$\text{Total exposure time} \geq [\text{time to read } (y \text{ bits} * n \text{ tags})] \quad (1)$$

ISO/IEC 18000-6 (2006b), Friedrich (2005) and ATMEL (2007) and the quantity of bits to be read from each ticket, the following formula can be solved:

Total exposure time is the total exposure time for the group of tags to reach the interrogator reading distance; y bits is the amount of bits of each tag; n tags is the amount of tags to be read.

To calculate the total time that each ticket is exposed to the interrogator, it is first necessary to determine the maximum reading reach to the right and left of the interrogator antenna. Considering the situation of an environment based on a conveyer belt moving from left to right and with an antenna pointed directly at the tickets, it can be seen that a point exists (T_1 on Fig. 5) where the tickets enter the leading edge of the interrogator reading window. Point T_2 is the exact front center of the interrogator and is half the distance traveled by the ticket within its reading area. As a corollary, one can say that a point T_3 also exists to the right of T_2, where the ticket moves out of the reading range of the interrogator. It is the sum of these two distances that provides the total exposure in meters (m) of the group of tickets

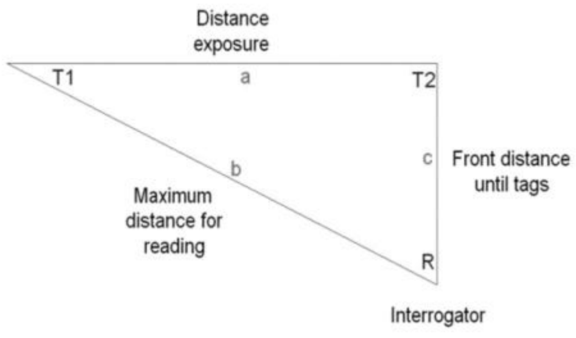

Figure 5. Calculation of the time and distance of exposure.

to the reader. Dividing this value by the velocity (m/s) of the ticket, one can obtain the total period of exposure. This is the time x cited in Equation (1) in which the interrogator should succeed in reading all the bits of all the tickets on each of the moving packages.

RFID-Env users need to supply somewhat simpler information about the environment, since this is generally known in advance. Figure 6 shows the input screen in Single Mode, where the following information is required: (i) temperature; (ii) ticket material; (iii) maximum reading reach; (iv) speed of ticket reading; (v) speed of movement of the tickets; and (vi) frontal distance between the interrogator antenna and the tickets (that is, the distance (c), or the minor cathetus of the rectangular triangle shown in Fig. 5).

It should be noticed that the calculation of the total time necessary for reading a group of tickets is performed after the simulation of a complete reading of a group of tickets with an anti-collision protocol selected on the initial RFID-Env screen. Given the total number of slots necessary for reading the group of tickets, the simulator will calculate:

$$t\_total = total\_number\_of\_slots \times each\_slot\_reading\_time. \quad (2)$$

t_total is the total reading time for a group of tags; total_number_of_slots is the number of slots generated in a simulation; each_slot_reading_time is the amount of bits to be read in each tag divided by the reading speed value of the tags.

With the information obtained from the interface in Single Mode, RFID-Env can calculate the distance of the cathetus (a), in view of the fact that the maximum

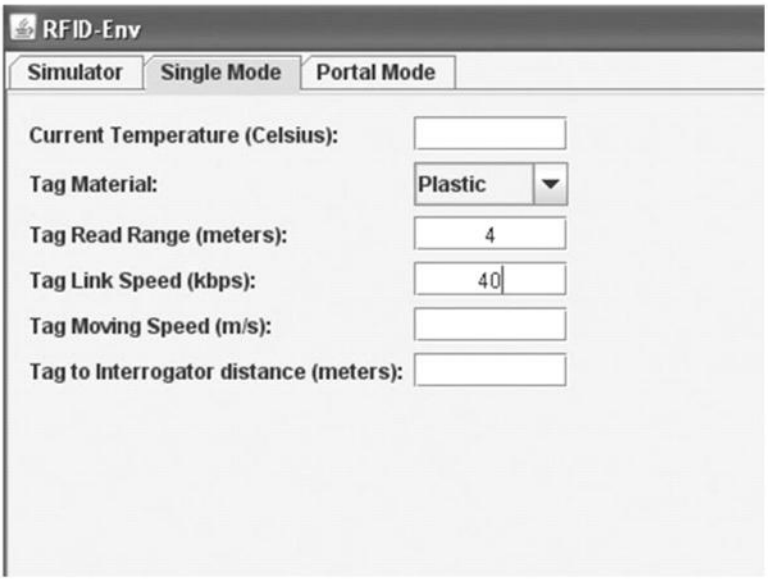

Figure 6. Data for the analysis of the environment in Single Mode.

