IEEE Brasil RFID 2015

Centro de Convenções
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IEEE

RFID
IEEE Technical Committee on RFID

Thank you to our Patrons

This is the second edition of IEEE Brasil RFID, an international event that emphasizes design experience sharing and collaborative approach between different research communities from industry, academy and government. The IEEE Brasil RFID series of conference aim at bridging the gaps in RFID design between applications, architectures, tools, and technologies to achieve rapid system prototyping and deployment of emerging systems.

For its second venue, the IEEE Brasil RFID seeks original contributions related to this target, encompassing a wide scope ranging from components design and verification to case studies of emerging systems and technologies. The conference proposes an inspiring international forum for discussing the latest related innovations and research activities. The conference program will include keynote speeches and technical papers on timely topics.

The IEEE Brasil RFID conference is co-located with RFID Journal Live! Brasil.

On behalf of the Organization Committee, we would like to thank all the authors for the swift and enthusiastic response to our Call for Papers and all the attendees for their interest in our event.

We thank you all for coming and we wish you a very productive Conference, with lively technical discussions and high-level intellectual and business interactions.

Welcome to IEEE BRASIL RFID 2015!

Fabiano Hessel

General Chair

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THE INTERNET OF THINGS AND NANOTECHNOLOGY

The effective realization of the Internet of Things will depend among other aspects, on the introduction of disruptive technologies, especially at the nanoscale. A scenario in which a network of tiny sensors deployed to monitor for instance, the behavior of a biological system, demanding a wireless high rate transmission of data, is one of the main motivations of this talk. Such situation is recognized to be part of the so-called Internet of Nanothings, and will be addressed in detail in this talk.

Keynote Speaker: Vinicius Garcia de Oliveira, Master Degree Universidade Estadual de Campinas (UNICAMP)

CPqD – Centro de Pesquisa e Desenvolvimento - Converged Networks Department

IOT CONCEPTS AND INTEROPERABILITY CHALLENGES

In this talk it is presented the main concepts related to Internet of Things and its challenges, in particular the interoperability issue. The definition and use of a common framework are critical for the development of IoT devices and applications that are able to fully communicate to each other. However, the major problem is not the lack of such framework but the large number of initiatives aimed to become the industry standard. The presentation shows this complex scenario involving technical and political issues as well the interest of various global organizations in the ICT sector that are trying to position himself as the major player in IoT market.

IEEE RFID BRASIL 2015
Conference Program

SESSION I
Chair Fabiano Hessel
PUCRS

8:30 AM	8:45 AM	**Welcome Coffee**
8:50 AM	8:55 AM	**Welcome:** Fabiano Hessel, General Chair
8:55 AM	9:40 AM	**Keynote Speaker:** Hugo Figueroa, UNICAMP **Presentation:** The Internet of Things and Nanotechnology
9:40 AM	10:00 AM	**Presentation Paper 1:** Optimized ultra-low power sensor-enabled RFID data logger for Pharmaceutical Cold Chain
10:00 AM	10:20 AM	**Presentation Paper 2: Using LabView to Automate RFID Tag Tests:** Comparison Between Implemented System and Voyantic Test System
10:20 AM	10:40 AM	**Presentation Paper 3:** Proposal for EPCIS System Implementation to control drugs in pharmaceutical sector in Brazil
10:45 AM	11:00 AM	**Coffee Break in Exhibit Hall**

SESSION II
Chair Renata Rampim

11:00 AM	11:15 AM	Session Chair Comments on Session I Works
11:15 AM	11:30 AM	**Presentation Poster 1: UHF RFID Tags in a Controlled Environment:** Anechoic Chamber Case.
11:30 AM	11:45 AM	**Presentation Poster 2:** Proposal for Implementation of RFID Technology to Combat Evasion of the Hospital Trousseau
11:45 AM	12:00 PM	**Presentation Poster 3:** Electronic Product End of Life Tracking Using RFID System – Smart Waste Project
12:00 PM	12:15 PM	**Presentation Poster 4:** Inventory Control With RFID Integration
12:15 PM	12:30 PM	**Presentation Poster 5:** Area optimization methodology for RFIDs combining capacitors placement within digital circuitry

Session II
Renata Rampim

12:30 PM	02:30 PM	Lunch Break in Exhibit Hall
12:45 PM	02:15 PM	Poster Presentations in Exibit Hall and Session Chair Comments

Session III
Chair Hugo Figueroa
UNICAMP

02:30 PM	03:15 PM	**Keynote Speaker:** Vinicius Garcia de Oliveira,CPqD, Campinas **Presentation:** IoT concepts and interoperability challenges
03:15 PM	03:35 PM	**Presentation Paper 4:** Towards a battery-free wireless smart glove for rehabilitation applications based on RFID
03:35 PM	3:55 AM	**Presentation Paper 5:** RFID Applied to Protective Equipment Inspection
3:55 AM	04:15 PM	**Presentation Paper 6:** iTracking - A Framework for Tracking Using RFID Technology
04:15 PM	04:30 PM	Refreshment Break

Session IV

Chair Fabiano Hessel

PUCRS

04:30 PM	04:45 PM	SessionChair Comments o Session III Works
04:45 PM	05:05 PM	**Presentation Paper 7:** Using RFID technology to Enhance Quality Information to Products in Agribusiness Supply Chain
05:05 PM	05:20 PM	**Presentation Paper 8:** Monopulse RFID Reader for Enhanced Intelligent Transportation Systems Applications
05:20 PM	05:40 PM	Wrap-up and Closing
05:50 PM	07:00 PM	RFID Journal Cocktail Reception

Session II
Chair Renata Rampim

Poster Session	
1	**Presentation Poster 1: UHF RFID Tags in a Controlled Environment:** Anechoic Chamber Case.
2	**Presentation Poster 2:** Proposal for Implementation of RFID-CHIP Technology in the outfits of evasion control on a Health Unit
3	**Presentation Poster 3:** Electronic Product End of Life Tracking Using RFID System – Smart Waste Project
4	**Presentation Poster 4:**Inventory Control With RFID Integration within digital circuitry
5	**Presentation Poster 5:** Area optimization methodology for RFIDs combining capacitors placement

Area optimization methodology for RFIDs combining capacitors placement within digital circuitry

Josué P. J. de Freitas, Everton L. G. Ghignatti Jr, Fernando R. P. Cortes, Julio Leão S. Jr,
Alfredo Olmos and Marcelo S. Lubaszewski
CEITEC S.A João de Oliveira Remião St., 777
Porto Alegre, RS - Brazil
Telephone: (+5551) 3220-9700
josue.freitas, everton.junior, fernando.cortes, julio.junior, alfredo.olmos, marcelo.lubaszewski@ceitec-sa.com

***Abstract*—Minimize integrated circuit area by crunching more and more digital logic in an ever diminishing area is a current trend in semiconductor industry. Frequently, higher transistor densities in digital circuits are achieved by the use all metal layers available for routing signals. However, when designing mixed signal circuits, such as RFIDs, capacitors and other passive components represent a significant area in the integrated circuit. This paper presents a method and apparatus to rethink the common view, that adding more logic in smaller areas always reduces the circuit area, by using a counter-intuitive approach. This method consists of exploring different capacitor types and their placement possibilities to reach an implementation with reduced area, along with a noise analysis flow to certify IC proper operation. Our solution empowers integrated capacitors to overlap digital circuits, reducing total circuit area, in spite of enlarging digital circuit area together with capacitor distribution approaches. A test-chip has been manufactured and tested to demonstrate the approach feasibility and preliminary results are presented. Moreover, area reduction for a commercial low-frequency RFID has been estimated in over 17%, by overlapping a resonance capacitor and a digital circuit using the method and apparatus presented.**

I. Introduction

Throughout the years, in order to reduce integrated circuits cost, area minimization has been achieved in digital logic by increasing transistor densities. Moreover, by using more and more metal layers to route signals in the digital circuits, area has also decreased. This approach can have a bigger efficiency on purely digital circuits. However, mixed-signal circuits are composed by passive elements, such as capacitors, and digital circuits where using this traditional approach might increase total area instead of reducing it. Also, area used for capacitors, represents a significant amount in Radio Frequency IDentification circuits (RFIDs) [1] [2]. Therefore, total area reduction must take into account both digital and passive elements to reach a better solution.

Placing capacitors elements over digital logic can maximize area utilization and consequently reduce total circuit area, as we will demonstrate in this paper. This placement must be carefully designed so that the effects between digital and analog components are taken into account. Failing to do so will result in under-performing circuits, low yield, and circuits that operate incorrectly.

This paper presents an optimization methodology that empowers designers to achieve area reduction. Section 2 describes the context in which this methodology is useful, as well as, related work. The components and methodology are presented in Section 3. Results measured in a test chip and estimates of over 17% area reduction for an actual commercial RFID are illustrated in Section 4. Finally, in Section 5 we present conclusions and future work.

II. Context

Whenever a passive element is required it can be directly integrated inside the die or added outside the die. In low-frequency RFID tags capacitors can be very area consuming when integrated into the die. Also the capacitors can lead to production line complexity and cost increases for the integrator when put outside the integrated circuit as in [3] [4].

Being essential for RFID circuits, specially in Low-frequency RFID, capacitors are required for the resonance LC circuit (where the inductor L is placed outside) and for providing supply and reference voltages. Considering these needs and the capacitor densities, some few fF/um^2, its area can reach up to 50% of the total area generating increasing costs in a market where the integrated circuits price is a great challenge (few cents per die).

Although our approach can be applied to virtually any circuit, our case studies refer to Low-frequency RFID circuits. It also frees the integrator from the task of adding an outside capacitor and, at the same time, saves internal circuit area leading to smaller die by better distributing capacitors.

Figure 1 displays a simplified block diagram of a passive Low-frequency RFID tag which is the RFID type in the context of this paper.

III. Methodology

The methodology is composed by two phases: Architecture Exploration and Noise Analysis, described respectively in Sections III-A and III-B.

A. Architecture Exploration

The architecture exploration step consists in analyzing the different types of available integrated capacitors together with the required digital circuitry, aiming total area reduction. This can be achieved by a combination of placing capacitors above the digital circuity area and routing/placing techniques.

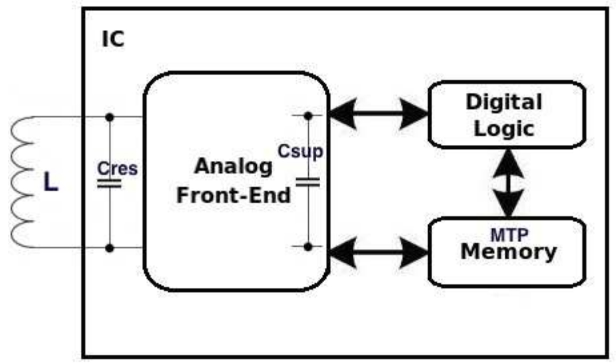

Fig. 1: Simplified block diagram of a passive Low-frequency RFID tag

If an integrated capacitor (usually formed by the last metal layers available in the technology) is placed over a digital circuit area, the digital circuitry cannot be routed with all layers of metal resulting in an increment in the digital area. However the overall spent area can be reduced since the integrated capacitor will occupy the same area as the digital circuitry.

Consider a low-frequency (LF) RFID chip with large integrated capacitors (nF) implemented in a deep-submicron technology, with 6 metal layers and a metal-insulator-metal (MIM) capacitor. If the digital circuitry is implemented with 3 metal layers it will spend about 30% more area than the implementation with all 6 metal layers.

Since MIM capacitors can be implemented over all digital area, it can contribute to the total area reduction. Considering the digital increase due to new routing, MOS capacitor filler cells can be added to the space without digital cells. Along with that, fringe capacitor can be placed over another parts of the chip where only the last metal layer is available (memory cell).

B. Noise Analysis

Capacitor placed over digital logic will affect its operation through parasite capacitances existent in the integrated circuit. Both performance and functionality may be altered by these parasites [6] [7]. Victim signals in the digital logic, situated in critical path delays, may be delayed or advanced causing setup and hold violations that decrease circuit performance. Moreover, coupling noise can be severe enough to cause glitches in the digital logic provoking incorrect operation [8].

The interaction between capacitance elements and digital must analyzed according to EDA flow steps [9] [10], and simplistically described below:

1) Code and simulate RTL
2) Make logic synthesis and physical synthesis
3) Simulate post-layout netlist
4) Create noise library including characterized gate-level data, SPICE transistor descriptions, Vds-Ids curves for each Vgs connected to each cell output, noise threshold for each cell input, and the I/O pin capacitance
5) Passive (capacitor) element design
6) Create noise model for passive element (User Defined Noise Model - UDN)
7) Noise analysis (delay and glitches) and noise report
8) Repair by buffer insertion, driver sizing, wiring spacing, and shielding
9) Run mixed signal simulation

IV. Results

Two different types of results are presented in this section. In subsection IV-A a real LF frequency RFID case study is presented taking into account the techniques here presented. In subsection IV-B results of a silicon proven test chip are shown.

A. Case of study: LF RFID tag area optimization

Taking into account a low-frequency (LF) RFID tag chip, composed by a resonance capacitor (Cres), a supply capacitor (Csup), an analog front-end (ANALOG), a digital block (DIG), and a memory block (MEM) [5] and considering the standard approach in a CMOS process with 5 metal layers and metal-insulator-metal (MIM) capacitor, it is reasonable to assume that most of the chip area will be spent with the capacitors Cres (̃hundreds of pF) and Csup (ñF).

Applying the proposed method, where the capacitors are placed over the digital and memory blocks together with additional routing analysis and process features, the final area optimization can reach a 17% gain.

Figure 2 depicts this mathematical analysis results, assuming a standard approach and comparing different approaches considering one different CMOS process (with 6 metal-layer) and placement/routing techniques.

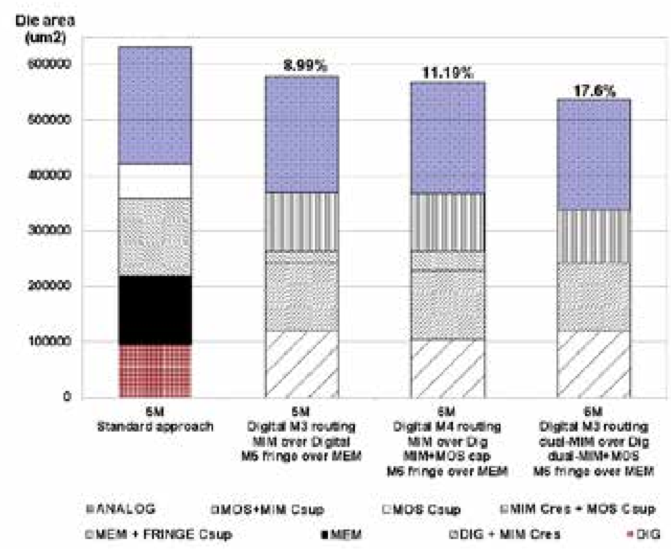

Fig. 2: Results of capacitor placement approach

The first bar represent the standard approach where digital circuit is routed with all Metal layers in a 5 metal-layer submicron process, it means, no MIM capacitor over it but already using the combination of MOS+MIM wherever is possible (MIM Cres + MOS Csup). Note that the existence of at least two different capacitors (supply and resonance), but sometimes more, on an RFID architecture may also lead to the need of using different types of capacitors, otherwise, only the highest density capacitor could be used. It is also important to note that the highest density capacitor may have limited integration, for example MOS capacitor cannot be placed over digital cells or memory and MIM capacitor that uses two layers of metal rarely can be placed over memories.

The second bar depicts a scenario where digital circuit was routed up to Metal 3 in 5 metal-layer process, this led the digital area to increase but at the same time allowing MIM capacitor over it (DIG + MIM Cres) and MOS capacitor as filler cells where no digital cells were placed (part of MOS + MIM Csup). Also, fringe capacitor was also added over Memory (MEM + FRINGE Csup); note that a supply capacitor was selected to be placed over memory due to smaller noise generation than resonance capacitor and, more important, due to the fact the non-volatile memory IPs are usually sold as black boxes not allowing noise analysis to be performed.

Third bar considered a 6 metal-layer on the same submicron process. The ̃11% area reduction was achieved by routing digital circuit up to Metal 4 and adding single MIM capacitor over it (DIG + MIM Cres); considering that digital circuit did not increased the same 30% than when routed with only 3 metal layers, there was more space outside digital area to place MOS capacitor with higher density (MIM Cres + MOS Csup) then achieving the required amount of capacitance in a smaller area.

Finally, the forth bar presented a scenario quite similar as the third one but using Dual MIM capacitor in the same 6 metal-layer. Digital circuit was routed with 3 metal layers which allowed, in this case, to a Dual MIM capacitor to be placed over it then reaching resonance capacitor requirements. Note that the combination MIM Cres + MOS Csup is not presented and then the Dual MIM could be used for supply capacitor needs (MOS + MIM Csup) leading to a reduction of 17.6%.

It is also important to disclaim that, although the techniques here presented can be applied virtually to any circuit containing capacitors and even other passive elements, the results here presented may deeply vary from circuit to circuit. For example, a complex digital circuit may increase 200% or more when routed up to Metal 3 compared to the same circuit routed up to Metal 5. Also, some memory IPs DRC rules may not allow metal layers over it or not always MOS capacitor could placed as filler cells inside digital area, it is the case when digital circuit voltage is different from MOS capacitor voltage, for example. Also, the specific technology node was omitted on purpose due to commercial issues.

Capacitances types considered to obtain the results presented are listed in table I.

TABLE I: Capacitor types

Capacitor type or Capacitor Combination	Density
Single MIM	2E-015 F/um^2
Dual MIM	4E-015 F/um^2
MOS3V	4.82E-015 F/um^2
MOS2V	8.46E-015 F/um^2
MOS2V as filler cells	5.92E-015 F/um^2
Single MIM + MOS3V	7.00E-015 F/um^2
Dual MIM + MOS3V	9.00E-015 F/um^2
Fringe Capacitor (Metal 5)	5.00E-016 F/um^2

B. Test chip: capacitor over digital area method validation

A 5 metal, MIM capacitor, CMOS submicron process test chip was designed, fabricated and tested, containing a test structure that validates the proposed method. The selected digital circuit was a 16-bit Cyclic Redundancy Check (CRC) ($x^{16} + x^{12} + x^5 + 1$, polynom) because any bit flip will lead to a dramatically different output.

As it is possible to see in Figure 3 two identical CRC circuits (both routed up to Metal 3) were prototyped; one with a MIM Capacitor to act as resonance capacitor and other without any capacitor over it. The objective behind this was to accomplish quick bring-up results by comparing on-the-fly outputs of both CRC thus requiring a very simple setup: a Function generator for clock and resonance capacitor frequency, and a Source for power and a Data 1 input. The chain of inverters depicted were added to create a longer net than the original circuit, thus getting closer to real circuits.

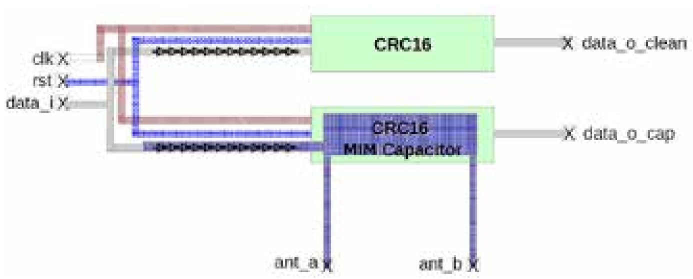

Fig. 3: Prototyped test chip simplified layout

The flow for Noise Analysis was applied on both circuits and over one of them the resonance MIM capacitor were placed. The bring-up procedure consisted on applying a 134.2 KHz wave on both antennas inputs with a specific slope (from 0V to 2V in some nanoseconds) where clock and power are 1.2V and the digital circuit was synthesized for 10 MHz frequency.

Table II presents the result of the post-silicon test and it matched the expectation provided by the noise analysis flow. The definition of error is whenever data_clean_o is not equal to data_cap_o output, it means, the noise influence the resonant capacitor generated a bit flip in the CRC circuit below it.

TABLE II: Test chip results

Antenna Signal	External resistor	Clock Frequency	Result
No signal	No load	10 MHz-22 MHz	Error @ 23 MHz
134.2 KHz; Slope 143 ns	No load	10 MHz-14 MHz	Error @ 15 MHz
134.2 KHz; Slope 143 ns	800k-96k	10 MHz-14 MHz	Error @ 15 MHz
134.2 KHz; Slope 10 ns	96k	10 MHz-13 MHz	Error @ 14 MHz
134.2 KHz; Slope $<=$ 8ns	96k	10 MHz	Error @ 10 MHz
134.2 KHz; Slope $>$ 9 ns	96k	10 MHz	No Error @ 10 MHz

Considering that the circuit was designed to operate at 10 MHz and with slopes less steeper than 9 ns, the most noticeable result in this table is where it operates without errors at 10 MHz and with slope steeper than 9ns, which is a common and expected behavior in our Low-frequency RFID chip.

V. Conclusion

This paper presented an area optimization technique for integrated circuits composed by digital parts and capacitors. In order to exemplify this technique, an industrial application utilizing series of capacitor distributions approaches has been presented. Considering the results presented, we demonstrated that those approaches significantly reduced area. Although some extra procedures have to be done during the design flow, such as noise analysis, the area reduction of over 17% indicates that these efforts are valuable and worthy to be considered during architecture exploration, in the very beginning of the project.

Regarding future work, we envisage two possible extensions for the methodology presented. Firstly, we plan to benchmark our technique to evaluate numerically against other alternatives. Secondly, we intend to extent our methodology to encompass other passive elements.

Acknowledgment

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Using LabView to Automate RFID Tag Tests: Comparison Between Implemented System and Voyantic Test System

Márcio Félix, Frederico Pereira, Vinicius Ferro
RFID CoE (Center of Excellence)
Flextronics Institute of Technology – FIT
Sorocaba – Brazil
{marcio.filho1, frederico.pereira, vinicius.ferro}@fit-tecnologia.org.br

Everson Martins, Ivando Diniz
São Paulo State University – UNESP
Sorocaba – Brazil
{everson, ivando}@sorocaba.unesp.br

Abstract – This article presents an alternative method to automate RFID tag tests using the tool LabView to control an RFID reader Sirit IN510 and a step motor drive. The article also presents a comparison between the results obtained with the implemented system and those that were obtained with the Voyantic testing system.

Keywords-component: RFID, Voyantic, Anechoic chamber, LabView.

I. INTRODUCTION

Radio frequency identification technology or RFID is already present in life of most people without notice. Security services in clothing stores, tolls and also livestock, which are already RFID tags used for earrings in cattle.

Despite being a consolidated market, according to the company IDTechEx it will present a large growth in the coming years. Currently the market is around 9.2 billion dollars. This increase covers various aspects of the RFID business, tags, readers and software / services. It is expected that this market will increase to 30.24 billion dollars in 2024 [1].

The major factor contributing to this growth is the possibility to control distribution (inventory management) and for being a totally wireless technology. In addition, advances in technology have denied the myths that are impractical to apply it in metals and products containing liquids. New antennas topologies developed while increasing the read range, robustness and system reliability also widened the range of possible applications of the technology [2, 3].

The increased use of the technology, coupled with development of organic electronics causes the called ORFID - Organic RFID - also be an area that attracts investment with the possibility of within a few years, lower the cost of technology and enables their use in products with low added value. [4].

With this projection in RFID market is expected increased demand for tests as well. To go through this increase is important to think in alternative ways to automate and let them faster.

II. MATERIALS AND METHODOLOGY

The system developed consists in a PXI National Instruments that communicates via serial with a stepper motor drive located inside an anechoic chamber, the drive is connected to a stepper motor coupled to this a reducer and encoder. Outside the anechoic chamber, PXI also communicates with an RFID reader via TCP / IP. The system block diagram developed is shown in Figure 1.

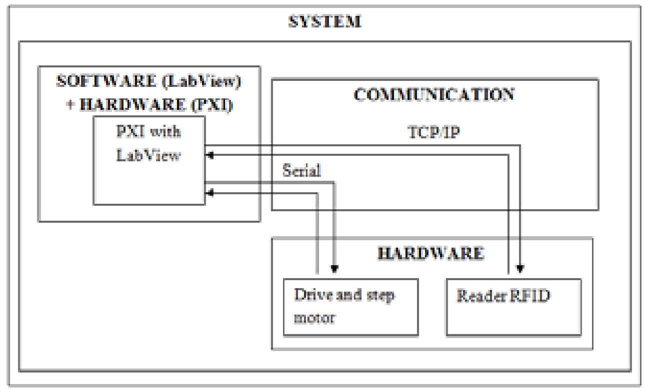

Figure 1 - System block diagram.

For assembly the system the following materials were used:

- PXI National Instruments with LabView;
- Drive ST10-PLUS;
- Source Delta 100-240 VAC - 24VDC
- NEMA step motor;
- RFID Reader Sirit;
- RF cables;
- Ethernet cable;
- Serial cable;
- Anechoic chamber;
- Antenna (Linear, 915 MHz);
- Reducer 1:60;
- Encoder.

HARDWARE

The mechanical system comprises the assembly of the reducer in the step motor and encoder. After the system has been assembled in a shielded box of RF inert materials and it was placed inside the anechoic chamber. The drive and the power supply were also embedded in the box and connected to the step motor. Figure 2 shows the turntable already mounted within the anechoic chamber.

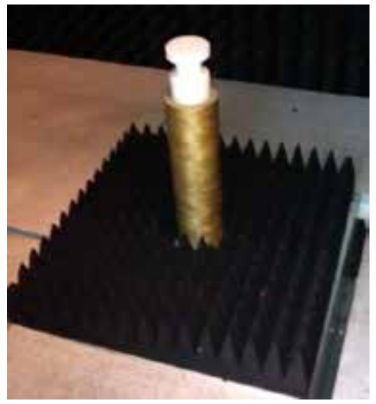

Figure 2 - Turntable inside the anechoic chamber.

The anechoic chamber is an environment designed to be immune to external electromagnetic sources that may generate noise in the environment, simulating a perfect open area. In addition, the chamber is designed to contain reflections of electromagnetic waves. Figure 3 shows the entry of the anechoic chamber located in FIT, in it is possible to notice the absorbing foams installed along the chamber walls, ceiling, and the rotating table already installed inside the chamber. The size of this environment varies according to the needs of the applications. For this case, it is able to test small products, such as printers, and even entire pallets of these products, the anechoic chamber has dimensions of 145 x 245 x 213 cm.

Figure 3 - UHF Anechoic Chamber for RFID tests.

The RFID reader, to be located outside the anechoic chamber, was connected directly with the PXI as can be seen in Figure 4 and the description of the following components is located.

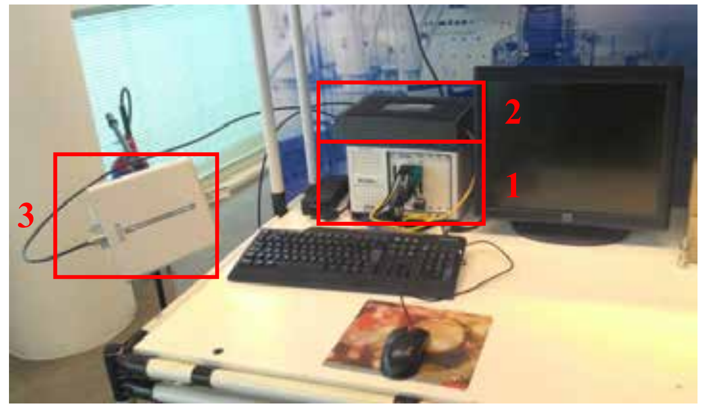

Figure 4 - Equipments of the test system.

1: PXI National Instruments;
2: Reader RFID Sirit;
3: Antenna.

The communication between the drive and PXI was performed through a serial terminal installed in the chamber signals input. These input can be seen in Figure 5

Figure 5 - Chamber signals input.

The signals output within the anechoic chamber are shown in Figure 6.

Figure 6 - Chamber signals output.

SOFTWARE

The software was developed using a graphical programming language, in this case, LabView. Figure 7 is an outline of the necessary features for the turntable and relates panel with the functionalities required for the VI (Virtual Instrument), how is called a software built in LabView.

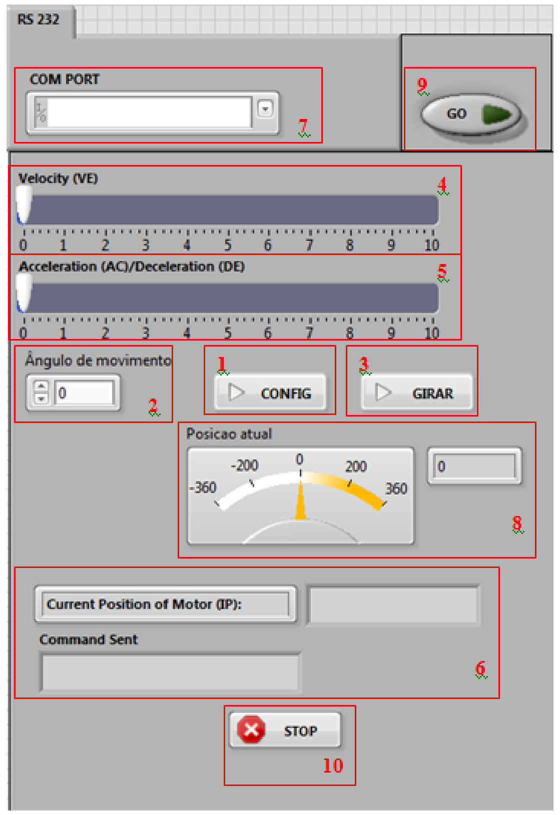

Figure 7 - Front panel for the turntable.

1. Configuration button: to be used when initially open communication on the serial port, set a speed and acceleration/deceleration predetermined and makes the turntable goes to starting position.
2. Field for the user to insert the degrees to rotate the turntable.
3. Rotate button: it causes the turntable to rotate the amount of degrees that was explained in the input field 2.
4. A bar for setting turntable speed.
5. A bar for setting the turntable acceleration and deceleration;
6. A field to show the position of the turntable, since there is no vision from inside the anechoic chamber during the tests and also to show the last command sent to it;
7. Field to select which serial port will be used;
8. Visual and numeric field to show the current turntable position;
9. Button to turn on the system after selected the port.
10. Button to stop the system.

Figure 8 is an outline of the necessary features for the reader and relates panel with the functionalities required for the VI.

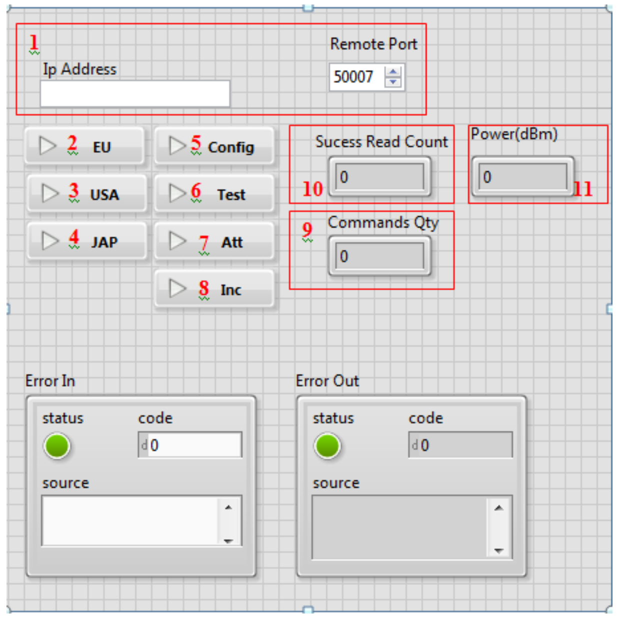

Figure 8 - Front panel for the reader.

1. Field to enter the IP address and the port of the reader;
2. Button to set the frequency for Europe (EU);
3. Button to set the frequency for the United States (USA);
4. Button to set the frequency for Japan (JAP);
5. Button for predefined initial settings;
6. Button to send thirty reading commands;
7. Button to attenuate the reader's power.(Att);
8. Button to increase the reader's power.(Inc);
9. Field to show quantity of reading commands;
10. Field to display the quantity of reading response have been successfully performed;
11. Field to display the current power in dBm.

III. TEST METHODOLOGY

The orientation test performed is summarized by, positioning the RFID tag away 26cm from the linear antenna and rotate it in steps of 30°, doing the test until reach the final positioning, 330°.

The both tests were realized using the following configuration:

Table 1 - Parameters configuration for tests.

Line Code	Tari Time	Modulation Type	Frequency
FM0	25µs	DSB	915 MHz

The RFID reader sends thirty read commands, if the tag did not respond; the power is increase in 0.5dB. When the tag responds, the table rotates 30° and the process starts again.

For the test, it was used the Confidex Steelwave Micro tag [6] in the implemented system; a know gain dipole was used to calculate the correction factor between the power on the reader port and the power on the place of test. The Figure 9 shows the dipole antenna being used to measure the power and calculates the factor. The configuration of the test setup is shown in Figure 10.

A second test of orientation was performed using Voyantic Test System [7] for compare the results. For rotate the tag the VI developed was used. The same RFID tag was used in both tests.

Figure 9 - Dipole antenna in the place of test.

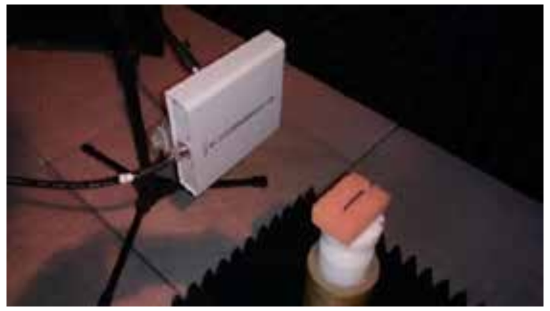

Figure 10 - Setup of test.

This factor can be calculated in dB by the Equation 1.

$$FC = P_{pt} - P_{or} \quad (1)$$

Where P_{or} is the Power in the reader out and can be calculate by Equation 2. P_{pt} is the power on the place of test and can be calculate by Equation 3.

$$P_{or} = P_{mes} + CL \quad (2)$$

$$P_{pt} = P_{mes} + CL - DG \quad (3)$$

Where P_{mes} is the power measured in the spectrum analyzer, CL is the cable loss and DG is the dipole gain.

So, the power on tag can now be calculated for each position of test by Equation 4.

$$P_{on} = P_{mes} + FC \quad (4)$$

Finally, the read range can be calculated by Equation 5 using the P_{on}.

$$R = \frac{c}{4\pi f} \cdot \sqrt{\frac{P_{max,EIRP}}{P_{on}}} \quad (5)$$

Where:

c is the velocity of the light;

f is the frequency of operation;

$P_{max,EIRP}$ is the maximum effective isotropic radiated power permitted.

IV. RESULTS

Calculating the FC using the Equation 1 the results are shown in the Table 1.

Table 2 - Data used to calculate FC.

Pmes (P_{or})	CL (P_{or})	P_{or}	Pmes (P_{pt})	CL (P_{pt})	DG (P_{pt})	P_{pt}	FC
18,71 dBm	1,81 dB	20,02 dBm	4,94 dBm	1,81 dB	2,2 dBi	4,55 dBm	-15,47 dB

The Table 2 presents the results obtained performing the test with the implemented system and Voyantic Test System. The Power on Tag Sirit was calculated using the FC obtained in Table 1. After it, the Read Range Sirit could be found using the Equation 5. The results of Power on Tag Voyantic and Read Range Voyantic were obtained by using Voyantic's Tagformance software. The Read Range Difference was calculated doing the difference between Read Range Sirit and Read Range Voyantic.

Table 3 - Results of both tests.

Position (°)	Power on Tag Voyantic (dBm)	Power on Tag Sirit (dBm)	Read Range Voyantic (m)	Read Range Sirit (m)	Read Range Difference (m)
0	0.48	0.47	1.413	1.416	0.003
30	2.26	3.24	1.152	1.029	-0.123
60	2.96	4.02	1.062	0.941	-0.121
90	1.26	1.88	1.292	1.203	-0.089
120	-0.36	1.01	1.556	1.330	-0.226
150	-0.56	-0.25	1.593	1.538	-0.055
180	0.24	0.47	1.452	1.416	-0.036
210	1.63	2.48	1.238	1.123	-0.115
240	1.93	2.46	1.196	1.126	-0.070
270	0.64	1.50	1.388	1.257	-0.131
300	-0.46	0.05	1.575	1.486	-0.089
330	-0.56	-0.26	1.593	1.540	-0.053

The Figure 11 shows a polar graphic of the read range with the comparison between the results obtained in both tests. Their behavior was similar in each position. The greater difference occurred in the position 120 ° (22.6 cm) and the smaller in the position 0° (0.3cm).

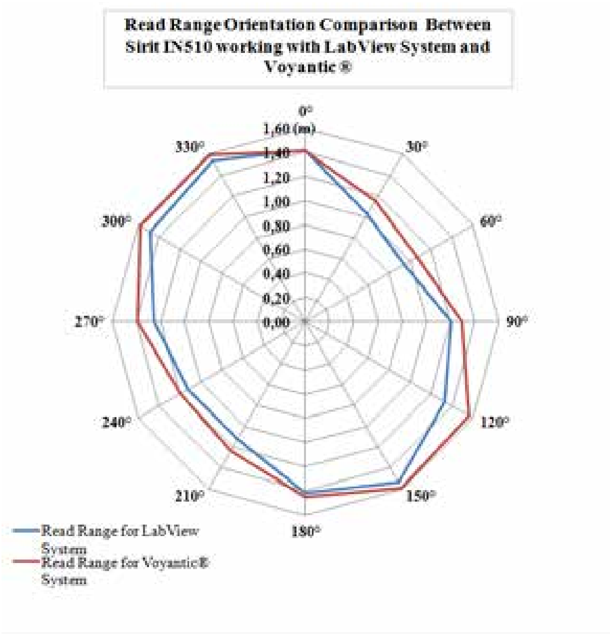

Figure 11 - Polar graphic with the comparison between read range tests.

V. CONCLUSION

Based in the results founded, the automated test system was considered reliable in comparison with Voyantic Test System, which is a consolidated company in the segment of RFID tests. The difference between both tests is a normal value founded when using different equipments and methodology. The software developed can be used as a base to a huge number of tests and applications.

VI. FUTURE WORKS

Using LabView as the software language, it permits to develop totally automated tests according to methodology and different purposes including the GS1 EPCglobal Tag Performance Parameters and Test Methods Version 1.1.3. The project's next step is to control the attenuation using an external attenuator, to increase the precision and reliability of the tests.

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RFID Applied to Protective Equipment Inspection

A research and development project focused on occupational safety in fieldwork

Clovis M. Cabreira, Mateus P. Capistrano, Alberto L. Pacifico, Michel H. Alves, Pedro H. Zacarin, Alessandro G. Andreo
Fundação CPqD
Campinas, Brazil

Harley Albuquerque
COELCE, Companhia Energética do Ceará
Fortaleza, Ceará

***Abstract*—This article presents the development of an efficient solution for checking the use of protective equipment in fieldwork through a R&D project between Fundação CPqD [1] and COELCE [2]. This is a monitoring tool applied in the supervision and oversight of field operations that through RFID technology (Radio Frequency Identification) tells the user the absence or inadequate use of protective equipment by warning signs. The functional description of the solution, its implementation and field tests are the points addressed.**

Keywords—Protective equipments, identification, radiofrequency, RFID, occupational safety.

I. INTRODUCTION

With the technological progress concerning the internet of things (IoT) enabling the insertion of intelligence in different objects, different areas of the industry and the market began to use sensing and control in their processes. In an electricity concessionaire, in which case the company's activities may contain high levels of danger to their employees, these technologies can be used seeking greater security in the workplace or while performing a service in the field.

For this purpose, the CPqD (Research and Development Center in Telecommunications) and COELCE concessionaire (Energy Company of Ceará) performed the R&D *"Sistema de Verificação do Uso de Equipamentos de Proteção Individual em Trabalhos de Campo"* [3][4] and its improvement. Based on RFID technology, hardware and software developed are capable of verifying the use of personal protective equipment (PPE) in fieldwork. However, because of the potential envisioned for the system, this solution was also prepared for the control of collective protection equipment and some vital tools for safety during fieldwork.

There are similar solutions in the market that add RFID into PPE's and utilize different methods of verification. The most common approach uses RFID portals to create "safe areas", where only the personnel wearing the recommended PPE can access [5][6], an impractical solution for the fieldwork. Another known method makes use of a handheld device which scans the protective equipment on the field [7]. In this case, the system can be wrong by reading PPE's not worn by the workers. The solution proposed by CPqD comprehends the issues addressed above. It is devised to be applied in both external and internal environments and guarantees the PPE's readings limited to the worker body, confining the read range.

This document presents this system, which aims to alert the user in case of inconsistencies between the mandatory list of safety items (collective or personal protective equipment) related to each service order and the items loaded on the vehicle or used at the field. However, the inclusion of the RFID protection equipment may also provide an optimized management of these items. Thus, the developed solution offers the following benefits:

- Centralize information of the concessionaire's PPE;
- Ensure the use of PPE by skilled employees;
- PPE usage in accordance with the service orders;
- Guarantee the usage of certified PPE;
- Control the life cycle of PPE.

II. RESEARCH DEVELOPMENT

A. General Description

The system architecture, illustrated in Fig.1, comprises two inspection levels, using radio frequency identification technology (RFID):

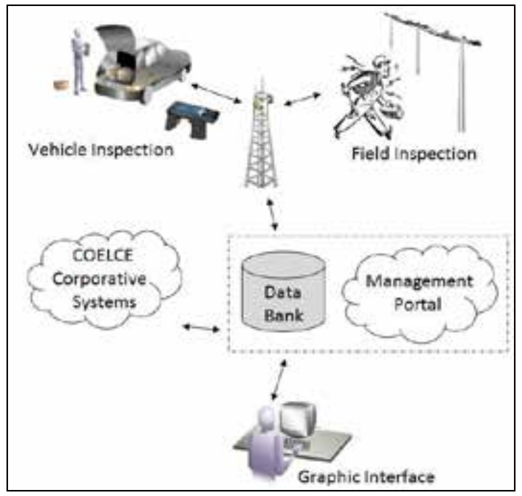

Fig. 1. System Architecture.

- **Vehicle Ispection**: At the moment the team is preparing to be released to work, still at the operation base, the inspection of the protective equipment and tools that should be in the vehicle takes place. In other words, the inspection happens before the teams go to the field;
- **Field Inspection**: already at the service spot, and wearing the necessary PPE to perform it, the professional conducts the inspection, where the configuration terminal displays the list of required PPEs for the activity to be performed and the list of found PPE during the verification.

To make these inspections possible, each protective equipment is provided with a Class1 Gen2 UHF RFID tag (passive RFID) [8], which operates in the 900MHz frequency range and has an unique identification code.

In both cases, the gathered information are sent to a centralized system and can be accessed from anywhere with internet access, enabling remote monitoring of all activities in real time.

B. Hardware

There are two hardware sets, one for each inspection level. The field inspection hardware consists of an operation terminal (for example, a smartphone), RFID reader module (operating in the frequency range 902-907.5 MHz / 915-928 MHz) and a vest where the antennas are encapsulated, whereas for vehicular inspection the vest is not used but a single antenna is coupled to the RFID reader module instead. In this second case, the hardware is regarded as a handheld or a portable reader.

The module autonomy is approximately four (4) hours of continuous operation, using the two antennas outputs at full power (+ 30dBm).

The vest was developed in partnership with a specialized manufacturer in industrial projects on demand. In association with this manufacturer, some prototypes were created before the final model, presented in Fig.2, with a material that: presented the lowest weight; did not influence the transmission parameters of the antennas and presented good ergonomics.

Fig. 2. Vest containing RFID reader module and antennas.

As shown in Fig.2, there are two different models of antennas. The near field antennas cover the PPE's positioned above the waistline(e.g., hard hat and goggles) and the far field antenna, the PPE's positioned below the waistline(e.g., boots). Both were designed to have limited radiation field in order to identify only the PPE's worn by the workers

C. Operation Apps

The operation terminal is the interface between the employee working in the field and the RFID reader module. It is responsible for the reader module configuration, through pre-established options supplied by the centralized system and selected by the users, and for the presentation of the set of the listed and found PPE during the verification.

These applications were developed using the Android platform, which is present in most gadgets available on the market. Therefore, they can be installed on smartphones or tablets that are already used by some companies in the sector.

The choice of this platform took place for the reasons listed below:

- **Data processing speed:** there is a myriad of devices with powerful features available in the market;
- **Features:** Android devices hardware contains many integrated modules such as GPS, which is used with the inspection application;
- **Scalability:** applications can be installed and used on any mobile device with Android platform, above the 4.3 version;
- **Data transmission speed:** most of Android devices supports the transmission of data packets at high speeds, through HSPA+ and LTE standards;
- **Interface:** the Android platform SDK (Software Development Kit) provides several robust interface elements.

D. Management Portal

The centralized system, which the operation terminal connects to perform its functions, can be accessed through a web interface. This portal, presented in Fig.3, provides the access to the management functions of the system, such as inventory control, inspection logs and its indicators, and management of the PE used in each operation.

Following, all the features available in the portal are presented:

- Creation and management of user account for different permission levels;
- Registration of partner companies;
- Registration and creating of item models (PE and tools);
- Management of skilled employees (COELCE and partner companies);
- Management of Protective Equipment and tools;

Fig. 3. Management Portal Menu.

- Query of system logs (changes and deletions);
- Query of indicator reports (ranking of companies and employees);
- Management of "Service Map", where for each type of service the required PPE are discriminated. Fig.4 exemplifies a "Service Map" implemented in the system;

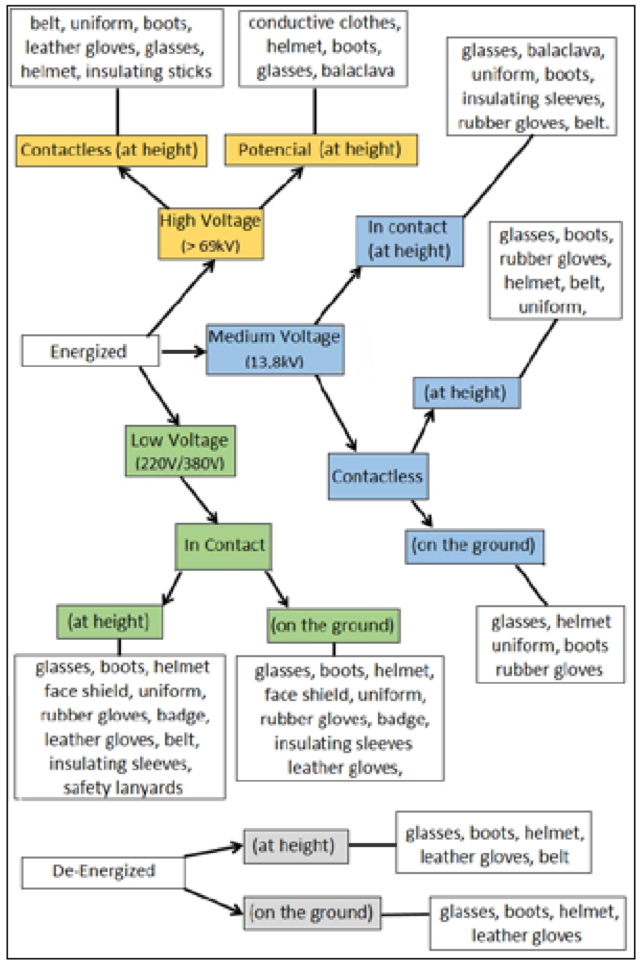

Fig. 4. Service map.