ticket reading distance is the length of the hypotenuse (b). The frontal distance between the interrogator antenna and the tickets refers to the cathetus distance (c). This configuration of the environment represents a geometric situation in the form of a right-angle triangle whose measurements may be calculated using Pythagoras' Theorem. In Fig. 5, the formula used by RFID-Env for calculating the cathetus (a) is the following:

$$a^2 = b^2 + c^2. \quad (3)$$

The interface of Fig. 6 shows the type of material selected (plastic) and the maximum distance of 4 m typical for this material (INTERMEC, 2007). Depending on the material selected by the user, the reading distance of that material is shown in the Tag Read Range box.

But as this value may vary from manufacturer to manufacturer and for other physical reasons, this distance is merely suggested by RFID-Env and the user can alter it to his/her convenience to align it with the technical information provided by his/her ticket supplier.

This applies also to the ticket-reading speed — RFID-Env suggests a speed of 40 kbs but the manufacturers' figures may be different.

Given this information, the RFID-Env can predict situations where it would be physically impossible to read a stated number of tickets. An example is given in the report shown in Fig. 7 — here the information supplied by the user was: (i) maximum reading distance (hypotenuse) of 4 m; (ii) reading speed 40 kbs; (iii) ticket movement of 5 m/s; and (iv) frontal movement (cathetus c) of 2 m. This data referred to a group of 1000 tickets (e.g. a box containing 1000 products moving on a conveyer belt) using the ISO 18000-6 protocol. With this configuration, RFID-Env would state that the system might not work.

Some potential solutions to the problem detected by the simulator and described in Fig. 7 include (i) changing the communication protocol to reduce the number of slots necessary; (ii) reducing the number of tickets to be read "simultaneously" (i.e., the number of tickets in one package); (iii) slowing down the transport speed;

```
-------------------|ISO 18000-6 C Protocol |-----------
-- Performance Report --
Tags: 1000
Slots needed for all tags to reply: 2822
Slots with tag collision: 727
Empty Slots (with no tag reply): 1095
Total required time to read all tags: 2.82 seconds (worst case)
Calculated Total Exposition Time: 1.38 seconds
-------------------------------------------------------
With this configuration the group of tags could not be fully read.
-------------------------------------------------------
```

Figure 7. RFID-Env Red Alert — Reading is impossible for physical reasons.

(iv) altering the distance between the tickets and the reader; or finally (v) a combination of some or all of the above.

3.1.2. *Temperature*

The environmental temperature has a profound effect on the duration that the registers can store the "0" and "1" logic values (ATMEL, 2007). Basically, the registers can increase their storage time when the temperature falls below 25° but above that temperature, the register's storage capacity is reduced by more than 8 s. In addition, operation may cease altogether at some temperatures and RFID-Env is designed to consider this factor. Thus, if the user specifies a value outside the temperature limits supported by typical circuits, an Alert Signal generated by RFID-Env informs the user of this.

As development improvement work continues on RFID-Env, the instrument will be enabled to take into consideration the time that register values can be maintained at different temperatures. This information may be related to the read speed of each ticket, the length of time the value is exposed to the electronic reader, the number of tickets present in the environment, and physical interferences which cause the tickets to be without power for brief periods. Because of these relationships, environmental temperature may strongly influence simulation results.

3.2. *Configuration of the RFID-Env for the Type of Environment*

Taking into consideration some of the typical environments in which RFID systems are installed, the RFID-Env user can simulate the reading of a group of tickets in three ways: (i) by ignoring possible variations in the environment (Simulator Mode); (ii) conveyer belt mode with an antenna (Single Mode); and (iii) portal mode for pallets (Portal Mode).

The process of simulation starts in the principal window as shown in Fig. 1. If the user only wants to simulate the operation of a one or more anti-collision protocols without considering the physical variations in the environment, only this interface needs to be used. While still in the principal window, it is possible to visualize the selection field for the type of environment: (i) None (simulation without environmental variables); (ii) Single Mode; or (iii) Portal Mode. The respective tabs are activated or not in accordance with the mode selected.

If a user desires to test a conveyer belt environment, he/she should select Single Mode. This will cause the respective window to be activated and information specific to that kind of environment to be requested such as (i) temperature in degrees Celsius; (ii) type of material onto which the RFID chip and ticket antenna are mounted; (iii) read speed (in kbs) of the ticket in use in the environment; (iv) speed of movement of the products on the conveyer belt in m/s; and (v) the frontal distance (in meters) between the antenna and the conveyer belt. As soon as the type of ticket material is selected, the corresponding value in meters will appear in the box provided for the typical value of read reach (between the antenna and the ticket) for that type of material. For example, when the user selects glass, the number 2 will appear in the box, the number 4 for plastic, and so on. These values, which are typical for various manufacturers, were obtained from references by Cheng and Jin (2007), Friedrich (2005) and INTERMEC (2007). In any case, these are values suggested by the RFID-Env system as a reference guide for the user, and he/she can easily alter them to reflect the real values obtained from the manufacturer's technical specifications for the tickets actually being used.

3.3. *Portal Mode — Quantity of Antennas versus Measurements of Portal and Pallets*

As shown in Fig. 2, the RFID-Env Portal Mode is designed to simulate environments with portals in the form of tunnels through which pallets and other transporter packages can pass. In addition to the information required for the Single Mode (distances, temperature, and read speed), the Portal Mode needs the dimensions of the Portal and of the pallets carrying the ticketed products. The user should input also the number of interrogators and antennas in the portal. Usually, each interrogator is limited to four antennas.

With respect to the antennas located in the portal, the user may select the position of each antenna (a maximum of eight antennas simultaneously if the option of two interrogators was chosen). The simulator should be provided with the approximate direction of the antennas in relation to the total number of tickets to be read, assuming that all the ticketed packages are uniformly distributed over the transporter. That is, if the user selects an antenna in each face of the portal (left, right, and upper), the simulator will consider that n tickets are distributed facing these three directions equally, which would mean $n/3$.

From the measurements of the portal and the pallet, the simulator can determine the lateral and superior distances between the pallet and the interrogator antennas selected as active by the user. In the present version of RFID-Env, the Portal Mode operates in the same way as the Single Mode, but with the difference that in the Portal Mode, the number of tickets to be measured is divided by the number of active antennas. This division is performed by the simulator in accordance with number of directional antennas located in each part of the portal as described in the previous paragraph. The lateral antennas work in exactly the same way as in the Single Mode, but the upper antennas are angled differently from the lateral antennas, although they too are positioned in a right-angled triangle formation. The advantages of a greater number of antennas in the portal are evident: an increase in the range of action in various directions and a reduction in the total number of tickets captured by each antenna. For the situation demonstrated in Fig. 7 (where the simulator found that it is impossible to read the tickets in that environment), one can make a simple calculation where, for instance, the 1000 tickets could be divided between eight antennas. This would drastically reduce the number of simultaneous readings required from the system.

As the development of RFID-Env continues, the parameters of analysis of the Portal Mode will be amplified, for example, by a more detailed consideration of the focus and positioning of the antennas, and of the antenna type itself. Some antennas are designed to operate over greater distances though only in a straight line, while others are better at reading wider angles. Greater attention will also be given to the physical characteristics of the ticketed products and the interference these materials cause by scattering the RF signal. It is known that the products in the center of the pallet present the greatest reading difficulties due to the interference re-transmitted from the surrounding products.

4. Conclusions

This chapter describes the results of experimental research undertaken to develop an innovative product — the Software for Simulating RFID Environments, or RFID-Env. The product is intended for use by developers in the computer sciences, and by engineers doing R&D for the solution of RFID problems. RFID-Env makes it possible to simulate a complete range of virtual RFID environments so that R&D can proceed in a non-factory environment.

The functionality and the applications of RFID-Env software were demonstrated, showing how the product permits simulation of the operation of four RFID protocols standardized by ISO 18000-6, viz. the types A LST and FST, the type B, and the type C.

The experimental application demonstrated that this new product can help potential users of RFID systems to select the protocol which best suits the characteristics of the system they intend to implement.

Considering the physical characteristics of an environment proposed for implementation of RFID technology, such as the speed of the tickets in relation to the interrogators, the distance, the number of antennas and the number of tickets to be read simultaneously, RFID-Env can help save money by determining if the particular standard or environmental configuration under consideration will attend to the necessities of that particular situation.

As we continue to work on RFID-Env, our research will consider other aspects of the physical environment such as the interference produced when the ticketed products themselves scatter RF signals, and attributes of the antennas such as their positioning, focusing, and model. The present RFID-Env version does not permit adjustment's of the antenna's direction.

Another improvement to be implemented is the option of indicating the amount of information (in bits) stored on the tickets (UID or SUID) in his/her system, so that the simulator knows the exact quantity of bits to be read, and can thus indicate which protocol would be best to cater to the necessities of that particular RFID project.

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