- Real-time monitoring (vehicular inspection and field operations), shown in Fig 5.

Fig. 5. Real-time monitoring.

III. System Operation

A. Operation

The vehicular inspection and the field inspection follow the same process in order to configure the operation terminal. The system operator, usually the team leader, follows these steps:

- Insert the login data in the operation terminal;
- Establish communication with the RFID reader module, via Bluetooth;
- Set the service to be performed;
- Start the reading of protective equipment;
- Send results to the centralized system.

The service configuration is based on the identification of the service using a known code (e.g. the Service Order) and on the discrimination of the service type that will be executed using the "Service Map".

During the PE inspection, the list of equipments presented by the operation terminal (PE inside the vehicle in case of a vehicular inspection or the used PPE by a worker in case of a field inspection) can present items in green (for the items that were found), red (for the items that were not found) and blue (for items that were found, though they were not part of the original list or required items). This feature was implemented in order to make this process easier for whom is tracking the progress of the inspection.

B. Field tests

The step of solution testing at the field was preceded by a step of knowledge transfer through a solution training. At first, the leaders of COELCE and its partners (especially safety technicians and operating engineers) were trained. Due to the management and coordination responsabilities of these professionals, this first training was focused on the management and monitoring of the inspections functions.

After that, the technical teams of the partners, that works with several types of service (such as, construction lines, inspection of gauges and network maintenance) were selected and trained, in order to evaluate the solution in different scenarios. This training was focused on the PE inspection modules (vehicular inspection and field inspection).

The employees, that were involved during the tests, evaluated the applications of operation terminal such as applications that have interfaces which enable the system configuration intuitively and easy to learn, due to the training of technical teams with other systems used to receive service orders field. The Fig.6 shows one of the teams selected during a PPE field inspection before a field activity.

Fig. 6. PPE field inspection.

During the field tests (January to March 2015) were performed measurements of average times of the inspections, as shown in Table I.

TABLE I. AVERAGE TIMES OF THE INSPECTION

Process	Duration
System access time (login)	34 sec.
Configuration time and PPE inspection time	43 sec.
Configuration time and PE vehicular inspection	210 sec.

At the end of the field test period, they were executed about 100 (one hundred) inspections by the trained teams. It is noteworthy that since the partner companies continue to use the system.

IV. CONCLUSION

After the field testing stage (about 2 months) positive results were obtained. The technical feasibility of the main purpose (the automation of PPE checklist during the fieldworks) was proved, minimizing the possibility of human error at the moment of relating PPE to be used, and increasing safety in this kind of service. It is noteworthy that such features are not restricted only to utilities, but meet the demand of companies from various sectors, which play activities in highly dangerous scenarios, such as petro-chemical industries and construction.

In addition, we saw that the system has the potential to be used not only as a occupational safety tool, but also a strategic planning tool for companies regarding the financial issues (resource planning in replacement of equipments and qualification of suppliers) and legal (evidence and records in cases of work accidents).

With the time indicators obtained during field tests, the economic project feasibility studies were conducted. Even with the costs involved in the project development, in the provided services by the concessionaire and in the manufacturing of 550 hardware units to the COELCE and its partner companies teams, an investment return is estimated at 10 months due to measurable gains in relation to PE inspection time and the optimized management of resources for them.

Before the start of the solution improvement project, it was thought about the need to develop a partnership with a PE supplier in order to get the RFID tags already embedded in the PE during the production process. Currently, using the information that the solution is feasible and there is a method to inserting and positioning the tags inside the equipments, it is possible to start planning in this way, involving the interested companies and allowing them that, soon, may implement this technique in the development of new products (PE's) with embedded RFID technology, and thus completing the development cycle for a secutry solution, that contains: software system (centralized system to manage the protective equipments); RFID hardware (vest - reader module and antenna); and Protective Equipment with embedded RFID tags.

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Monopulse RFID Reader for Enhanced Intelligent Transportation Systems Applications

Carolina Alcaraz
Universidad Nacional de Colombia
Bogotá, Colombia
Email: calcarazr@unal.edu.co

Juan Vicente Balbastre
Universitat Politècnica de València
Valencia, Spain
Email: jbalbast@itaca.upv.es

Félix Vega
Universidad Nacional de Colombia
Bogotá, Colombia
Email: jfvegas@unal.edu.co

***Abstract*—This work is focused on integrating a monopulse system into a passive RFID (Radio Frequency Identification) reader operating in the ISM (Industrial, Scientific and Medical) band centered at 915 MHz to identify the sense of motion of RFID tags installed on vehicles. The channel between the reader and the tag is modeled using the basic Friis equation for free space with measured values of antenna gains. The statistical behavior of both readers and tags is derived from measurements using actual components and it is introduced in the system model using the Monte Carlo Method to obtain more realistic performance figures at the system level.**

Keywords— Hybrid coupler, monopulse, reader, RFID, tag

I. INTRODUCTION

The knowledge of traffic flows in a city is the basis of urban ITS systems. Information about traffic flows can be gathered in several ways: using buried magnetic loops, cameras and image recognition software, or even manually. Buried loops can provide information about the sense, the speed and even the category of vehicles crossing over them, but they are invasive and in some cases they are frequently broken due to the deterioration of the outermost layers of the road pavement. On the other hand, all-weather operating cameras can be expensive, especially if the plate number is going to be used to vehicle identification purposes.

RFID tags are being increasingly used in traffic applications to limit the access to restricted areas to residents or to public transportation systems and in payment for congestion systems. Therefore, those tags could also provide information on traffic flows to ITS subsystems which generate traffic statistics to support strategic decisions on traffic regulation.

Conventional passive RFID systems with a single antenna can detect and register the EPC (Electronic Product Code) of a tag attached somewhere on the vehicle surface, but the direction of movement cannot be easily determined (unless two separated readers are installed, thus doubling the system cost).

However, the integration of a monopulse antenna allows to detect and to identify the vehicle through the sum channel, as in conventional RFID systems, whereas the polarity of the signal received through the difference channel can be used to determine the sense of the vehicle motion with respect to the antenna location (for instance, the change of positive to negative polarity could mean that the vehicle is circulating from left to right [1]). In this way, the sense of movement detection feature is added to the reader at the cost of a second printed antenna.

In section II, the design of the monopulse system is presented along with simulated and measured values of the antenna gain. Section III details the system model based on the Friis equation; also the numerical results obtained with the Monte Carlo simulations are described therein. Finally, the conclusions of the work are highlighted in section IV.

II. MONOPULSE DESIGN AND RESULTS

A. Design and fabrication of a 180º hybrid coupler

The monopulse system consists of two rectangular patch antennas, which are commonly used on RFID readers due to its portability and easy fabrication. To implement the monopulse system, two identical patches must be connected to a 180º hybrid coupler in order to produce the sum (Σ) and difference (Δ) channels. The 180º hybrid is obtained from a standard branch-line coupler (90º hybrid) just by adding a meander type phase shifter to introduce the additional 90° phase shift needed to get the desired 180º one.

The monopulse system shown in Fig. 1 has been designed using CST Studio Suite. A prototype has been fabricated on FR4 substrate of 1.6 mm thickness. Measured values of significant scattering parameters are presented in Fig. 2, showing a reasonably good behavior for the monopulse application (less than 4% error in phase shift and less than 0.15% (S13-S14) and 0.19% (S23-S24) asymmetry between the coupled ports). [1] This work has been partially supported by the Universitat Poli[1]técnica de Valencia through the researcb licence of Prof. Balbastre.

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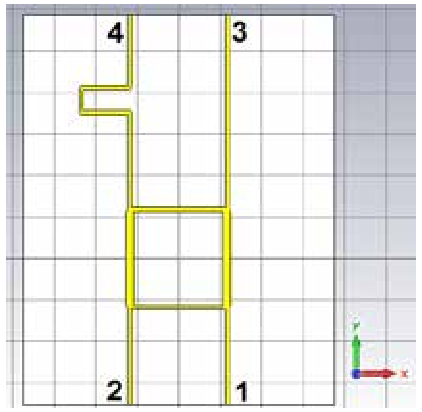

Fig. 1. Monopulse design

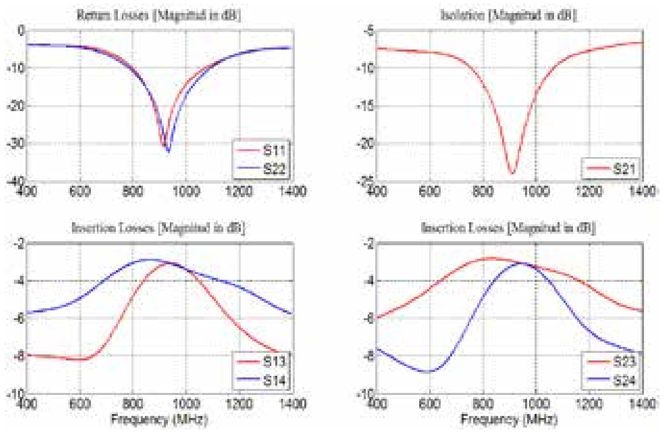

Fig. 2. Measures of monopulse system S-parameters

B. Design and fabrication of a monopulse receiver

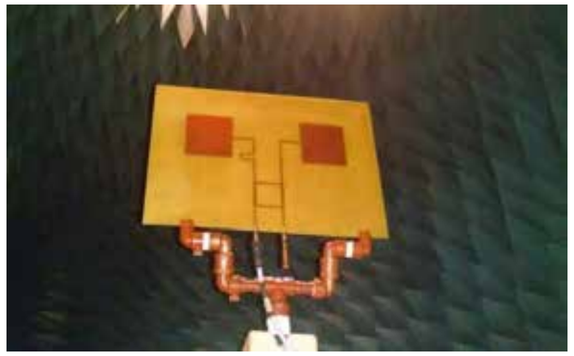

Fig. 3. Monopulse receiver

The circuit of Fig. 1 has been used to design and to fabricate a monopulse receiver, connecting two squared resonant patches ($\lambda/2 \times \lambda/2$ at 915 MHz) to the coupled ports of the hybrid. The separation of the patches (center to center) was 20.35 cm. The prototype shown in Fig. 3 was fabricated on FR4 substrate of 1.6 mm thickness.

The monopulse prototype was characterized in an anechoic chamber using an Agilent Model HP E5062A VNA) and an ETS-Lindgren reference antenna (LPDA) Model 3148B [2].

The results for the return losses are shown in Fig. 4, where a slight phase shift is observed. This shift is due to the uncertainty in the relative permittivity data and is typical of resonant structures like that considered in this work. Although this effect can be removed using broadband antennas, this simpler form is preferred herein for the sake of simplicity and cost, as far as acceptable system performance is achieved with it.

Measured radiation patterns are shown Fig. 5 and Fig. 6, along with the simulated ones, showing a good agreement.

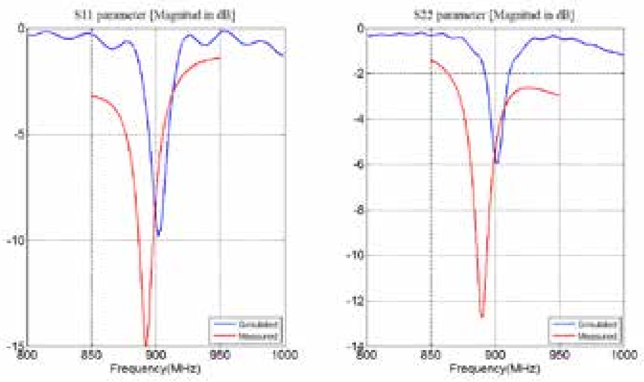

Fig. 4. Measured results vs simulated results of return losses

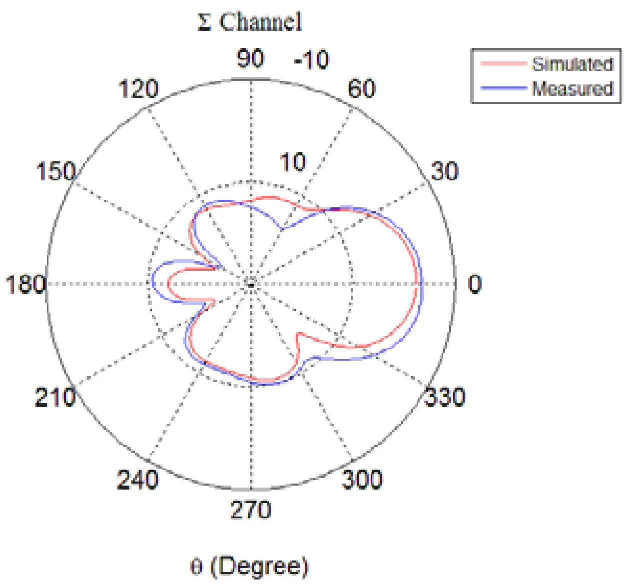

Fig. 5. Gain pattern (Σ channel)

iTracking - A Framework for Tracking Using RFID Technology

Thiago Manuel Fortunato da Costa, Vanessa Telles da Silva, Gabriel Lavoura dos Santos, Lucas Barbosa Parzianello, Marcelo Takashi Rodrigues Ishikame, Everton Luis De Grandi, Pedro de Botelho Marcos, Silvia Silva da Costa Botelho and Nelson Lopes Duarte Filho
Center of Computational Science
Federal University of Rio Grande
Rio Grande, RS, Brazil
E-mails: thiagofortunato@furg.br, silviacb@furg.br, nelson.duartefilho@gmail.com

***Abstract*—This paper presents iTracking, a software framework proposal for tracking using RFID technology. With the iTracking is possible to develop diverse applications for tracking, without worrying about low level programming issues. It is possible to use different RFID readers and tags models without changing the software structure. The framework is organized in modules responsible for communication, storage, visualization and position estimating. In this work it is specified the operations and how each function was implemented on each module. Despite its use in many kind of applications, the focus in this paper is in industrial applications.**

***Keywords*—Location and mapping, RFID, Framework, Wireless sensors networks.**

I. Introduction

With increasing demand and competitiveness industries need to have a better control of their production line, maximize results and quality of services. The use of tracking technologies can aim information that can be used to support these optimizations. Nowadays these tracking technologies are increasingly automated, safe and precise. For example Radio Frequency Identification - RFID is a technology widely used on automation processes [1], where systems can take decisions from position data collected by readers from tags emitting unique ids through communication using radio frequency. Car assembly plants [2], systems of managing logistic and asset [3], among others, they can be largely found. Currently, the RFID market turns around 9.2 billion dollars a year and the prediction is that this market will increase to 30.24 billion dollars in 2024 [4]. Due to diversification of devices and software among RFID manufacturers, there is a difficulty in portability updating and maintenance services of the equipment involved in the tracking systems. Aiming to solve these shortcomings a software framework was developed for the purpose of abstracting different types, brands of equipment and their protocols, to estimate position of a particular objects, storing information collected and to providing views data, without requiring low-level programming.

II. Concepts

The following definitions are necessary for understanding this work.

A. Framework

"A framework is a sotware and hardware architecture, developed in order to obtain the maximum reuse, represented as a set of abstract and concrete classes with great potential for specialization." - Wohlin, C et al [5].

B. RFID

RFID is a technology used to identify objects or people through radio waves emitted by tags and collected by readers. It adapts well to systems automation because of its flexibility and easy utilization. They can work in modes of read-only or read-writing, not require contact nor line-of-sight to operate, can work under a variety of climatic conditions, provide a level high data integrity and of safety [6].

This technology offers several contributions to control supply chains, through its advanced properties such as unique identification of products, ease communication in real-time [7][8]. The importance of this technology can be observed in different administrative needs of the supply chains, such as stock management, logistics management, programming of the production, management orders, inventory management and asset management [9]. By controlling the real situation of the supply chain it is possible to manage the demands of customers and adjust the production plan to improve the efficiency of the industry [10][11][12].

Some specific equipments are used in this technology that must be understood. They are antennas, readers, transponders (tags).

1) Antennas: Tags are activated by the antennas through a signal radio to send/receive information. When the antenna, transceiver and decoder are in the same enclosure they are called "reader".

2) Readers: The reader emits omnidirectional radio waves, with lenghts since some centimeters to a few meters, depending on the output and radio frequency used. These electromagnetic fields powers the transponder, which in turn responds to the reader with the content of his memory. This information is then collected by the reader and stored in a database.

3) Transponder (tag): The tag has a unique serial code in its memory and is used to identify objects or people when passes in the antenna's coverage area. The magnetic field is detected by the reader who decodes the data sent by the tag. Then passes it to a computer that perform processing and storage of the data [13]. The most commonly used models of the tags are passive and active. Passive tags are smaller and cheaper because its lack of battery. They receive the radio signal frequency of the emitting source and this energy is transformed into current electric within the tag that will generate a response signal. The active tags have a battery that powers its internal communication chip, thereby transmitting its identification sign periodically, regardless of receipt the reader signal. However they are more expensive but have higher storage and read range [6].

Fig. 1: Basic System RFID - [14]

III. Related Work

There are some hardware and software frameworks for tracking by RFID in the literature. They are work protocols and specific applications. The framework called PIA (Privacy Impact Assessment) [15] deals with privacy. It consideres best practices, national laws and local laws for collection, processing and storage personal information from customers by a company. Moving on to a software approach there are a framework called IdeIA [16], which emphasis the interpretation of the data collected, and not in their collection. Among the more relevant papers found, the one which is closest to the proposed model is the framework Athos RFID [17]. This project was developed in Java programming language and, in accord with its developers, the focus of the Athos RFID is on the resources of security in the protocol communication. So, as it is difficult to support all protocols of RFID, it is useful to have a generic communication protocol supporting new readers or to those who do not yet have protocols implemented. This is the focus of the iTracking.

IV. The iTracking

The iTracking is a framework that uses RFID technology and has intention to facilitate the work of user in constructing tracking systems. It abstracts low-level programming details in order that the users should only worry about passing parameters in XML, including the communication protocol to be used in the tracking system. The software framework executes the function of formatting and storage of the data for later use. In order to prioritize the performance it was developed in C++ programming language, along with a modular design approach, with modules of independent operation, to make easy the modifications and maintenance of the system. The modules are responsible by the communication, storage, positioning and visualization.

A. General operation

The software framework begins its operating reading a XML file with information of the basic hardware, the credentials of the user and also which communication protocol to be used. After done this configuration the system connects itself with readers and start sending and receiving info from the tracked objects, estimating its positions, storing these informations in a database and generating the graphic visualization automatically. For the tests, the supported protocols are the one used by RFID reader model LRX201 manufactured by Wavetrend, and by the reader model RFID AP-16 supplied by ACURA[18]. The latter is used together with passive tags of ACUPROX model. The iTracking also provides support for an open protocol called User. This protocol is generic and was proved to support communication with both protocols mentioned, in any reader that makes use of a serial communication. After receiving the data captured by the readers iTracking stores them in a database that can be consulted at any time. Furthermore, iTracking estimates the position of tags and readers when they are in movement. The stored data can be visualized in real time or within a given time interval.

B. Communication Module

This module is responsible for establishing the communication between the system and the RFID readers. The communication is done through the serial port. For the reader AP-16 it was developed a protocol that catches the bytes coming from the serial port and stores them in a vector. The bytes are delimited by a trailer that is a specific label for the ACUPROX cards. The trailer corresponds to ten characters in ASCII format inserted at the end of each taken reading. The vector is then stored in a database. Another two protocols were developed. One applied to LRX201 and LRX210 readers and the other is a generic protocol called User.

C. Positioning module

To estimate the position of a traceable object the ITracking was implemented in three different ways. The first procedure to estimate the position is used when only one reading parameter from the object is given to the Position Module. The second procedure is a little more complex. It uses information from two readers. The (x,y) position of the two readers that has received the strongest signal from the object are passed to the Position Module. In the third form, a Trilateration (Bisatto and Peres) [19] is used. The positions of three or more readers who received the object signal are passed to the Position Module. Then the module estimates the position of the object. Figure 2 shows the points A, B and C, the fixed positions of the readers, dA, dB and dC are the intensities of the signals received on each reader and P is the location of wanted point.

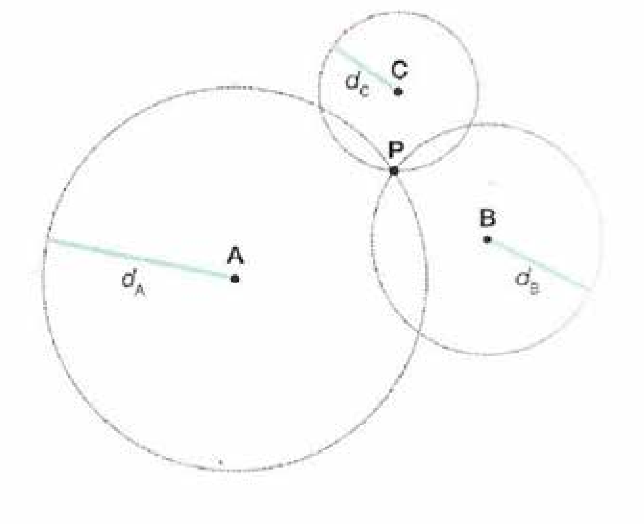

Fig. 2: Scheme for calculating position by trilateration

D. Storage Module

The storage module is responsible for storing data collected by readers. This module implements classic methods used in databases: creation, insertion, removal, editing, and query. For that, the MySQL database was used. Information such as name of the file, password, port user, among others must first be described in the same XML file quoted above.

E. Visualization Module

This module was build with Allegro5 library. It is used to display the positions of tracked objects in real time. The figure 3 shows the operation of this module. The drawing shows a effect heat map. In this kind of map the more times the same position of a object is painted on the screen stronger and wide its representation becomes.

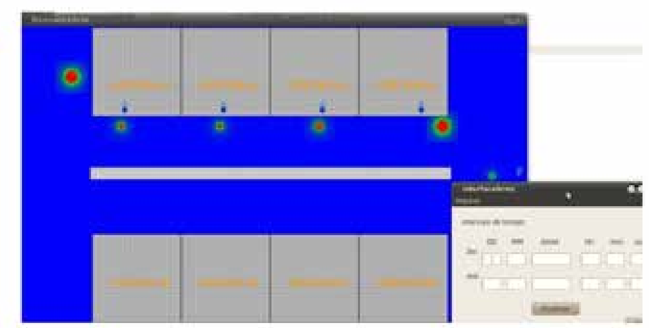

Fig. 3: Readings of real-time visualization

V. Testing and validation

The modules were tested individually. In the tests they receive inputs and have their behaviors and their outputs checked. Finally, integrated tests were done.

A. Testing Communication module

Using the readers models LRX201 and LRX210, were tested the connection of a PC with them. The software has connected successfully with the two models of readers. It have been made attempts of connection with wrong info. In this cases, it was returned error messages. For tests on sending information there are three different commands. These commands make the reader stops, puts it in automatic receiving mode and restart the reader. In all three cases the reader sent response messages acknowledging receipt of the commands.The communication module was also tested with the reader passive tags AP-16, which were also connected to the software successfully.

B. Testing Storage Module

This module was tested with and without readers. To connect to the database, the user must enter the password, host, database name, port and socket in the XML file. If no connection is established, the method should return a message with the occured error. Queries in the database depend on the software connected with it. The message with a query should be in SQL format and if the sending cannot be done the method should return an error message. To test the connection, queries were inserted in different times with incorrect data in the XML fields and the expected error messages were returned. Then, correct messages with information about users and queries were inserted. In these cases the connections and queries were successfully executed without error messages. The same behavior was observed in the use of the protocols developed, specially in the User Protocol.

C. Testing Positioning Module

The positioning module shall calculate and store the positions of the tracked object. To verify that the three algorithms were correctly builded, known positions were arbitrarily chosen and then the estimates were checked to see if they were reliable. The algorithm to estimate position from only one reading parameter is useful only to control the passage of the object in a specific area. The results of the algorithm to estimate the position based on two points show that the accuracy decreases when the object moves away from a collinear line between the fixed points. In the trilateration algorithm the tests showed that the estimated positions have had a variation of accuracy from 72.5% to 90%. Therefore, this algorithm provides a best accuracy in general. However, depending on the application this accuracy may not be satisfactory. This would lead the user to develop his own position estimation and put it in XML file.

D. Testing the Visualization Module

Tests have shown that the data displayed on the screen correspond the information saved in the database. This can be verified using the same queries in a software external to the framework.

E. Applications

The results obtained in these tests showed the correct operation of the developed software. This way, the iTracking can facilitate building of applications on it or be used as a own application. As an example of application, the framework is being tested and validated in Naval Industry. In this application the focus is the tracking of blocks and vehicles that transport it. The used architecture in this case consists of a mesh active RFID tags distributed over the area of analysis along with RFID readers coupled to the great vehicles and on the blocks transported by them. These readers would provide data to a mobile hardware (an Arduino board) that processes them and temporarily stores them. These boards wirelessly communicate with synchronization stations that are directly connected to the database. So, this database could be accessed for any station of consultation and even for mobile devices through the internet.

VI. Conclusion and future works

It was presented iTracking, a software framework proposal for tracking using RFID technology. With the iTracking it is possible to develop diverse applications for tracking, without worrying about low level programming issues. It is possible to use different RFID readers and tags models without changing the software structure. The framework is organized in modules responsible for communication, storage, visualization and position estimating. In this work it was specified the operations and how each function of the system was implemented on each module. Despite its use in many kind of applications, the focus in this paper is in industrial applications. Particularly, a system for tracking assets in a shipyard is in progress. Future works to be developed are protocols that accept models of readers with other types of connections not serial. Further improvements can be mentioned as the addition of new modules, for encryption for example, and the addition of other positioning calculation algorithms.

VII. Acknowledgements

We thank CNPq for partially funding this work.

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Optimized ultra-low power sensor-enabled RFID data logger for Pharmaceutical Cold Chain

J. C. S. dos Santos*§, F. O. O. Gomes†, M. A. dos Santos‡, M. C. Felippeto de Castro‡, N. Grando§, R. Travessini§ and R. S. Weirich§
* Programa de Pós-Graduação em Engenharia Elétrica PUCRS, Porto Alegre/RS, Brazil
Email: joao.santos.004@acad.pucrs.br
† RFiDo Design, Porto Alegre/RS, Brazil Email: contact@rfidodesign.com
‡ PUCRS, Porto Alegre/RS, Brazil
Email: see http://www3.pucrs.br/portal/page/portal/fengppg/ppgee/ppgeeEquipe
§ WaveTech Soluções Tecnológicas, Florianópolis/SC, Brazil
Email: joao.carlos@wavetech-st.com

***Abstract*—This work presents an ultra low power, high sensitivity, high memory utilization, sensor-enabled, battery-assisted passive tags (BAP) as a data logger for pharmaceuticals cold supply chain. The BAP tag monitors the pharmaceutical products conditions during transportation and storage. As proof of concept, the BAP tag was developed to monitor only the temperature, but other sensors as light, moisture and vibration could also be applied. The development includes a different BAP tag architecture survey using low power techniques and smart memory management.The developed BAP tag consumes 1.9 µA in idle mode, 12 µA in Active mode, has -24.5 dBm sensitivity and can store up to 32.7k measurements using a 128 kbits memory.**

Keywords - RFID, sensor-enable BAP tag, temperature data logger, low power consumption, Pharmaceutical Cold chain

TABLE I
Market Survey of some existing data loggers.
[1] Quoted online with distributors.
[2] Sampling rate was not specified in their datasheet

Product	RT0005	Log-Ic	Track-It	SensTag
Manufacturer	CAEN	Log-IC	Monarch I.	Phase Iv
Read Distance	10m	–	–	N/A
Price (USD$)[1]	45	28	79	22
Temp. Samples	4k	4k	8k	800
Size (mm)	107x107	81x63	50x33	86x54
Battery Life[2]	1 year	3 years	1 year	1.25
Communication	UHF	USB	NFC	UHF

I. Introduction

Several applications have been developed using Radio-frequency IDentification (RFID) technology, such as: access control, logistics, inventory, tagging, electronic identification and manufacturing management. Moreover, other applications for cold chain management were proposed using built-in sensors for blood bags, food and perishable items tracking [1] [2]. The cold chain management is of interest of governments, companies all over the world (manufacturers and distributors) and also final customers.

In the pharmaceutical cold chain, for instance, most of the products are sensitive to temperature and need to be monitored, but other environmental conditions should also be considered, including light, shocks, humidity, pressure, oxygen and vibrations. The environmental changes usually occur during shipping, but they can also happen during storage, compromising the quality of the product to be applied in the patient [3] [4]. Although some RFID chips have embedded temperature sensors, no commercial tags are available integrating all the sensors mentioned previously in a single chip [5]. Table I shows a market survey conducted to check similar products currently in the market.

The best cost-benefit data loggers in the market have a small memory capacity, short battery life time and, often, use contact communication to transfer the information from the data logger to the system.

Focusing on the difficulties and market needs mentioned above, an optimized ultra-low power sensor-enabled RFID data logger for pharmaceutical cold chain is proposed. The system is presented in Section II, its implementation is detailed in Section III, the results are discussed and compared with others works in Section IV and the conclusion in Section V.

II. Proposed Solution

Figure 1 illustrates a pharmaceutical cold chain using RFID technology. Initially, the drug receives a passive tag at the end of production line. The tag identifies individually the item during the whole chain and it can receive the lot number, production date and time, expire date, as also others information related to the product. Later, these products are placed inside of a cooler box for transportation. This box receives a battery-assisted passive tag, a.k.a. BAP tag, acting as data logger that is properly configured by a RFID reader. The reader sends the passive tags plus BAP tag information to a remote server, that stores this information into a database. The boxes are transported by a vehicle that could have a RFID reader with GPS and internet connection, providing the exact position of the goods and also its sensors data to the remote server during transportation. The BAP tag will store the measurements into its internal memory and, when the boxes reach their final destination, the user could retrieve the measurements, assuring

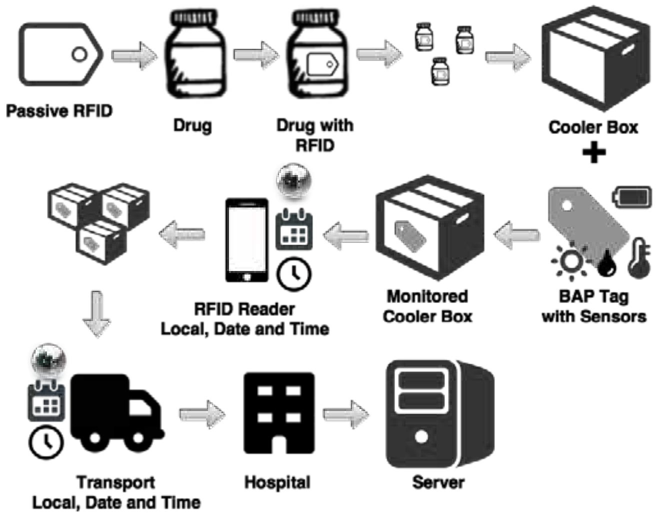


Fig. 1. Example of a pharmaceutical cold chain management with RFID

TABLE II
MARKET ANALYSIS OF EXISTING RFID WITH COMMUNICATION INTERFACES

Product	UCODE I2C	EM4325	Monza X	SL900A
Manufacturer	NXP	EM	Impinj	AMS
Sensitivity (dBm)	-23	-31	-19.5	-15
USD$ (1k units)	0.60	1.02	0.90	3.63
Temp. Sensor	No	Yes	No	Yes
Memory (bits)	3k	4k	2k/8k	9k
StandBy Power	10µA	1.7µA	15µA	1.6µA
Active Power	–	10µA	100µA	200µA
Communication	I2C	SPI	I2C	SPI

that the products are good or not for use or storage.

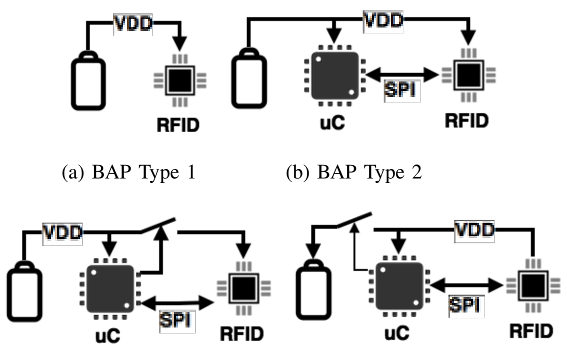
This work explores two different kinds of BAP architectures for a data logger in the system mentioned above: a single RFID and the RFID chip with a microcontroller (µC), allowing the introduction of new features and sensors.

A. BAP Tags Architectures

A market analysis of the existing UHF RFID chips that can provide connectivity to other devices is shown at Table II. Their prices, sensitivity, memory size, sensor enabled, communication protocol and power consumption vary a lot. This work proposed the development of a low power, low cost and higher sensitivity BAP tag as data logger device. Based on the market analysis, the best option is the EM4325 RFID chip [6] because of its high sensitivity, both passive and semi-passive operating modes, integrated temperature sensor, lower cost and power consumption. The chosen RFID chip can act as SPI Slave or SPI Master to communicate with the µC. Therefore, all models, prototypes and development were made using this IC.

The proposed BAP architectures are explained below and can be seen in Figure 2. These architectures, together with power management techniques, can increase drastically the battery life during in-shelf mode and active mode.

- BAP Type 1 (Figure 2a): RFID connected to battery.
- BAP Type 2 (Figure 2b): RFID and µC connected to battery;
- BAP Type 3 (Figure 2c): µC connected to battery, providing power to RFID;
- BAP Type 4 (Figure 2d): RFID in energy harvesting mode, providing power to µC. Later, the µC can connect both to battery.



(a) BAP Type 1 (b) BAP Type 2

(c) BAP Type 3 (d) BAP Type 4

Fig. 2. Proposed BAP tags architectures

B. Microcontroller Software Architecture

There are several ultra-low power µC in the market today, some comparison can be found at [7]. In this work, the MSP430G2553 from Texas Instruments [8] was chosen due to its memory size, GPIOs, timers and its support for the most common serial interfaces: SPI, UART and I2C. Other studies also use the MSP430 family, including the well-known wireless identification and sensing platform (WISP) [9] [10].

Another major concern was the memory utilization and, in order to increase the number of measurements stored in a small memory capacity, some storage methods were suggested and they are explained below. All of them were developed considering the minimum write/erase operations as possible to prolonging the service life of the memory.

Recording Methods:

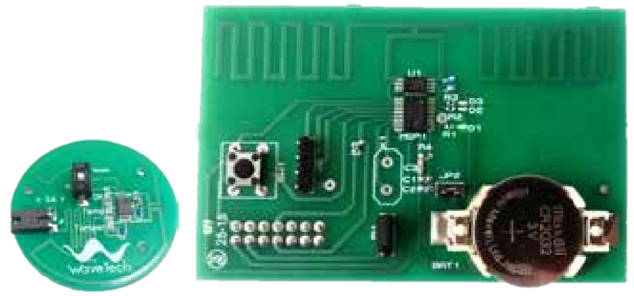
- Linear: It records from the first up to the last memory position and halts;
- Circular: Records continuously. It goes back to memory's start when it reaches its end.

Data Storage:

- Absolute: Stores 9-bits raw data measurements;
- Relative: Stores 4-bits difference between two consecutive measurements;
- Outside-limits: Stores 9-bit raw measurement plus timestamp when it goes outside configured limits.

EM4325 has 3072 bits memory that can be used to store data and its embedded temperature sensor provides a 9-bit data measurement, with a resolution of 0.25°C and a temperature range from -40°C up to 60°C, with typical accuracy of ±1.0°C over the full range and ±0.6°C over the ISO range for cold chain. For example, using the EM4325 in an inefficient memory usage, one measurement could be stored at one memory position, resulting in only 192 measurements. Using the proposed storage algorithms, the EM4325 can store up to 765 measurements.

In order to check the proposed algorithms efficiency, a matlab model was developed. Figure 5a shows the amount of measurements stored in the EM4325 memory, considering 4 combinations in 3 different standard deviations of temperature normal distributions. When the same techniques are applied in a 128kbits µC memory, the Linear Relative method could store up to 32.7k measurements.



(a) BAP Tag Type 1 (b) BAP Tag Type 3

Fig. 3. Developed BAP Tags

III. IMPLEMENTATION

The developed BAP tags are shown in this section. BAP type 1 is presented on Figure 3a and BAP Type 3 on Figure 3b. BAP Type 2 and 4 are very similar to BAP Type 3 and they were implemented in the same circuit with few changes.

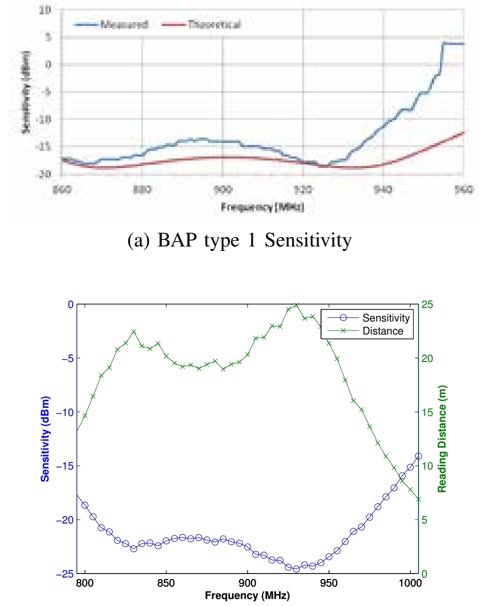
A. Antenna Design

The RFID tag was designed intended to work from 860MHz to 960MHz, that is, assuring interoperability between the Americas, Europe and Japan. So, a wideband meandered dipole antenna was designed to match the chip impedance optimized to BAP tag mode, $Z_{chip} = 7.6 - j114$ at 915MHz.

Both BAP tags were measured in a semi-anechoic chamber. The BAP type 1 sensitivity is shown on Figure 4a. The BAP type 3 sensitivity and theoretical read range can be seen in Figure 4b.

B. Power Consumption Model

A matlab model to analyze the battery lifetime of a CR2032 (coin cell with 220mAh) during active mode was developed. It considered the power consumption of the BAP tag, depending on its architecture and sampling time interval between two consecutive measurements. It is important to mention that the self battery discharge and the temperature effects over the battery were ignored in this model for simplicity. The model results in Figure 5c shows that the battery can last theoretically up to 50 years depending on the applied technique. Each analyzed operation mode is explained at Table III.



(a) BAP type 1 Sensitivity

(b) BAP type 3 Read range and sensitivity

Fig. 4. Developed BAP Tags results

TABLE III
BAP MODES DESCRIPTION
[3] TURNING ON/OFF THE RFID IC

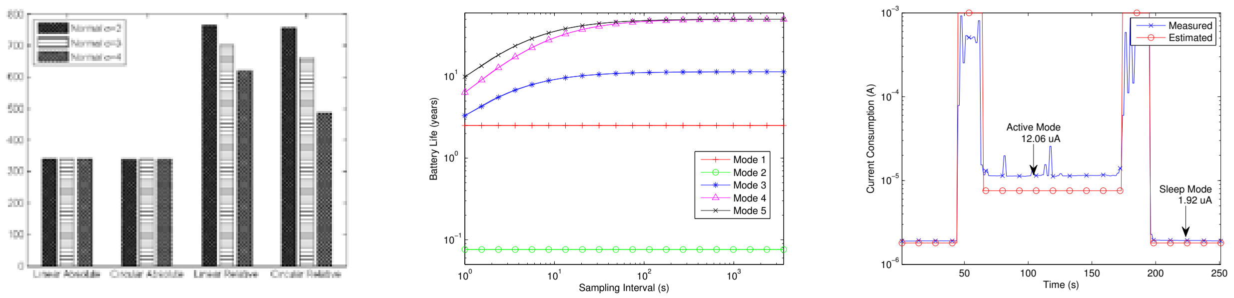
Mode	BAP Type	$F_{\mu C}$ (MHz)	Average Current (µA)	Low Power Techniques
1	1	–	10	No
2	2	1.10	330	No
3	2	1.10	7.6 - 2.2	Yes
4	3	1.10	3.9 - 0.5	Yes[3]
5	3	0.58	2.5 - 0.5	Yes[3]

C. Power Consumption Results

The power consumption model built was based on the components datasheet and their expected power consumption. In reality, those values are slightly different from the measurements, mostly because the µC embedded software was not ready. Figure 5c shows the power profile of BAP Type 2 changing from idle mode to active mode and going back to idle. Two current consumption peaks can be seen during the mode transitions, they are related to the LED blinking to notify the user that a RF command (start logging or stop logging) was executed.

IV. COMPARISONS

Table IV compares similar BAP tags with this work. As can be seen, this work presents a BAP logger that can measure temperature with the lowest power consumption, using smart power and memory management techniques that increases the battery life and memory usage. Other works just inform the temperature measurements through the EPC Code [10] to the



(a) BAP memory storage methods comparison for 1k measures with different standard deviations for normal temperature distribution

(b) Battery lifetime model in active mode for different sampling intervals

(c) Power profile of BAP Type 2 with 1 second sampling interval

Fig. 5. BAP model and results

TABLE IV
PERFORMANCE SUMMARY AND COMPARISON

Paper	[12]	[10]	[11]	this work
Sensitivity (dBm)	-24	-24	-15.1	-24.5
Operation Distance (m)	22	22	9.5	24.9
Size (cm)	8x6	8x8	8x5	8x5
Sensing Range (°C)	-50 to +150	-50 to +150	-20 to +50	-40 to +60
Sensing Inaccuracy	±2.7°C	±2.7°C	-1.0 / 0.8°C	±1.0°C
Average Consumption (uA@V) for 1s	68@3.0	230@1.8	20.5@1.8	12@3.0
Memory	2kb	2kb	192b	128kb
Temp. Samples	30	1	–	32.7k

reader, store only 30 samples [12] or even only one sample [11].

The developed system presents a short temperature sensing range in comparison with other works at table IV. However, higher temperature values are not applied to cold chain. It is important to keep in mind that other sensors could also be applied to the I2C μC bus, increasing its sensing capability.

The BAP tag type 3 developed in this work can also be compared to commercial tags shown at Table I. It can store 4 times more measurements than the Track-It with the advantage that it could be read at longer distances.

It is difficult to compare the others battery lifetime with this work, because they do not mention their sampling time interval, which is crucial to this kind of application, as can be seen on Figure 5b.

V. CONCLUSION

The proposed BAP tag has a ultra low power consumption, increasing the battery life in-shelf and also during usage. The BAP type 3 has also a good sensitivity and read range and can be compared to current products in the market and academic works. Nevertheless, its smart memory management, associating the RFID with a μC, makes it possible to store a large amount of temperature samples, specially when the temperature does not change drastically during time.

(a) Setup Screen

(b) Temperature Chart Screen

Fig. 6. Portable Reader with Android Screens

Although, the develop BAP tag was designed to be use in the pharmaceutical cold chain, it can also be used in other supply chain that needs to control and monitor the temperature or other environment variables.

A. BAP Tag tests and validation

The developed BAP tag is being tested in a real system using portable RFID readers using Android as shown in Figure 6a and Figure 6b. The readers send the data logger information to a remote server that shows the information through a website as Figure 7.

The tests were conducted using two different portable RFID readers: AretePOP from Phychips and MC9190-z from Motorola. The first is considered a simple reader with short read range and 25dBm power; the second is a professional reader with long read range and 30dBm power.

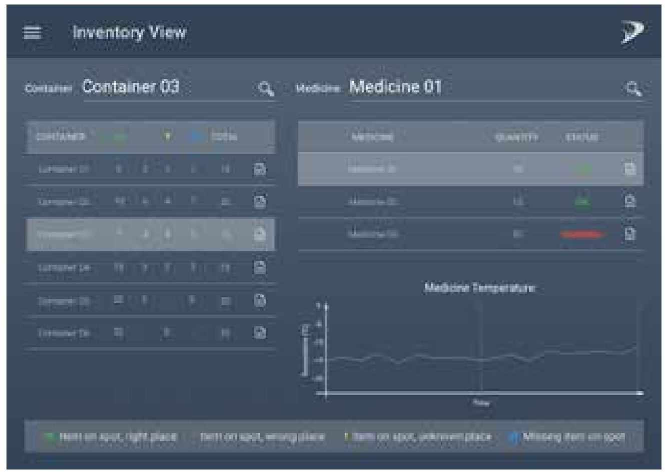


Fig. 7. Web Page for Temperature Monitoring

B. Inherent Issues and Future Works

The system has not been tested in a real life scenario, but the current results are very promising.

The developed BAP tag needs a plastic case to support harsh environment envisaging an IP67 protection. This plastic case will shift the tag sensitivity towards lower frequencies. Nevertheless, the antenna wideband characteristics is supposed to accommodate this shift.

The CR2032 battery may have undesired behavior under lower temperatures, as already mentioned by some academic researches and maybe other battery should be used.

ACKNOWLEDGMENT

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UHF RFID Tags in a Controlled Environment: Anechoic Chamber Case

Luiz R.M.Costa[#1]

[#]RFID CoE, Flextronics Institute of Technology
[1]luiz.costa@fit-tecnologia.org.br

Abstract - **This paper is a part of studies developed in RFID CoE Laboratory. The objective is to show the technical difference of RFID UHF tags when applied in different kind of materials in a controlled environment (anechoic chamber). Three types of UHF Tags were tested in six different materials inside an anechoic chamber with a RFID UHF reader and one circular transmitting antenna inside the chamber. The results shows what is the bests and worst materials to apply a RFID Tag and show that depending on the material that these tags were applied, their efficiency can change.**
It was concluded that in the begging of a RFID Implementation, different kind of tags of different manufacturer must to the tested in the final product to evaluate the performance of each and leave the final client decide what is the best cost X benefit for its application.

Keywords words: Anechoic Chamber; RFID Tag; ECP Global

I. INTRODUCTION

The RFID technology low cost started to be necessary in medium and large compannies and retail when the Wall Mart, world's largest retailer, started the passive UHF RFID implementation in its Distribution Center and its retail stores. Soon after, a significant number of retailer and the North America Department of Defense (DoD) adopted the UHF RFID in their Supply Chains. Consequently, the demand for RFID-tagged items without human interference at supply chain points has increased [2]; [3]; [7]; [8].

With the increasing numbers of RFID Tags avaiable in the market, the need for a technical performance analysis began to be discussed, to evaluate their performance, costs, and applicability in different kind of products [1]; [4]; [5]; [6].

This analysis is just to verify that a particular type of label will function properly and with high performance when applied in a determinated product. The cost-quality and performance interferes directly in a RFID system implementation [10].

II. MATERIALS AND METHODS

The material used for the test configuration was 3 RFID Tag models from different manufacturers, 1 linear antenna, 1 commercial reader, 1 anechoic chamber, 2 circulators, 1 directional bridge and 1 spectrum analyzer. The Tag performance test results were foolowed by the GS1/EPCglobal Static Test Procedure V1.9.4 , which establishes standards for computing the minimum power required to energize a RFID Tag.

All the testes were performed using UHF Tags. The choce of UHF tags and equipments is because these tags are the most common in the applications areas and have a signicantly high amount of models and manufacturers available in the market.

The UHF tags work normally on the three tested frequencies (902.250MHz, 915.250MHz and 927.250MHz.

Additionally, all the tested tags used was passive tags (without any kind of internal battery) to create a "internal standards" to evaluate all the tags in the same standard and same internal conditions of umidity and temperature.

A. Material

The material used during the tests can be seen in Table 1

Table 1 - EQUIPMENTS USED

Equipment	Manufacturer	Model	Standard
RFID Tag A	Imported	-	ISO18000-6C
RFID Tag B	Imported	-	ISO18000-6C
RFID Tag C	National	-	ISO18000-6C
RFID Reader	-	-	
Antenna 1	-	Circular	
Wooden Plaque	-	-	
Styrofoam Plaque	-	-	
Plastic Plaque	-	-	
Glass Plaque	-	-	
Cardboard Plaque	-	-	
PVC Support	-	-	
RF Cables	-	-	
Anechoic Chamber	RFID CoE	-	

All tests were performed in an environment free from outside interference (anechoic chamber) to ensure that the calculation of the minimum power to energize a RFID Tag will not suffer external interferences.

The RF Noise was measured to evaluate the "background noise" inside the anechoic chamber. A dipole antenna was used in both horizontal and vertical polarizations. In horizontal polarization the maximum value found was -72.79 dBm ($5{,}26x10^{-8}$ mWatts) and in vertical polarization the maximum value found was -72.40 dBm ($5{,}75x10^{-8}$ mWatts), both results were satisfactory. Cable loss and antenna gain were considered as compensation.

The Figure 1 below shows the RFID CoE anechoic chamber used for the tests.

Figure 1 – RFID COE anechoic chamber

B. Methods

The GS1/EPCglobal specifies how the UUT (Unit Under Test) must to be tested to evaluate the minimum power necessary to energize an applied RFID tag based on 50% read rate [9].

- The RFID tag was applied on different materials by RFID CoE lab personnel.
- The tag applied position was defined by RFID CoE.
- It was tested 3 types of tags, 2 imported tags and 1 national tag.

Range Power Correction:
The range power correction is an adjustment factor of the losses in the free space between the transmission antenna and the calibrated dipole antenna positioned in the exact point where the tag will be (reference point).
This adjustment factor will be used to correct the power in a minimum tag turn on evaluation.
Figure 2 illustrates physical set-up configuration used to perform the range power correction. A circular polarized antenna connected to the reader was positioned parallel to the dipole antenna, the centerline of both antennas were aligned; the dipole antenna was vertically oriented.

Figure 2 – Range Power Correction Illustration

Minimum Tag Turn On Power
The configuration used to evaluate the minimum tag turn on power is according with figures 3 to 5 below, where a circular polarized antenna connected to a reader was positioned parallel to the tag, the centerline of the antenna was aligned to the centerline of the tag.
The reader was set to work with the following configuration:
Reader Output Power: 33dBm

- Tari: 12.5 µs
- Modulation: 90%
- Data rate: lf256
- Miller rate: miller 4
- Frequency Inhibit: 902.250MHz, 915.250MHz and 927.250MHz

The frequency inhibition is allowed only in a controlled environment and serves to secure the transmission signal only in one hopping channel (to be sure that the power will not vary with the frequency hopping). Initially the measurements were made in the channel 902.250MHz, 915.250MHz and 927.250MHz lastly.

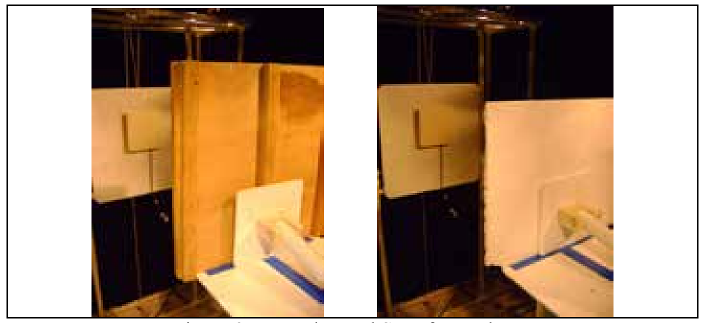


Figure 3 – Wooden and Styrofoam Plaques

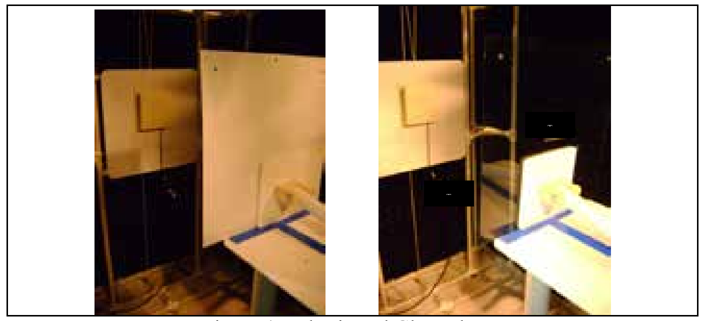


Figure 4 – Plastic and Glass Plaques

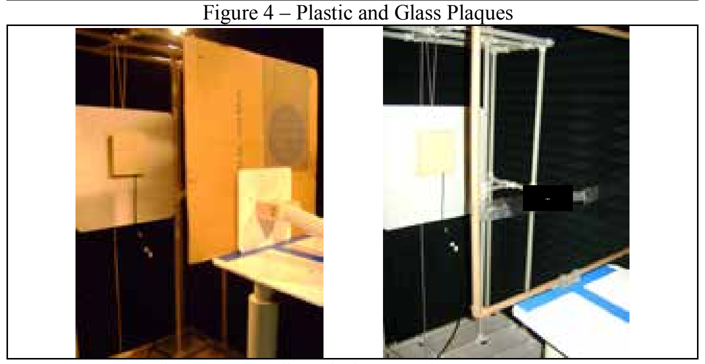


Figure 5 – Cardboard Plaque and PVC Structure

III. Results

The static test requires the range power correction verification. The power measurement at the reference point can be seen at Table 2.

Table 2 – RANGE POWER CORRECTION

Range Power Correction			
Channel:	Low (US)	Mid (US)	High (US)
Frequency:	902.250 MHz	915.250 MHz	927.250 MHz
Pstandard:	29.02 dBm	28.90 dBm	28.75 dBm
Transmission Line Loss:	3.71 dB	3.71 dB	3.71 dB
Receive Line Loss:	2.47 dB	2.47 dB	2.47 dB
Dipole Gain:	1.66	1.66	1.66
Meas. Power. at Ref. Point[1]:	2.40 dBm	1.77 dBm	0.83 dBm
Power Adjust Factor:	**-26.63 dB**	**-27.14 dB**	**-27.93 dB**

A. Results

Table 3 shows the Tag's results (in dBm) for the three tested frequencies:

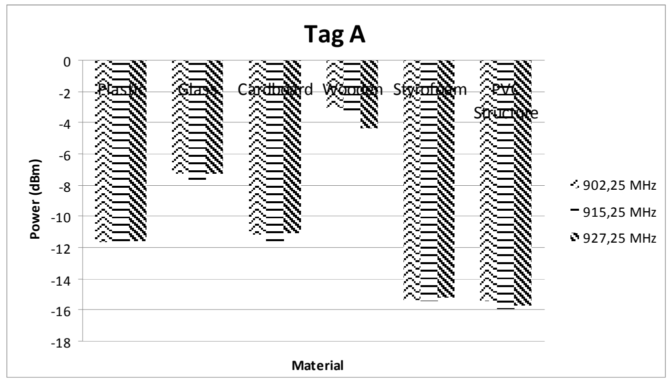
Table 3 - RESULTS

902.25 MHz						
Tag A (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-11.63	-7.23	-11.15	-3.02	-15.32	-15.43
Tag B (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-10.88	-5.9	-10.6	-2.59	-13.87	-14.34
Tag C (National)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-5.4	Not respond	-5.6	Not respond	-8.56	-8.92
915.25 MHz						
Tag A (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-11.92	-7.9	-11.8	-3.5	-15.38	-15.9
Tag B (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-10.4	-6.02	-10.54	-2.9	-13.99	-14.32
Tag C (National)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-5.2	Not respond	-5.6	Not respond	-8.1	-8.4
927.25 MHz						
Tag A (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-11.54	-7.23	-11.07	-4.32	-15.2	-15.67
Tag B (Imported)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-9.89	-6.51	-9.56	-3.25	-14.21	-14.6
Tag C (National)						
Material	Plastic	Glass	Cardboard	Wooden	Styrofoam	PVC Structure
Minimum Tag Turn On Power	-5.6	Not respond	-5.64	Not respond	-8.32	-8.78

It is possible to observe that the tags A and B responded in all materials and in all tested frequencies. Only the Tag C did not respond when applied in wooden and glass plaques.

B. Graphical analysis

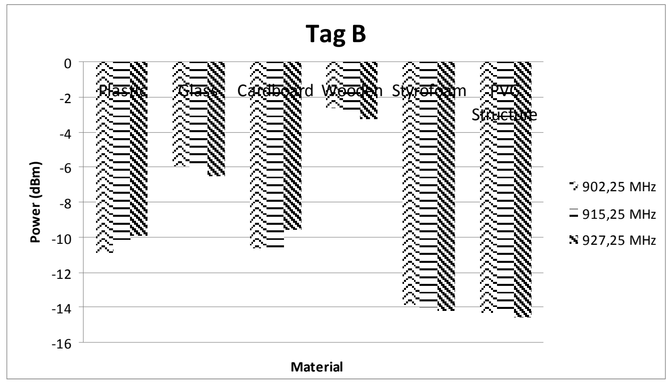
The Graph 1 Below shows the Tag A results for the three testes frequencies:



Graph 1 – Tag A Results

The tag A answer in all tested materials, with greater sensitivity when applied in the Styrofoam and in the "free air" (PVC structure)

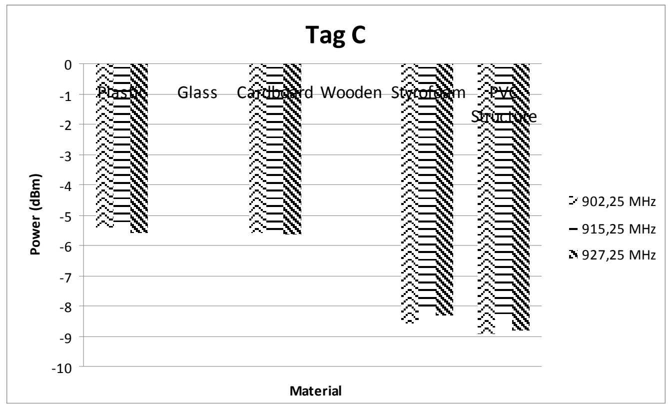
The Graph 2 Below shows the Tag A results for the three testes frequencies:



Graph 2 – Tag B Results

The tag B answer in all tested materials, with greater sensitivity when applied in the Styrofoam and in the "free air" (PVC structure)

The Graph 3 Below shows the Tag A results for the three testes frequencies:



Graph 3 – Tag C Results

The tag C did not respond at all tested materials, leaving to send a response to the reader when applied in glass and wood.

IV. Conclusion

After the graphical analysis and data acquired, it is possible to say that different RFID tags from different manufacturers have different sensitivity when used with different materials.

The tag A showed the best performance in all material with respect the other tags, while the National Tag C showed lower response relative to other tags, especially when applied on glass and wood, which could not send any response to the reader.

It is possible to conclude that a real RFID implementation is directly influenced by the type and quality of Tags used. The customer cost-benefit should be analyzed before implemented an RFID system.

Future and next trends for RFID

RFID can still be considered as an evolving technology, every day is emerging new manufacturers and new application areas in different segments.

IN a not too distant future, there will be integration between people and RFID, making the RFID industry get started in more usual application. RFID tags will be commonly found in commercial products doing with whom the customer can obtain further information about a particular Product.

The "Internet of Things" is a new term that suggests that the usual objects of a home will become intelligent and be able to "communicate" with each other through RFID tag. May cite as an example that a refrigerator can tell your "owner" with no more certain food inside it, and so on.

The trend in the coming years is really an increasing significance of RFID technology in all segments.

Areas with potential market for RFID Tags analysis.

RFID can still be considered as an evolving technology, are emerging every day new manufacturers and new application areas in different segments using the RFID technology.

At present, the area with the greatest potential for the RFID tags analysis is the general industry (medium and large companies, whereas an RFID implementation still has a high cost) in which various models of RFID tags have to be tested on the customer's product.

Due to the growth of RFID tags manufacturers, this kind of analysis tends to be increasingly common for RFID service providers.

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Electronic Product End of Life Tracking Using RFID System – Smart Waste Project

Luiz Costa
RFID CoE (Center of Excellence)
Flextronics Institute of Technology - FIT
Sorocaba - Brazil
Luiz.costa@fit-tecnologia.org.br

Paula Valerio
RFID CoE (Center of Excellence)
Flextronics Institute of Technology – FIT
Sorocaba – Brazil
Paula.valerio@fit-tecnologia.org.br

Yukiko Sasaki
RFID CoE (Center of Excellence)
Flextronics Institute of Technology– FIT
Sorocaba – Brazil
Yukiko.sasaki@ fit-tecnologia.org.br

Abstract— Considering that HP wants to act as a pioneer in sustainable technological development and thinking in new environmental policies that are emerging worldwide, this paper aims to demonstrate how HP in the category sustainability is considering recycling issues, reuse of materials, application of information intelligence equipment at the end of life using RFID technology to correctly direct the recycling process of their printers. This paper also demonstrates how we conduct the development of an analytical lifecycle analysis software for printers.

Keywords—Smart; Waste; RFID; EPC

I. INTRODUCTION

The Smart Waste project uses RFID technology to track the results of reverse logistics (return of printers at the end of their lives) since HP printers are already RFID tagged in its manufacturer partner, Flextronics International. Despite having similar objectives to the barcode, RFID - a technology that uses radio frequency to capture data in real time [1]- allows identifying objects at a distance using the EPC code (electronic product Code) which is a world standard identification established by GS1. The e-waste recycling process starts with the operation of receiving the material in pallets by the HP recycling partner. Until the electronics are in fact recycled, all equipment goes through a strict process of disassembly, separation of parts according to type (plastic, metal, rubber, glass) and grinding.

The RFID solution was implemented right before the disassembly line which is natural bottleneck of the process. This assures that all equipment is scanned by the RFID system before being disassembled avoiding any sort of bypassing.

The solution created has a dashboard where the user can see the graphs generated by a central data base. It shows the most recycled products, the amount of each material recycled as ABS, HIPS, metal, etc; the number of products recycled per month on the last year and the goal for recycling as well as the actual value.

The dashboard generates reports in different formats such as text, tables and non-editable formats regarding the readings, products and other important information for recycling control.

For that to be possible, the tool has a list of materials linked to a list of products containing a reference to part numbers that contains a reference to materials, all editable by users with required permission. This list is what is used to transform the RFID readings into important data for the recycling business.

From this measurement, it is possible to direct these materials for reinsertion into the HP's supply chain in new products or delegate them to other industrial segments for recycled parts. Recycling minimizes environmental impacts associated with waste disposal and reduces the need for raw materials and energy to manufacture new products.

II. LIFE CYCLE ANALYSIS - LCA

Life cycle analysis is a technique for assessing the environmental aspects and potential impacts associated with a product, comprising steps ranging from the nature removale of basic raw materials entering the production system to the final product [2].

Analysis of product life cycle is actually a technical tool that can be used in a wide variety of purposes. The information collected in the LCA and the results of its analysis and interpretations can be useful for decision-making in the selection of relevant environmental indicators for project performance evaluation or redesign of products or processes and / or strategic planning.

The main objective of the project proposed in this paper is to develop a solution using RFID to control electrical and electronic waste reverse logistics considering quotas. The solution consists of a quota collected equipment control software and an RFID system proposed in the reverse logistics of HP products.

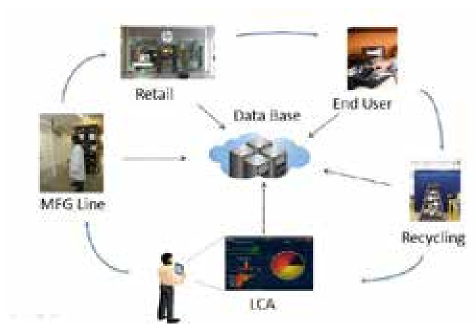

Fig. 1. Product life cycle analysis example

III. Work Development

Since HP seeks opportunities across the life cycle of a product - from the material it uses and the way it is manufactured, packaged and shipped, to the energy it consumes and how it is disposed - based on experience during the implementation of RFID in the factory in Brazil, it was concluded that the project would be a smart way to track printers on recycling points in the country, using the infrastructure of its center of excellence in RFID (RFID CoE) and with the contribution of its partner network.

The goal of this project was to support reverse logistics strategies through a tracking system of collection and disposal of electronic products in end of life, whose purpose is to ensure the correct disposal of these products and consequent responsible management of electronic waste, and reduction environmental risks.

A. Application Description

Considering that the RFID allows the possibility of identifying objects at a distance or through a physical barrier, HP has implemented in its manufacturing line in Brazil flow control systems using RFID tags in inkjet and laserjet printers. Similarly to the example given within the manufacturing printers, to the extent that the products are in range of the antennas that are located at the entrances and exits of the stock area, the readings of the labels attached to the products are made, and the information is posted saying if the product is "in" and/or "out" of stock (Figure 2).

Fig. 2. RFID system deployed in the manufacture of inkjet printers.

Smart Waste project also uses RFID technology, however, instead of working in the flow of products manufacturing, this technology was used in this case to track the outcome of the reverse logistics in the recycling service provider.

The first phase of the project was to establish with the recycling partner the installation of an RFID reading system in the recycling plant. The system was placed on the step before the disassembly of products; thus making sure the product will be tagged before the disassembling process (Figure 3).

Fig. 3. RFID system deployed in the return inkjet printers.

The RFID system developed consists of portals located on the receiving docks of recyclers partners, to read the printer RFID tags that are received for recycling.

The figure 4 below show an example of the Recycling reading point using the RFID System inside in one of the recycling partners.

Fig. 4. Example of a RFID Recycling reading point.

At the receiving stage, the printers are identified by their EPC code (Electronic Product Code) inside the RFID tag. The EPC code contains information EPC / EAN which are product and manufacturer identifying patterns commonly used in barcode and additionally it contain a digit range intended for serialization manufacturer. Thus it is possible to identify not only the manufacturer and the model, but also the product serial number [3].

For this application, RFID technology offers reasonable advantage over barcode, as to have the same results using the later technology we would need UPC/EAN code on products and generally, they are in containers which are discarded and do not return to the products in end of life. Another advantage is that the EPC code reserves a range defined for serial manufacturer, allowing the unique identification of a product through its serial number. In products using barcode this information is available, but the manufacturers use a multitude of patterns which make it difficult to establish a common software usage for different manufacturers.

The next phase of the project was to develop software capable of managing the readings of RFID labels on products over the internet. The developed software resides in the Cloud, and the interfaces are accessed over the Internet. At first the software quantified the number of products received according to your model and generate an accumulated amount.

Once the products returned have been identified by reverse logistics, some of them were brought to HP's sustainability lab, and held the dismantling of activity of each of the models to characterize them according to the different types of materials in the product. Thus for a specific product we were able to calculate the percentage by weight of plastic, glass, metal, etc. With this information, the project was integrate this information with the RFID information management software and built a business analysis tool, or also known as BI tool (Business Intelligence).

The overall architecture solution designed for this project is showed on the figure 5 below.

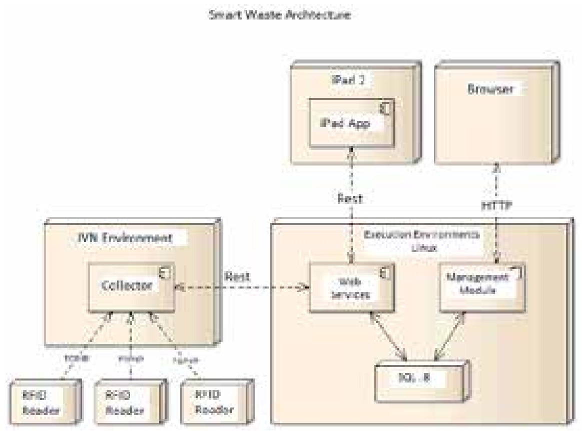

Fig. 5. Smart Waste Architecture.

The developed architecture provides a modular system and easy way to use, which aims to offer this service at any public interest that has responsibility in the electronic product collection process at the end of life. Specifically, the system functionality provides the following capabilities to each business partner:

Manufacturer: only track their products, however, in any of the reverse Logistics chain links, which can also make use of its system to ensure that their products are being sent to recyclers, and quantify the potential use material recycled in their production processes;

Retail: if of interest, to exercise responsibility for collection point, which can be able to see any destination of your entire product collected, regardless of manufacturer, and recycling to which the material will be used;

Recycling service provider: to have a tool capable of quantifying and qualifying all of the material received, and thus the possibility to elaborate recycling strategies and forecast revenue in view of the capability of the materials present in each of the products returned;

End User: using an applet oriented identify a collection point for your electronic equipment, and will be assured that using an integrated collection point in SmartWaste guaranteed that your electrical and electronic product end of life will have its traced allocation and disposition appropriate;

Government: as sectorial agreement, to use partially or totally the system with the permission of the companies involved, through direct access, or extracts with the output data of interest.

B. GS1 Standard Used

GS1 EPCglobal standard used for data exchange between applications [4].

EPC Scheme	SGTIN
Tag Enconding	SGTIN-96
Partion Value	5
GS1 Company Prefix Digit	7
Item Reference Digit	6

Tab. 1. Data between applications.

Using the EPCglobal standard we identified the manufacturer and the printer model and also the product serial number. When the products are identified they returned via reverse logistics to disassemble activity of each of the models to characterize them according to the different types of materials in the product. Thus it was able to calculate the percentage by weight of plastic, glass, metal, etc. for a given product. This information was integrated with the RFID information management software (SmartWaste dashboard).

An example of an EPC code using HP-96 format SGTIN used to decode the printers is showed on Figure 6:

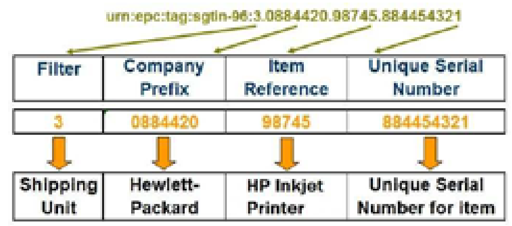

Fig. 6. HP-96 SGTIN example.

IV. Paper Results

The main concept used in software development was the RFID technology applied in HP printers. A RFID reader was installed were the segregation of printers is executed. The software developed aims to decode the received tags and get the reference item for each printer. With this number identified the software assign it to a mapping profile already registered in the database, generating information related to the materials and part numbers constituting the given printer. From these data generated by reading, the software has the functionality to generate comparative charts and reports.

Below it is possible to see an example of the Dashboard tab acquired from the software that was developed and is used exclusively for this project.

Fig. 7. Initial Dashboard.

More details about the charts presented in the Figure 7 (Dashboard) are provided in the following charts:

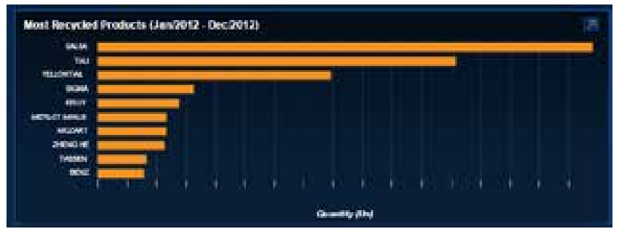

Fig. 8. Most Recycled Products.

In this chart it is possible to see which were the most recycled products that were received for segregation and disassembly on the recycling partners.

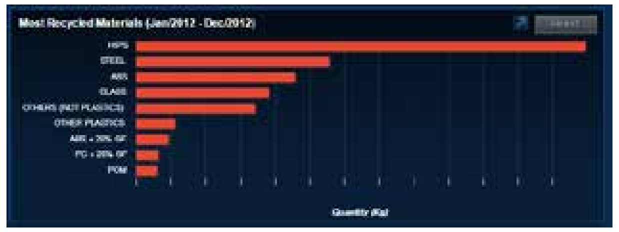

Fig. 9. Most Recycled Materials.

In this chart it is possible to see how was the most recycled materials (Hips, Steel, Abs, Glass, Plastic, and others) that were received for segregation and disassembly according with each printer model that was previously registered on the system.

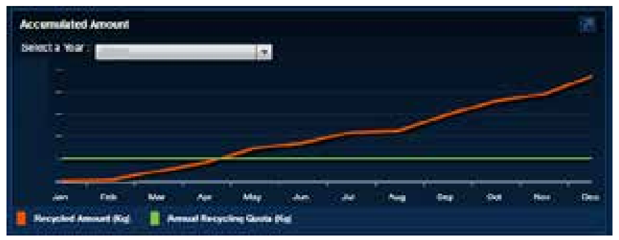

Fig. 10. Accumulated Amount

Here it is possible to provide quotas for recycled products for day / month / year.

Fig. 11. Recycled Product Quantity in Last Year

In this graph is generate the accumulated quantity of printer recycled per month, during the last year of the software operation.

These graphs allow a quick view of the HP product recycling information. One can understand through a graph which products and recycling volumes, more recycled materials, by date and cumulative values. It is understood that this is the kind of information a manager needs quickly for decision making.

In the second tab (Users) we can see the following features:

- Users - Displays all registered users and allows the addition of new users
- Role - Here we can define each user's profiles and add new profiles

Fig. 12. Second Table example

In the third tab (Products) we can see the following features:

- Products - Displays all registered products and allows the addition of new products
- Part Numbers - Displays all registered part numbers and allows the addition of new part numbers
- Materials - Displays all registered materials and allows adding new materials

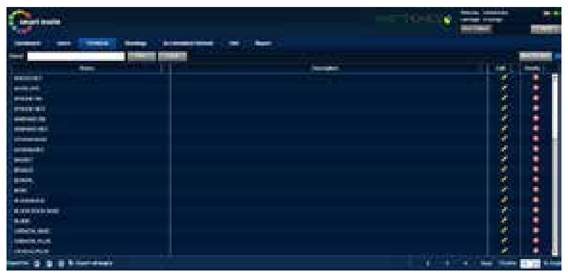

Fig. 13. Third Table example

In the fourth tab (Reading) we can see the following features:

• Readers - Displays all registered readers

• Reading - Displays all performed readings that were properly associated with a product registered in the database, since the beginning of the operation on a given reader.

• Temporary Readings - Displays all the readings performed that were not properly associated with a product registered in the database, since the beginning the operation of readers.

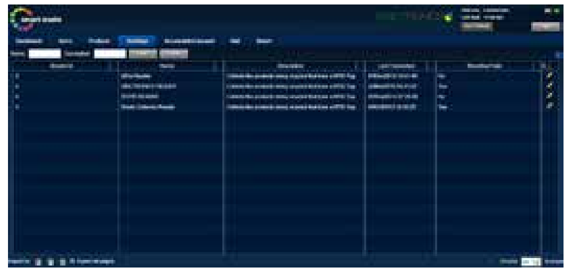

Fig. 14. Fourth Table example

In the fifth tab (PNRS) we can see and edit the recycling quotas set for each year.

Fig. 15. Fifth Table example

In the sixth tab (Unit) we can see the units registered and allows the addition of new units.

Fig. 16. Sixth Table example

In the seventh tab (Report) we can see the following features:

- PNRS Report - Displays the amount recycled each year and their annual quotas
- Recycling Tracking Report - By means of this item you can perform searches readings performed by a given EPC number, by product, date, time and user. Furthermore, it is possible to identify and track a product that was read in more than one point in the reverse logistic process.
- Recycled products More Reports - Displays the amount (in units) of each recycled/products (displayed both as grid or in graphical form).
- More Recycled Materials Reports - Displays the amount (in kg) of each recycled material (displayed both as grid or in graphical form.

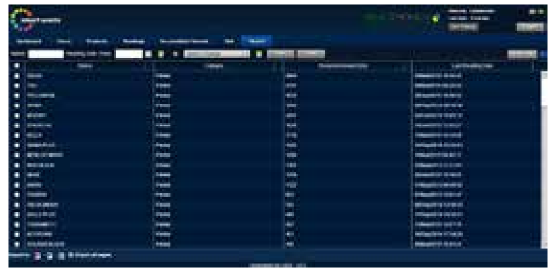

Fig. 17. Seventh Table example

With the generated reports, it is possible to acquire from the software, that until January 2015 (last year finished on Dec/14) the SmartWaste tool tracked a significant number of tons of raw materials since the beginning of the project that can be used by HP or for other industries, qualifying and quantifying materials of interest for reinsertion on HP's own products manufactured in Brazil, such as engineering plastics.

All the recycled materials became new parts that is reinserted at the printers' production lines.

V. Conclusion

Based on the data obtained from the software and mapped printers with RFID tags, we can conclude using the software developed for this project shows that is possible to provide a solution for LCA using the RFID technology .

This is an innovative project and there is no knowledge of similar projects to track and quantify the return of the printers materials that compose the electronic waste using RFID technology. From the information received from the SmartWaste tool, it is possible to define strategies to reuse and recover these materials. Its innovative character is in the recycling proposal not only to recover materials but also in the reintegration of the collected material in the manufacture of new products, closing the entire life cycle of the product, contributing to an integrated management of environmental sustainability.

Before being recycled, all equipment goes through a strict process of disassembly, separation of parts. According to type (plastic, metal, rubber) and grinding. Of course, by automatically reading the inventory it moves across the supply chain, the RFID system angiograms errors inherent in the manual processes, since it works without human intervention. Also, provides higher levels of accuracy, predictability, and accountability. However, the benefits brought by this technology go far beyond the usage of the tag. The advantages of the RFID technology are in the actionable information we get to improve effectiveness, efficiency, and security of high visibility, ie, the value of this powerful tool is in how we use the date to achieve better business outcomes.

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PROPOSAL FOR IMPLEMENTATION OF RFID TECHNOLOGY TO COMBAT EVASION OF THE HOSPITAL TROUSSEAU

ANDRADE FILHO, Manoel Pereira, OLIVEIRA, Eduardo Jorge Valadares
Center for Strategic Technologies in Health
State University of Paraiba
Campina Grande, Brazil
Email: manoandrade2005@hotmail.com

Abstract— **The increases in the cost of providing health services impose on hospital manager's search for best practices for the administration and management of supplies and hospitalares technologies. A case where one can get a significant reduction in operating costs is the proper management of the hospital trousseau [1]. In Brazil, to monitor hospital outfits, the most commonly used techniques are the use of barcode (bar code) and RFID (Radio Frequency Identification). Barcode is considered the cheapest per unit, however, is restricted handling of soiled garments. The use of RFID allows good monitoring of the hospital trousseau for introducing mechanisms that allow, with reliability and speed of data collection, the purpose of monitoring and control of parts [2]. The system via RFID has been presented as a better resource that the technique of Barcode, however, is still considered expensive, although the cost is not yet well established since its assessment depends on the focus given to the management of the hospital trousseau. The objective of this study is to develop a methodology for the implementation of RFID technology in the control of hospital trousseau, identifying technical requirements and conditions and management for RFID technology can best be used in the promotion of good hospital management practices.**

Keywords— Hospital Trousseau, Tracking, Monitoring, RFID.

I. INTRODUCTION

Good management practices require the hospitals to have control of all inputs and critical technologies used in patient care. In addition to observing the safety and efficacy requirements, the service provider must ensure hygienic conditions and preservation of all that is used by the patient. In this sense, a critical item is hospital trousseau, which must be handled with care to prevent it from becoming a vector of contamination and infection. The choice of this material must consider as comfort factors, technical, life useful and security. Depending on how you receives this type of trousseau hospitalar, and the degree of turnover of patients, a hospital 150-200 beds can have an yearly expenditure of about R$ 300,000.00 with the acquisition of parts of the hospital trousseau [1]. Thus, the purchase of hospital trousseau should consider in addition to requirements health costs and return on investment (medium and long term), not just the lowest price or lower expenses in the short term [2]. The hospital trousseau is now considered one of the great allies in reducing hospital infections however, its management and cost can impact the quality of hospital services [2]. Investing in technology can be an opportunity to improve the management and cost reduction, the problem is still a gap of objective information about techniques for the measurement of cost-effective technologies available today on the market [3]. In Brazil, for monitoring the trousseau hospitalar, two technologies are more common: The Barcode and RFID (radio Frequency). Consolidate the information and evidence on the use of this technology can help to demystify their problems and validate it as hospital management tool. One way to provide a control over the trousseau is to use tools that allow their monitoring, which can be conventional, mechanical or with the aid of computer technology. The Radio Frequency Identification (RFID Radio Frequency Identification-) is a seemingly simple technique. Data stored in an RFID tag, are transmitted via radio wave to a reader that sends to a computer with the purpose of a further processing. Although, it is easy to describe the RFID system has many challenges to be faced in its implementation, both in the areas of application of this technology as the operating system integration organization [4]. In the future, the use RFID will be complete and marked by the widespread introduction of the technology, not only for large systems as well as for small applications, including home applications [5]. Figure 1 shows the operating diagram of an RFID antenna, used to track and monitor hospital trousseau within the health unit.

Figure 1 - Operation RFID
Source: DATAMARES [7]

Therefore, the goal of this study is to propose systematization for the implantation of using RFID-chip technology in controlling mobile assets in hospitals to reduce a evasion hospital trousseau, identifying information about this resource that can be used as a basis for improvement the process.

II. MATERIALS AND METHODS

For the implementation of this project, work steps have been set. At first, a literature review was conducted on the topic, although important, is little explored in the monitoring and hospital trousseau traceability. In the second stage, a hospital was identified with average structure 200 active beds, which was interested in studying the implementation of an RFID solution, in a joint effort with the hospital, the study followed by identifying the concepts and technical base operation of RFID technology system, systematically from the definition of its requirements to the details of the necessary infrastructure for the operation of radio frequency communication protocols. In the third step, in conjunction with the hospital, were established 11 indicators to compare the RFID technology with Barcode technology, as shown in Table 1. Also during this step, o lifting cost the implantation the RFID through the ROI (Return on Investment), is underway, very important for the final decision.

TABLE I. Comparison between RFID and Barcode

Indicators	RFID	BARCODE
1- Allows changing data	Yes	No
2-IDs simultaneously	Several once	Only once
3- Accuracy	Without Professional intervention	Dependent on the Professional
4- Reading Distance	Without contact	Line of sight
5- Security Data	Trusted data	Dados Não confiáveis
6 - Error Possibiliteis	1%	99%
7- information storage capabilities	100%	Restricted information
8- Deployment cost	High	Considered Low
9- Frequency types most used HF x UHF	HF	It has often
10- Durability	Durable in the washing process - 2 to 3 years	With the wear of etiqueta- no longer happens reading less than 6 months.
11- Label Fixing the fabric	Safe	After 72h loose tissue

The first four indicators were obtained from the literature available. The others are objects of study, but was taken into account information from a supplier of technology RFID. For the number of indicator five, it was observed that the use of RFID the obtained data management has a veracity of the information obtained in relation to the barcode, this, is partly because of the bar code to depend on his performance of the human factor, providing the error. For the number of indicator six, it was observed in practice that the error rate for obtaining data management with the use of RFID is almost zero, we can see that this indicator is directly linked to the number indicator five. When the indicator of number seven, and notorious fact is the advantage of RFID use in relation to the barcode, that is related to the fact that one can get various management information with the adoption of RFID, fact that can not be using the bar code. For the number of eigth, it can be seen when the future, Case ROI presentation. For the number of indicator nine, its use has been proved through the study related to the systematic approach, Finally, for the numbers of indicators ten and eleven, was observed in a practical way its application in the hospital.

III. DISCUSSION

The RFID technology is already a reality in many health centers in other countries. The RFID technology is already a reality in many health facilities abroad. In Brazil, the use of this technology in hospitals is still shy and she, when used, is usually used for the purpose of tracking and tracing of medical equipment (infusion pumps, mechanical ventilators, stretchers and wheelchairs), temperature monitoring in refrigerators and chambers of blood banks and laboratories [6]. Of the 6,837 Brasilian hospitals, very few use a technology solution such as RFID or bar code for control equipment, permanent material and other inputs such as hospital trousseau [6]. The future of this technology in monitoring and hospital trousseau traceability is apparently very promising, especially with the reduction of the implementation costs due to the maturation of the technology. Reducing the cost of the solution may be a determining factor for the growth and expansion of the use of RFID technology in hospitals increasing the efficiency and effectiveness of processes and procedures in hospital settings. Despite all efforts, there is little information in the literature on the real gains that this type of solution can bring to the activities of management and governance of hospital services and especially the applicability of hospital trousseau. Information on how the technology works, its components and comparisons with other technological solutions are not always the theory can predict all the details that occur in practice. This causes information to extrapolate the application of this technology in other industrial sectors for the hospital sector. The problems encountered in the use of RFID technology make its insertion in the hospital an even greater challenge when considering issues related to electromagnetic compatibility and their interaction with electro medical equipment. [1].

IV. CONCLUSION

His most trivial application Occurs in the control and monitoring equipment and permanent, However, its application in monitoring and traceability of the hospital trousseau still Occur in a shy way, although, Significantly impact on the quality of services provided. A solution RFID for the control of hospital outfit is more than an indicator of location and concentrator information. It is a technology what a allows technical data management by hospital manager, planning its distribution and replenishment of the hospitalar trousseau, and also minimizing the evasion of the trousseau. The RFID solution is a tool that, in a hospital may allow the definition of economic indicators that allow the manager to improve planning and set appropriate methodologies for control of hospital supplies such as layette. With the overall cost increases in the provision of health services, it is important to identify cost-effective Technologies to the hospital reduce financial expenditures, avoidance of hospital materials and still allow the systematization and optimization of procedures for control and logistics inputs hospital. With this Project the possibility to determine the requirements and technical and managerial conditions for RFID technology can be better utilized in promoting good hospital management practices, improving reliability in the provision of health services.

V. ACKNOWLEDGEMENTS

The teacher and mentor Dr. Eduardo Jorge Oliveira Valadares, first by chance, then by attention to the logo of this work. The Strategic Technology Center of Health - NUTES. The FIOTEC - Foundation for Scientific and Technological Development in Health At partner health facilities. The health unit and hospitalar laundry, study sources. And to all those who directly and indirectly contributed to the development of this work

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Towards a battery-free wireless smart glove for rehabilitation applications based on RFID

Rafael V. Aroca, Roberto S. Inoue, Leonardo M. Pedro
Federal University of São Carlos (UFSCar)
São Carlos, Brazil
aroca@ufscar.br, rsinoue@ufscar.br, lmpedro@ufscar.br

Glauco A. P. Caurin and Daniel V. Magalhães
University of São Paulo (USP)
São Carlos, Brazil
gcaurin@sc.usp.br, daniel@sc.usp.br

***Abstract* —Several studies have shown the effectiveness of recent rehabilitation technologies such as games, robots and data gloves to perform rehabilitation of several brain and physical deceases with motor and functional deficits as side effect. Specifically, special gloves equipped with sensors have been used as assessment technology in several stroke rehabilitation over the last two decades, however current commercial data gloves are typically expensive and have several disadvantages for rehabilitation applications, such as cables for computer interface and batteries for wireless communication. Cables generally disturb the movements and batteries increase their weight. Additionally, these data gloves are expensive and as a consequence the same device is shared by several patients. Moreover, they are not washable, thus they are not appropriate for clinical usage. This paper presents a new concept of data glove technology based on UHF RFID that is wireless, lightweight and battery-free. The proposed system can have several sensors and can be used for rehabilitation applications.**

Keywords—stroke; glove; therapy; RFID

I. INTRODUCTION

According to the American Stroke Association, stroke is one of the top causes of death and the leading cause of adult disability in the United States [1]. A report from the American Heart Association Statistics Committee states that someone in the United States has a stroke every 40 seconds and someone dies every 4 minutes [2]. The same study also reports that 45% of patients return to home after the stroke and 32% of these post stroke patients use home healthcare services. Moreover, about 33% of stroke survivors suffer from post stroke depression [3]. Furthermore, more than 500,000 people have a stroke each year, leading to loss of motion, muscle weakness and reaction time reduction [4]. Boian et al. also review several studies and conclude that "*intensive and repetitive training may be necessary to modify neural organization and recover functional motor skills*" [4]. In that way, stroke patients are frequently treated with rehabilitation techniques that are repetitive, demotivating and need constant supervision from therapists.

In order to provide more cost-effective, interesting and effective rehabilitation programs, several authors have proposed new technologies to aid stroke rehabilitation [4,5,6,7,8,11]. Moreover, a review of virtual reality usages for stroke rehabilitation have found that such technologies may be beneficial to improve upper limb functions when used together with traditional care or when compared with similar traditional therapy [9].

In that way, robots [8], games [10] and data gloves [4], are being used as tools for hand rehabilitation. One of the advantages of using such technologies is that the rehabilitation progresses can be precisely measured and monitored for each system, while traditional therapists cannot precisely and quantitatively measure the progresses. Furthermore, some exercises can be done at home and more frequently, reducing costs and reducing rehabilitation time.

One type of rehabilitation system commonly used today are interactive video games [10], which in some cases are controlled by smart gloves that are equipped with several sensors to measure the orientation and position of hands, fingers and thumbs. These sensors are used for movement's assessment and to control games and also to monitor patients' progress during the exercises.

Thus, several smart gloves (or data gloves) have been developed and some commercial products are already available on the market. Such gloves are typically connected to the USB port of a computer and have one or more cables connecting the glove to the computer. Some other gloves offer wireless communication, giving higher freedom to the user or patient, however at the cost of extra weight due to batteries, processor, antenna, enclosures and other items to make the wireless operation possible.

It is well known, however, that post stroke patients have weak muscle movements and low amplitude, so that gloves with extra weight disturb and sometimes avoid movements, especially considering the need of a large number of repetitions of certain rehabilitation exercises. The present article proposes a novel rehabilitation glove based on Radio Frequency Identification (RFID) technology for rehabilitation applications. The proposed glove communicates wirelessly with a RFID reader that report glove's sensors data to a computer without the need of any battery, cable or processor. With the reduced list of materials to build the glove and the simplified circuit, the proposed system is lighter and more practical for hand rehabilitation applications than commercial data gloves, improving typical issues for multiple users such as glove's size, lifespan, sanitation and difficulty to wear.

II. RELATED WORKS

Boian et al. [4] reports the usage of an instrumented glove to reduce impairments in patients' finger range of motion, speed, fractionation and strength. With only three weeks of exercises, authors reported that the treated patients had gains in thumb range of up to 140% and of finger speed of up to

15%. Another work describes the development of a system that uses a smart glove to control a video game [5] to aid rehabilitation exercises. Zhang et al. [6] present the usage of commercial data glove integrated with an interactive virtual piano with biofeedback, in a way that stroke and other rehabilitation treatments can be more entertaining and motivating.

Similarly, Lin et al. [7] describe the development of a Bluetooth based wireless glove with inertial and bending sensors. Authors argue that such a glove can help physicians realizing patients' recovery easily and can also improve the efficiency and accuracy of hand function evaluation. A similar system recently presented by Friedman et al. [11] presents promising results to the usage of the MusigGlove, a smart glove prepared for rehabilitation tasks through musical feedback. MusicGlove usage analysis showed that six sessions of 45 minutes each led participants to improve their ability to grip small objects when compared to traditional hand exercises. Friedman et al. also argues that the results are due to many repetitions of thumb and finger exercises thanks to higher motivation and engagement.

In 2014, Polygerinos et al. [12] presented a novel robotic glove to aid patients with grasping difficulties in daily life activities. The presented glove detects movements of the user fingers and, as the muscles are weak, hydraulic actuators help the person to complete the task with grasping characteristics similar to healthy people.

As already discussed, it is desirable to use wireless gloves in rehabilitation for greater flexibility for therapists and patients, however such gloves typically need batteries. In that way, one possible solution is to harvest energy from the environment to dispense battery usage. One possible solution is to use RFID technology. Radio Frequency Identification (RFID) is based on the general concept of one antenna that emits a radio signal that is received by the antenna of a remote device, called tag, which responds with some information (commonly static and permanent as an identification code) [13]. The main application of RFID is barcode replacement for faster and more practical product identification in supply chains. There are several standards and RFID technologies usually associated with different applications and frequencies. The standard EPC/GEN2 (Electronic Product Code Class-1 Generation-2 UHF) operates at frequencies between 800 MHz and 950 MHz and enables reading of RFID tag at distances of up to several meters or even tens of meters.

RFID tags can be passive, operating without batteries, active, which uses batteries, or a variation of both active and passive operations, such as the Battery Assisted Passive (BAP) tags. Passive tags harvest energy to power their circuits only from the received antenna radio signal. It is common to find passive tags in the form of adhesive labels of paper and costing a few cents. Active tags, on the other side, are equipped with battery and can reach larger reading distances and features. They are usually encapsulated and cost a few dollars to tens of dollars. One recent research trend is the use of RFID tags as sensors of several types, which are called Sensor Tags [14].

One of the pioneer works of sensor tags was developed initially at Intel research labs by Joshua Smith, which resulted on the open source project WISP (Wireless Identification and Sensing Platform) [15]. WISP is a battery-less EPC/GEN2 compatible RFID tag that harvests energy from the UHF RF signal to power a MSP430 processor, execute a custom embedded program and sent sensor readings to the inquiring reader. WISP also features an onboard accelerometer and external inputs for sensors. In that way, several medicine applications based on the WISP were already proposed, however still none using gloves.

The main sensors used in rehabilitation gloves are flexion sensors to measure fingers bending. In that way, a recent patent filled by Disney Enterprises (Entertainment Company) [16], is characterized by a battery-free wireless bending sensor based on RFID technology. Grosinger and Griffin, the inventors, argues that one possible usage of this system in to build smart gloves for thematic parks that can be distributed to visitors, who could use these gloves to interact with robotic characters and other park activities wirelessly and without batteries.

III. RFID BASED GLOVE

Sensor Tags can be implemented in several ways, but usually they are composed of an energy harvester circuit block which provides energy to a low power microcontroller and to sensors. Due to the interest on sensor tags, some companies have designed products to aid faster development of RFID based sensing systems. One example is the SL900A IC [17] created and marketed by Austria Microsystems (AMS). Figure 1 shows an internal block diagram of the SL900A.

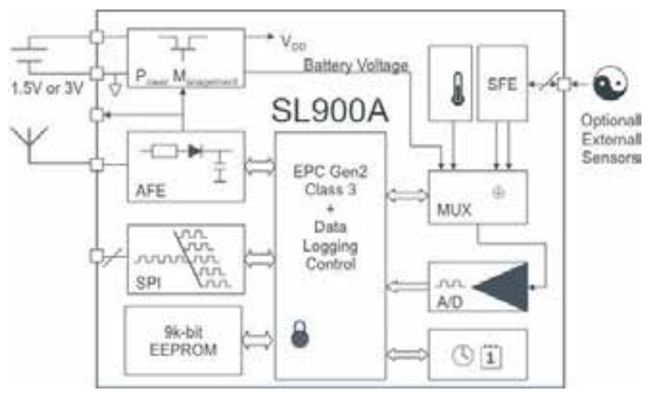

Figure 1: SL900A internal block digram. Image adapted from Austria Microsystems (AMS) [17].

SL900A provides a 900 MHz energy harvester (AFE on Figure 1), a data-logger, a temperature sensor and two external input ports for optional analog sensors connected to an internal analog to digital converter. All these functions are packaged on a QFN-16 chip with size of 5x5x1mm. SL900A can also provide limited current to power sensors without any battery, allowing remote reading of such sensors via EPC/GEN2 custom commands. Optionally, if a battery is used, SL900A can operate as a data logger using its internal permanent memory of 9 Kbits. One example application based on this chip is described on the work of Bauer-Reich [18], which uses the SL900A sensor tag to build a battery-free wireless soil moisture sensor which can be read at distances of up to 3.7 meters.

As shown on Figure 2, the SL900A is the core component of the proposed system. It obtains energy from the RF signal, uses it to power and read the sensors and report back to the RFID reader the the readings. An optional capacitor can be also added to the system to increase the read distance from the reader to the sensor tag based on the SL900A.

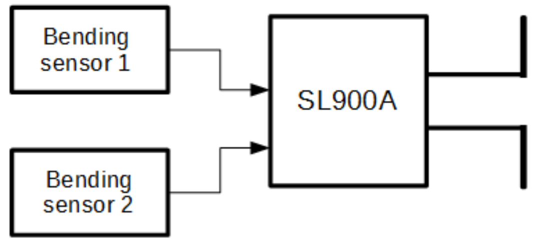

Figure 2: Block diagram of the glove's circuit. Bending sensors and a 900 MHz antenna are directly connected to the SL900A chip.

Figure 3 shows an overview of the entire system architecture. Data from the glove can be used in any kind of application, such as mouse pointer control, game or other therapy software. A software abstraction level can be implemented to allow the glove to act as a mouse, a keyboard or a joystick, avoiding the need of rewriting existing rehabilitation games or other software already existent for such purposes. One interesting possibility shown on Figure 3 is that a single RFID reader can be able to receive sensor data from several gloves at once, reducing costs for a therapy sensor, where, for example, a single reader could be used for all the patients. As each SL900A installed on each glove can be configured with a unique EPC/GEN2 ID, software can filter data from each patient and send movement updates to different screens using a computer network.

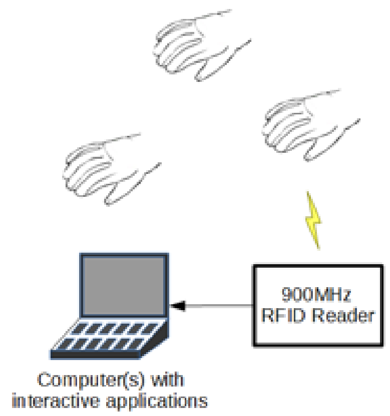

Figure 3: Possible use of a single reader for several gloves.

As the SL900A has resistive and capacitive external inputs, several types of sensors could be attached to the system. As a proof of concept, this work focuses on the use of a Flex sensor to measure finger bending, which is a typical application of data gloves. Figure 4 depicts the characteristics of the chosen sensor (Flex Sensor 2.2" from Spectra Symbol) [19], which present a resistive output proportional to the bending angle.

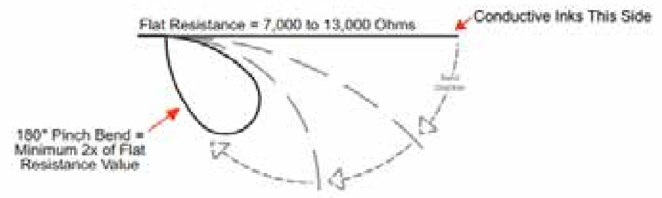

Figure 4: Flex sensor bending characteristics according to manufacturer. Image adapted from the sensor datasheet provided by Spectra Symbol [19].

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In order to develop a proof of concept of the proposed system, a circuit board with a dipole antenna, a SL900A IC and a Flex sensor was built. The dipole antenna has a total length of 15 cm and was built using two pieces of AWG 24 wire, each piece with size of 7,5 cm. The flex sensor was directly connected to the SL900A VRef and EXT1 pins. As the SL900A already has a signal conditioning system configurable by registers, no network divisor was needed. Figure 5 shows the circuit used in the experiments.

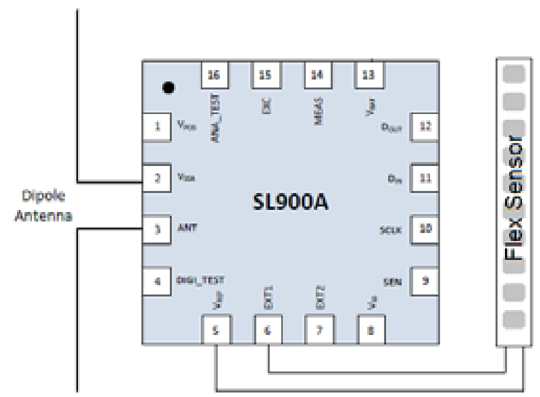

Figure 5: Circuit diagram to interface a finger bending flex sensor with the SL900A IC in the proposed system. Image adapted from the SL900A datasheet from AMS [20]

Figure 6 shows prototype boards built with the SL900A IC. One with the sensor directly connected to the board, one with external connection for the sensor and one with Dual In Line pins for prototyping and executing tests.

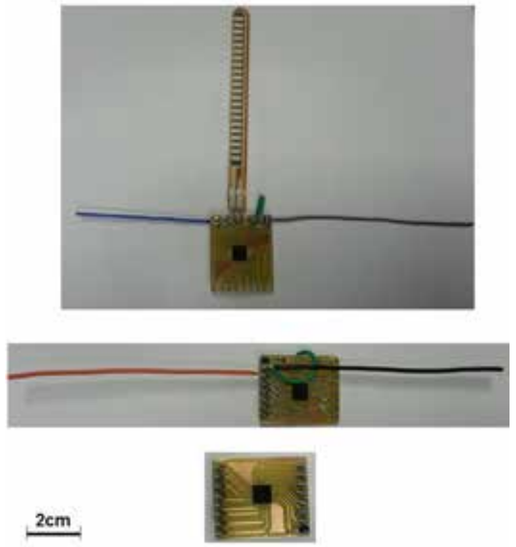

Figure 6: Prototype boards built with the SL900A IC.

After the prototype boards were tested, one of them was sewed on a glove for handcraft works typically sold on hardware shops, as shown on Figure 7. When the board was attached to the glove, the tips of the dipole antenna were folded in 2,5 cm. All the electronic parts of the glove weight 2,7 grams, and the glove alone weights 33 grams, so the total weight of the prototype glove is less than 36 grams, however this weight could be reduced using lighter fabrics.

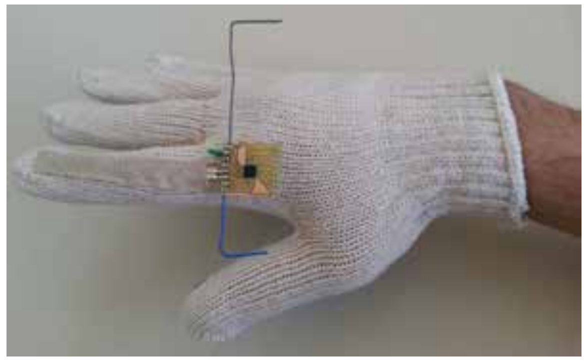

Figure 7: Glove with the Flex Sensor sewed and the SL900A IC board.

To perform the tests, an AS3993 (Radon) reader from Austria Microsystems (AMS) was attached to an UHF 7 dBi RFID patch antenna with circular polarization from Poynting (model PATCH-A0025). A C# program was developed to continuously read the values of the bending sensors by issuing EPC/GEN2 custom commands (cool-Log^{TM}) to the SL900A IC requesting the analog to digital conversion of each external sensor connected to the SL900A. Results are then sent to the software abstraction layer to map these readings to keyboard, mouse or joystick inputs, or optionally to send the information to other devices via network.

After the experimental environment was setup, some tests were performed using the glove. On average, data from sensors could be read at a rate of 2 Hz with peak reading rate of 10 Hz at distances of up to 40 cm from the reader's antenna. Figure 8 shows two examples of collected data sets using the proposed system: in the figure, SL900A analog to digital conversion result was mapped to the sensor bending angle. Figure 8 also shows two series of data: on the top, one of the authors moved the finger from the flat position to the maximum angle of the fingers several times. On the bottom, the same person moved the index finger several times again, but with lower finger movement amplitude, avoiding to completely closing his hand to simulate a motor difficulty. The developed software allows data collection and plotting in real time or saving the results to a Comma Separated Values (CSV) file for later analysis.

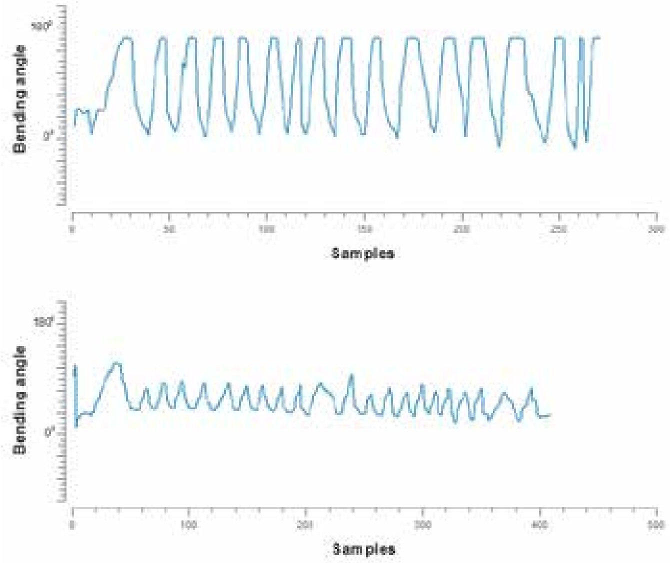

Figure 8: Examples of two experiments conducted with the proposed system. Top: opening and closing the hand several times. Bottom: opening and closing the hand several times without completely closing it. Each sample is taken at each 100 ms.

With a weight of less than 36 grams, the presented concept glove is lighter than other traditional data gloves. For example, one commercial light weight data glove weights 300 grams [21]. Moreover, more sensors can be added to the proposed glove by adding new SL900A boards for each pair of sensors, which would add 2,7 grams to the system. The light weight is important because the exercises done with the glove are long and repetitive.

One difficulty that was observed occurs when the circuit board and antenna are near the human body: in such cases, the reading distance is considerably reduced. Several UHF RFID tags were also tested near the hands' skin and the obtained results were similar. Although the read distance obtained was of 40 cm, other works that use EPC/GEN2 RFID technology for human body sensors monitoring already showed results with 2 meters distance of reading [22] or even 10 meters [23]. In that way, some approaches can be taken in the antenna design and board placement (such as a silicone spacer) to enhance reading range of the system when near the human body (hand or arm in this case).

Overall, the glove itself is low cost (about US$ 14.00 for purchasing parts in small quantities for a prototype construction), which even in small scale would allow each patient to have its own personal glove, reducing typical issues of sanitation and glove size that occurs with typical and more expensive data gloves that must be shared among several patients.

V. Conclusions

This article presents a low cost, lightweight and battery-free wireless concept of a data glove mainly developed for hand rehabilitation exercises. A software layer allows it to act as a mouse, keyboard or other input devices, so it can be used with any current software already available for rehabilitation, such as games created to keep patients motivated during upper limb rehabilitation exercises, which are typically monotonous.

Although this work proposes the usage of the presented system for hand rehabilitation, especially for stroke patients, it should be noted that the system is generic enough to receive other sensors and be used with other applications such as virtual reality or other human-machine interaction systems. The system is based on EPC/GEN2 custom commands to allow sensors connected to the AMS SL900A passive sensor IC to be read and reported back to standard UHF RFID readers.

The use of such kind of glove, allows glove size customization for each patient, reducing typical problems that exist when a single data glove is shared between several users, such as sanitation, lifespan and wear due to frequent insertion and removal.

In the future, it is planned to redesign the board antenna, add more sensors and conduct experiments with select patients to evaluate the gloves performance in a real environment.

Acknowledgment

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Using RFID technology to Enhance Quality Information to Products in Agribusiness Supply Chain.

Roberto Candido[1], Javier Martinez[2] and José Reinaldo Silva[3]

***Abstract*— In this work we present a case where an Informed Process Model to Supply Chain is applied to agribusiness, particularly to a process that benefits seeds. This process uses RFID to provide proper information which is attached to the product in different phases and also to the final package, which stores all important information concerning the production and the quality of the final artifact. The intent of this proposal is to associate quality information with the automation of precision agriculture processes. The characteristic of this RFID application allow a wide distribution of final packets without a lack of quality information and independent of the access to centralized information systems. However, such achievements also depend on a good plan for the design of such systems. Thus, we also include a design process based on Goal Oriented Requirement Engineering to provide focus on project goals since the very beginning of Requirements Elicitation and Analysis phase. Partial results already show the advantage that emerge from the combination of formal - based on Petri Nets - and semi-formal - based on KAOS diagrams - approach to efficiently model tagged processes.**

***Index Terms*— RFID (Radio Frequency Identification), Precision agriculture, Informed Supply Chain, KAOS, GHENeSys**

I. INTRODUCTION

In the 21st century, industry services has become increasingly competitive, specifically in suppliers management and in the process of delivering products anywhere in the world efficiently, associated to quality information. The success of such tendency relies on the capacity of researchers and practitioners to deliver a good design for the tagged applications, capable to automate the process partially or totally.

In this scenario, the consumer society is engaged on finding providers around the world that posses a reliable process to generate and preserve quality information. Therefore, there is also an effort from the academy and from the industry to provide technology to achieve such goals. If we consider also the diversity of opportunities raised in the global marketing, precision agriculture will demand a wide distribution of artifacts - from seeds to final products, composing a large network. Quality information should then be attached to these component artifacts using the best of the technology available to support a modern supply chain, which result in good and consumable final products.

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[1]Rua Sete de Setembro 3165 Rebouas DAELT 81280-340 Curitiba, Pr - Brasil rcandido@superig.com.br
[2]Rua Prof. Mello Morais, 2231 Cidade Universitria 05508-030 - Sao Paulo, SP Brasil javsilva@usp.br
[3]Rua Prof. Mello Morais, 2231 Cidade Universitria 05508-030 - Sao Paulo, SP Brasil reinaldo@usp.br

RFID is a good candidate to provide such technology in agribusiness since we observe some special concepts in these processes: i) flexibility, once quality information would change very fast from different stages; ii) storage capacity, since more information would be integrated to qualify the whole process, composing what is called "information process" [1]; iii) traceability, where ordered information is arranged so that it would be possible to trace partially (or completely) the process that generated the product [2]. Those are the most important factors to add value in automated quality informed systems based on RFID. We claim that RFID is a more flexible scalable technology to add an increasing amount of data tagged to the product to guarantee its quality. Traceability is also defined by Zhang et al. [3] as a process to assure quality and safety to very known process applied to the production of beef breading. The evolution and dissemination of the traceability concept stressed the need for more information about production, specially in what concerns perishable artifacts. In this domain there is a tendency to include production processes with a modern Supply Chain, where a multi-step compositional product must keep track of it production history.

Up to some years ago bar code had supported the traceability of items over the Suply Chain, and this practice uncover a key disadvantage: all product information was stored in centralized databases with difficult access by the stakeholders, especially by end customers. Even if this method maintain traceability and storage capacity it is not flexible and make it more difficult the distribution of products without an expensive structure to keep all the necessary data - besides the cost of consulting such databases each time some information is demanded.

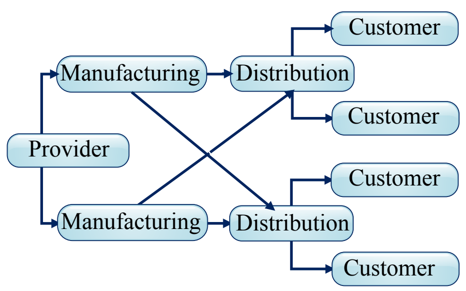

Fig. 1. The supply chain divided into four areas

Fig.1 shows a schema for the structure of supply chain networks as it is designed in manufacturing environments [4]. Precision Agriculture has a similar problem in what concerns the existence of a product to which we need to associate quality information. However, the overall structure is different, in the sense that instead of a central provider, new components are generated during the process - or in a particular process such as the seed benefiting - which has to be distributed. That characteristic is connect with the concept of *flexibility*.

Besides having a distributed provision, the precision agriculture also has a demand to change from one process to another by generating important information: a feature to which is attributed the concept of *flexibility*.

The demand for flexibility raises a pressure to expand the storage capacity of RFID tags and to provide a partial order organization in the tag. Some authors in manufacturing suggested to include a Petri Net to cover a need for a formal representation to this partial organization in storage [5]. We prefer a more direct approach based on a total ordering representation through an ordered list in the RFID tags.

Finally, traceability is a property of the system that can be associated to its design process. Thus, such issue could not be derived from what is stored in the site. Instead, this information should be used to consult project documentation. That is why the use of a Goal oriented approach is so important to this kind of application.

This paper is organized as follows: Section 2 describes aspects of Informed Supply Chain, introducing the use of RFID and detailing its structure. Section 3 presents the use of KAOS (Knowledge Acquisition On automated Specification) as a method for the elicitation and analysis of requirements to reinforce traceability. Partial ordering representation is introduced by analyzing the whole process (and the information it generates) using a unified Petri Net approach called GHENeSys (General Hierarchical Enhanced Net. System) [6][7]. Finally, we analyze the prototype and some conclusions of our proposal.

II. INFORMED SUPPLY CHAIN

In what concerns RFID Technology, the concept of Supply Chain has been associated to its management using information inserted in the tag. Generally a centralized model is issued to help in this process, what demand a strong organization. SCM (Supply Chain Management) has been a widely adopted practice to ensure customer satisfaction. The EPC Global, in his magazine (RFID4u), said: "The SCM aims to increase the performance of companies in the global supply chain, maximizing customer value and minimizing costs."

However, as we stressed before, this approach could suit very well the classic architecture of Supply Chain used in the manufacturing industry. In Precision Agriculture, as in the modern manufacturing process, the Supply Chain is in fact a distribution of actors (or suppliers) ubiquitously merged in the production process[8]. Thus, it is important now to carefully design the insertion of information in the tag as well as it organization and ordering.

Such change in architecture of the Supply Chain strongly affect applications in precision agriculture. In order to minimize this impact (and obtain a simpler application) we adopted a direct approach to the ordering of information in the tags (using total ordering approximated processes), but preparing the whole system to compose an display consolidated information in an Information System that could be in a cloud system. Probably that would be a new position for EPC Global and similar institutions.

This decision allow an implementation where a centralized background still exists and could give confidence to the process but such background does not interfere in the flexibility of the process. As a consequence, it is possible to provide traceability in a very simple way without the consult of large databases.

A. The structure of RFID

An RFID device allows the identification of a particular item with no direct contact or without the need to keep the product under a vision angle. That helps to make the process faster since there is no need for positioning between the equipment tag and the reader. It accepts a larger set of unique IDs enabling the management of additional data, such as: manufacturer, product type, and even to measure environmental factors such as temperature [9].

The use RFID tags was originated at the end of the Second World War by British Air Force to track its owns aircraft and distinguish them from the enemy's. Afterwards, in the 70's the focus was the study of system with re-writable memory partially funded by US government. Also in this period the US government encouraged the research on tracking system of radioactive material and also on animal tracking. According to Dolgui and Proth[10], the combination of RFID technology with existing software management would create an intelligent system in Manufacturing by speeding up responses and the work with data collection.

Lee and Clark [2] and also A D. Smith[11] show another advantage of RFID tags besides the absence of physical contact with the monitored element - eliminating manual operations in existing bar code: the scalability of its storage section. Therefore, the whole RFID system consists of three basic elements: *antenna*,*reader* and *RFID device (tag)*.

The working frequency of the RFID devices is an important issue and its specification is driven by the desired application. The storage section of an RFID tag is divided in the following sections:

- Memory Reserved - KILL: stores a password to "kill" the device after it fulfills its task.
- PC Memory: memory location that records the unique Electronic Product Code universally recognized.
- tag serial number provided by its manufacturer. It is also unique and inseparable.
- memory space allocated for the user, who might even be an empty space.

Scalability of the memory storage is connected with the possibility to expand the slot dedicated to the user, and several companies risked the introduction of tags with a large memory, up to 64KBytes, as the one from Fujitsu.

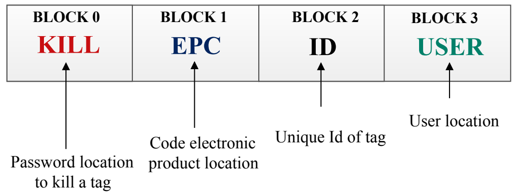

Fig. 2. Memory structure of RFID tag

III. USING KAOS METHOD TO THE MODELING OF REQUIREMENTS

As we claimed before, the traceability of the process, that is, the possibility to associate value parameters or the occurrence of related events is not captured in the process that is stored in the RFID tag. Although this is possible, as in manufacturing, this is not really an important issue in precision agriculture. Meaning that when this demand appear it is more connected with the design of the system than with the occurrence of events - in seed enhancement for instance. The project and its documentation is certainly the base for the centralized background, besides de identification itself.

To evaluate the importance and the role of this process we introduced a design that no generic but goal oriented, as described in the following.

A. The KAOS Method

According to [12] to provide efficient requirements in engineering it is important to go beyond the dichotomy between functional and non-functional requirements, that is, the more direct way to do this is to focus on goals. Goal oriented methods assign responsibilities to the agents (human, hardware or software) related with each requirement accomplishment, which is the base to reach good results with traceability.

GORE (Goal-Oriented Requirement Engineering) provides a policy to identify the completeness of requirement specification which is fulfilled as the goals involved are reached. GORE methods have key efficient mechanisms to manage conflicts between different viewpoints; and provide justifications (rationales) arguing to the "why" requirements.

KAOS (Knowledge Acquisition On automated Specification) is one of the GORE methodologies dedicated to the analysis of requirements driven by goals.[12]. KAOS provides mechanisms based on formal logic LTL and graphical modeling representing goals. Goal diagrams are shown in Fig.3 where part of the seed enhancement process is translated in goals with respective responsibilities attributed to the process operator and to the Verification System[13].

We can use these diagrams to introduce a general specification of the problem which already has a description of responsibilities and the relationship between agents and processes allowing the association between value parameters and the achievement of goals.

We could shortly describe our process as getting seeds from different providers which should be received and classified according a quality standard. Therefore the first

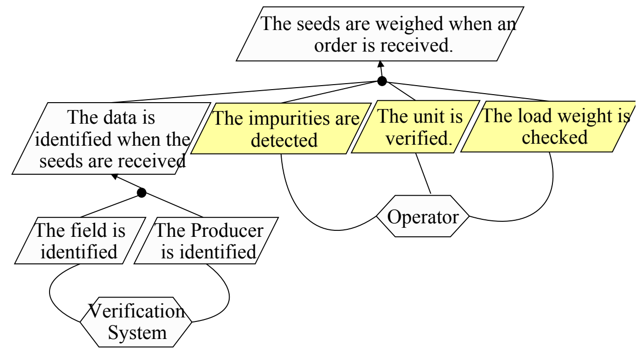

Fig. 3. Goal Diagram of KAOS for the goal *The seeds are weighed when an order is received*

information necessary to the process is the origin of the seed accommodated in packages (from the same provider). Our first goal is to classify seed, and there are specific agents responsible for that (another information to the tag).

Seed packages are used as input to the enhancement process and could follow different paths depending on their classification (seed from different providers could be mixed in they have the same classification, which is also valuable information to be included in the tag). Following, different kind - we will assume them to be exclusive - of chemical enhancement could be applied which should also be registered, with the data they were performed and the final result. Possible accidents should also be marked.

Finally, after the enhancement seed should be packed again in bags which would receive the proper tag with all its history - described just superficially here.

IV. GHENESYS HIGH LEVEL PETRI NET

There is a difference between the process prescription, that is, all relations in the process and all alternatives available and the path followed by a specific path. It is not difficult to associate the general prescription with a network (or a product of automaton) and the path followed by a bag as a path in its transition graph.

A generic and formal way to represent this product of automaton is certainly to use a Petri Net, or, in special a unified net system - that could represent different kind of nets - as the GHENeSys (General Hierarchical Enhanced Net System) [6][7]. Such information would be very useful if a more detailed analysis of the product history is necessary. However, as we said before, sch information not necessarily should to with the product and it is something associated with the background information.

Fig. 4 depicts a general model of the enhancement process.

The Fig.4 shows the GHENeSys net obtained from the translation rules defined in Martinez and Silva[14] to transform a Goal diagram into a corresponding GHENeSys net. Except for the goals represented by place (with the same interpretation in elementary Petri net), the rest of goal diagram elements have associated a GHENeSys element as pseudoboxes to represent a place with a persistent marking,

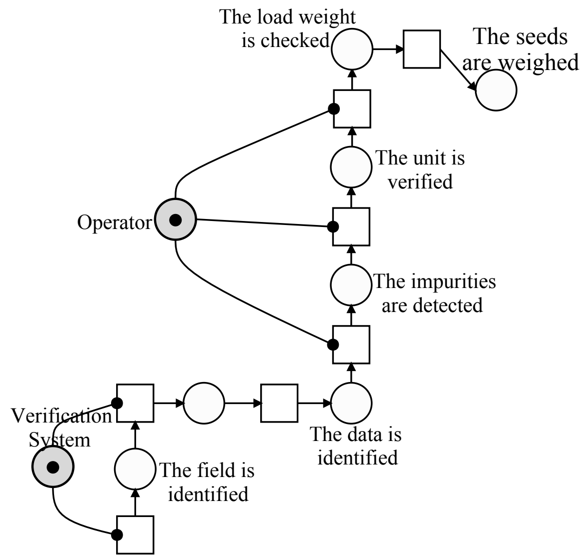

Fig. 4. GHENeSys net resulting of translation from Goal diagram represented in Fig.3

used to model agents responsible for achieving a goal, as well as to model Domain properties. The use of enabling arcs linking these pseudoboxes with transitions and the use of macro-pseudoboxes to model KAOS behavioral goals which involve a set of operations (modeled on operationalizations KAOS diagram). Subnets could be used to model operations, becoming in the hierarchical network.

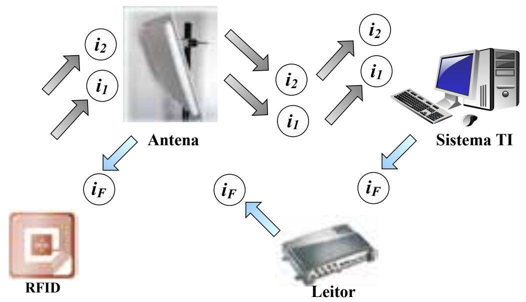

Fig. 5. Model of flow of permanent information

From the set of GHENeSys model it was possible to determine optimal points where more information is inserted (or excluded) in RFID tags. These locations are called Communication Stations (CSs), and the work-flow of the information is called Permanent, Composite and Independent, according to the form of storage. Fig.5 shows one of this flow.

V. THE PROTOTYPE

The process described above were implemented in simulator specially designed to repeat the real process - which works in a rural facility. This process were modeled in Petri Nets and its workflow were analyzed to spot the communication stations (where information is inserted/retrieved from the tags. The formal process can then be reproduced in a computer. Also real sequence of events can be taken from the real process and repeated in the mathematical model to test the proposed system. The simulated model is shown in Fig.6 (where we can see, reader, antenna and computer and independently RFID tags).

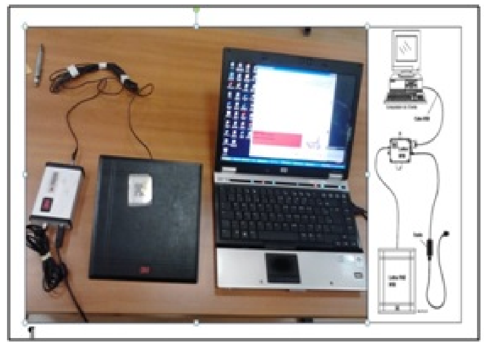

Fig. 6. Prototype of Informed System

The simulated system were not prepared as a product but as a real reproduction of the real system. Meaning that the objective is not to implement the simulation but to assure that it could be reliable in the reproduction of what really happens in the seed enhancement plant. Of course, a product could be encapsulated in a smaller arrangement to fit in the real plant, but until the model is tested there is no point in investing such effort and costs.

On the other hand the experiment was committed in using industrial equipment available on the market. And the authors of this work thanks the company 3M Brasil for the collaboration with equipment and also providing information enough to couple this equipment with devices and algorithms used in the simulated experiment which general architecture is shown in Fig.7

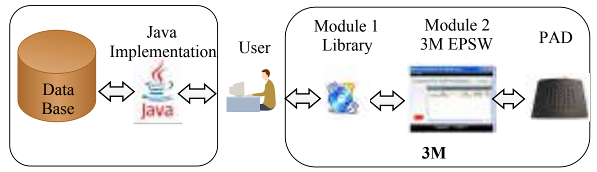

Fig. 7. System Architecture

Communication Stations run a interaction and information exchange software we developed which interface can be seen in Fig.8. In this snapshot a screen for collecting and inserting information is depicted. All transactions could be stored in a centralized database, but this was not a priority in the experiment. This is an important issue to detect errors reproducing the processes.

The simulated environment could also be used for training since if reflects all interactions which occur in a communication station. Fig9 shows the real plant and all possible paths

Fig. 8. Final Report Reading

seeds could take. We can map communication stations over this plant and justify all communication processes as welll as the information exchanged with the process.

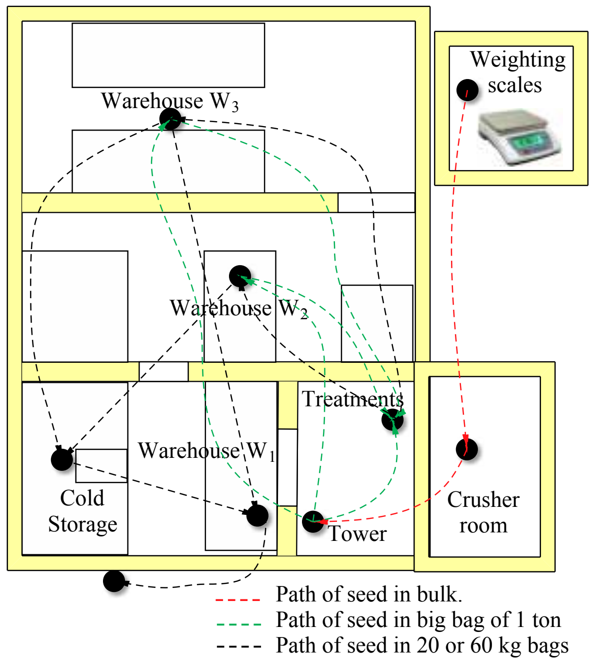

Fig. 9. Real Plant

VI. CONCLUSIONS

Besides being a good case study for the use of informed processes, that is, for processes were we explore the expansion of the user data stored in the tags, this experiment also allowed to discover some issues that need to be addressed before the implementation of a more generic Supply Chain Informed System using RFID:

- disseminate RFID culture in precision agriculture environment, showing also a model to automated the process (see enhancement in this particular case) exposing the differences from the use of bar code.
- training employees so that they experience the new technology and test the supply chain, by using the proper software, even if the real plan were not fully adapted to work with a product especially developed for that.
- establish an effective partnership commitment between suppliers and customers.
- creation of a synergistic relationship in R & D & I involving technology providers in order to reinforce the design of a new system that can automate seed enhancement project, using the simulation as a proof of concept.
- test the performance of RFID devices in the seed enhancement environment to spot interference, Doppler and other effects that could compromise results of an automated facility that uses this technology. Results show that the use of RFID in precision agriculture would be very promising and a real plant can now be constructed.

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Porposal for EPCIS System Implementation to control drugs in pharmaceutical sector in Brazil

Patrícia Amaral
GS1 Brasil
São Paulo - Brazil
Patricia.Amaral@gs1br.org

Marcus Vinicius dos Santos
GS1 Brasil
São Paulo - Brazil
Marcus.Santos@gs1br.org

Luiz Costa
RFID CoE (Center of Excellence)
Flextronics Institute of Technology–FIT
Sorocaba – Brazil
luiz.costa@ fit-tecnologia.org.br

***Abstract*— Considering GS1, a multi-sectoral non-profit global organization for managing information that facilitate the marketing of items in supply chain and communication between companies different parts through the supply chain.. The healthcare scenario today requires traceability, shows a specific need. Thus, GS1 intends to assist this sector in this matter / issue with a global communication standard between health supply chain companies using EPCIS (Eletrocnic Product Code Information Service).**

***Keywords*—RFID; GS1; EPCIS**

I. INTRODUCTION

The EPC Information Services (EPCIS) is a GS1 standard that enables trading partners to share information about the physical movement and status of products as they travel throughout the supply chain – from business to business and ultimately to consumers. The goal of EPCIS is to enable disparate applications to create and share visibility event data, both within and across enterprises. Ultimately, this sharing is aimed at enabling users to gain a shared view of physical or digital objects within a relevant business context.

Based on the need to use a international standard to exchange information with all the supply-chain partners, GS1 Brazil developed a proposal of how to comply with the law.. This Paper aims to present the best identification and codification best practicesfor secondary packaging (cartridge) and tertiary (transport) and how this information will be traced on the national Brazilian System (ANVISA), like is showed on figure 1 below.

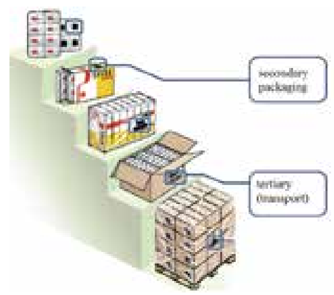

Fig. 1. Secondary and tertiary packaging system.

A. Application to the ANVISA RDC 54/2013

The Resolution RDC No. 54 provides the implementation of the national drug control system and the mechanisms and procedures for tracking drugs in the chain of pharmaceuticals and other measures.

Expected benefits

- Technical support for proper application of the codes in secondary and tertiary packaging.
- Direction to ensure quality printing of codes.

For the purposes of this guideline, the RDC 54/2013 can be viewed as a two-milestone implementation over three years:

- The first milestone, at December 10th 2015, defines that all supply chain participants get involved in a pilot exercise of at least 3 (three) batches of pharmaceutical products serialized and tracked with complete traceability technology implemented . The traceability information required for these batches involve the end-to-end movement of goods, from the manufacturing plant, including transaction between subsidiaries, until the sales or administration point , that can be understood as a hospital, drug store, physician handling free samples, and others. The responsibility to report the traceability information to Anvisa resides with the Industry and an alignment of assumptions and approach is required with all other supply chain participants to make this pilot phase happen.
- The second milestone of the RDC 54/2013, ending at December 10th 2016, requires that all supply chain participants have already in place the processes and technology to support the serialization and traceability of all pharmaceutical products with sanitary register in ANVISA and commercialized in Brazil. All movement of goods need to be registered by all these participants, including subsidiaries, within their information systems, and is responsibility of the Industry to consolidate all this information and attend the Anvisa expectation around the reporting requirements. Anvisa defines the

Datamatrix as the mechanism to identify serialized pharmaceutical products and leaves with the Industry the responsibility to create, own and maintain a traceability solution that will connect all the supply chain participants in a specific IT solution.

B. Use of GS1 Standards

Secondary Packaging – GTIN Identification

- The GTIN (Global Trade Item Number) is a number that identifies goods and services uniquely. It consists of the GS1 company prefix, an item reference and a check digit. Despite the GTIN not mandatory, their use ensures interoperability in supply chain and adherence to international markets. When a GTIN is assigned, the owner of the brand / registration must link this identification number to item characteristics, such as description, weight, dimensions, the active ingredient, etc. in its database. The GTIN most commonly used for identification of drugs is GTIN-13 (with 13 digits).

GTIN-13
(EAN / UCC-13)

0 123456 789012 >

Fig. 2. GTIN13 - Structure.

Secondary Packaging – GS1 Data Matrix

- The GS1 DataMatrix is a two-dimensional symbology that can encode, with the use of Application Identifiers (AI), a series of information such as product identification (GTIN), expiry date, lot, serial number, etc. The RDC 54/2013 determines that the Datamatrix code minimally the following data that make up the IUM (Drug Identification Single):
  I - the drug registration number at Anvisa;
  II - Serial number;
  III - Expiry Date;
  IV - Lot Number.
- The number of positions in the DRC 54/2013 mentioned range according to the table below. Note that GS1 standard in some cases, has a larger capacity position.

(01)07898357410015
(713)3210987654321
(21)1234567890123
(17)150206
(10)123ABC
IUM

Fig. 3. Data Matrix- Structure.

Tertiary Packaging – Serial shipping container code: SSCC

- The SSCC is a standard voluntary que establishes a system of identification que can be used by all parties in the supply chain, from the manufacturer to the carrier, distributor and retailer, to track the distribution of products.
  It is an 18-digit number que Allows exclusive and serialized identification of logistical / transport units.
  When combined with shipment information provided in advance by electronic means (ASN, eCom, etc.), the SSCC will support applications such as shipping/receiving, inventory update, selection, reconciliation of purchased orders, product traceability, etc.
  The SSCC is particularly suitable for identifying transport packaging including that which is mixed and / or contains serialized items, allowing the merchandise that is packed to be identified and thus enabling checking and control.

SSCC - Serial Shipping Container Code (SSCC)

(00) 0 0718908 562723189 6

Fig. 4. SSCC - Structure.

These are the most important standards to be used for screening drugs using the EPCIS development platform (it is important to note that any global standardization of GS1 can be used for communication between links in drugs chain).

II. EPCIS STANDARD

EPCIS is GS1 Standard that defines a way to enable disparate applications to create and share visibility event data, both within and across enterprises. Ultimately, this sharing is aimed at enabling users to gain a shared view of physical or digital objects within a relevant business context.

The EPCIS standard was originally conceived as part of a broader effort to enhance collaboration between trading partners by sharing of detailed information about physical or digital objects. The name EPCIS reflects the origins of this effort in the development of the Electronic Product Code (EPC). It should be noted, however, that EPCIS does not require the use of Electronic Product Codes, nor of Radio-Frequency Identification (RFID) data carriers, and as of EPCIS 1.1 does not even require instance-level identification (for which the Electronic Product Code was originally designed). The EPCIS standard applies to all situations in which visibility event data is to be captured and shared, and the presence of "EPC" within the name is of historical significance only.

Additionally, the EPCIS has in its structure, four key elements:

- EPCIS Capture Interface, understand the business context in which the capture of EPCIS information occurs. That is, an EPCIS capture is able to provide a context of the highest level of business for the captured GS1 data.
- EPCIS Accessing Applications, can be any application that accesses EPCIS. Generally, this application is responsible for performing a business process. The application access can stay outside the company.
- EPCIS-Enabled Repository, records EPCIS events generated by one or more EPCIS capture applications and makes them available for further research using EPCIS accessing applications.
- EPCIS Query Interface, provide a standard way for internal and external systems to request business events from repositories and other sources of EPCIS data using a simple, parameter-driven query language.

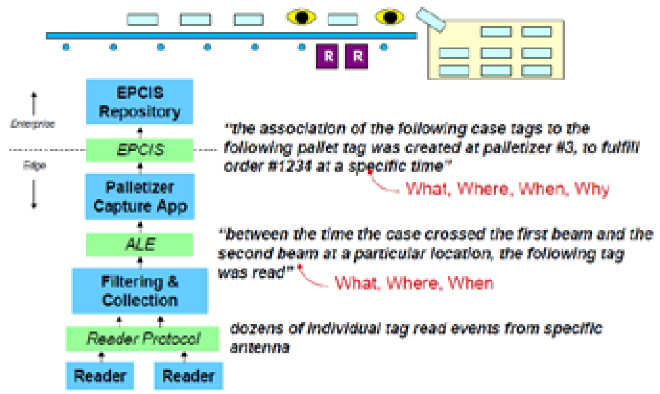

Fig. 5. Data Capture example.

Product Identification that can be captured may come in the form of:

- Passive RFID Tag –UHF Gen 2, HF
- **Barcodes –Linear, Data Matrix**
- Active RFID Tag
- Human Readable Number

Finally, EPCIS provides the critical foundation for the visibility needed to improve business processes, comply with regulations, and increase consumer and patient safety. At the same time, its flexibility and extensibility are geared to support both current and future needs of trading partners across multiple industries, regardless of data carrier.

III. WORK DEVELOPMENT

Anvisa expects from the pharmaceutical supply chain participants the evidences that they were able to deliver what is expected from the 2 (two) different milestones as described above.

Both milestones consider serialization and traceability capabilities, in this way differing from other countries like US where serialization and traceability are handled separately from an implementation timing perspective.

Another important aspect of the transition between the pharmaceutical market current state in Brazil and supply chains with serialization and traceability capabilities is to consider a smooth and clear approach with final customers. Communication for example needs to be planned in advance for a scenario where products non-serialized will co-exist with serialized ones, clear rules on how to correctly identify a counterfeit and diverted product.

The figure below shows the storage processes and logistics distribution of pharmaceutical drugs:

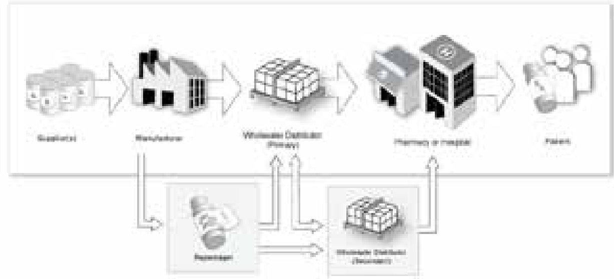

Fig. 6. Data Capture example.

Global standards such as EPCIS could allow applications and processes across the industry to support the Five Sure, improving patient safety and supply chain efficiency:

- Traceability of medicines: Partners supply chain can use integrated barcodes with EPCIS system to control all drugs throughout the supply chain, according to their risk category and in the case of some products, full traceability of medical supplies could improve the processing of recalls and facilitate inventory management.
- Drug receiving authentication: distributors, pharmacies and hospitals could use the EPCIS system to track and confront all medicines with manufacturers' data and possibly elsewhere in the supply chain, making it much more difficult for counterfeit and damaged goods arrived to the patients.
- Collaborative inventory management: dispensing points, distributors and manufacturers could easily exchange information on use of health products and medicines, location and availability of products. Program planning and forecasting stocks could analyze data to optimize inventory levels, improve the availability of medical supplies and medicines throughout the supply chain, and ensure availability of medical products in critical moments of treatment.
- Transaction automation: The processes and systems may be automated, removing most of the insert, validation and data correction today made manually. The administration of medicaments and the use of medical devices could be captured by reading the bar code and automatically fed in logistical systems.

IV. Conclusion

With the proposed implementation of the EPCIS system in health, concludes in this article that this standard meets ace regulations along the National Agency of Sanitary Surveillance (ANVISA).
After implementing this system, the following benefits are estimated:

- Reducing product waste due to obsolescence;
- Reducing the cost of data management;
- Improving the accuracy of transactions;

In a conservative approach, it is estimated that the costs in the health sector could be reduced by $ 40-100 billion worldwide, mainly through the reduction of medication errors cost (US $ 9-58 billion), cost of improvement of inventory management (financing, processing, reduced obsolescence cost at $ 30-42 billion) and reducing data management costs ($ 1-2 billion).

Acknowledgment

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Inventory Control With RFID Integration

Authors: Willian Grégory Barlati de Matos, Marcos Ueda and Tamires Roberta de Camargo
College of Information Technology
University Center Nossa Senhora do Patrocínio
Itu - Brazil

Co-Author: Profª Adriana Morais
College of Information Technology
University Center Nossa Senhora do Patrocínio
Itu – Brazil

***Abstract*— As the company and its volume of stored products grow, errors in the products inventory checkpoint are quite common due to both human failures and the lack of additional resources. Costs also come from the need to control the inventory and the information of stored products, where companies often hire specialized professionals in products inventory and in gathering information to carry out this task. Once they are stored in a disorganized way. The system is a software for inventory control, focusing on Radio Frequency Identification Technology (RFID) integrated into the Open Source Hardware board Radiuino, which offers great advantage because of the implementation cost. All of this resumes in a technology that is increasingly gaining share for being used in many technological areas. Based upon the information gathered, we developed a software using this technology to control the products in stock. In doing so, we monitor the ins and outs of the products flow, as well as addressing them in stock. This process facilitates the control, the maintenance and the dispatch of the internal products of the company.**

I. Project Vision

The purpose of this document is to collect, analyse and define the needs and requirements of those involved in the project, which aims to develop a software using a new technology called Radiuíno, integrated with a RFID module, controlling the inventory of products with tags via radio frequency.

A. Scope

The main objective of the system is to develop an application for monitoring and controlling products inventory, using a tool of software embedded 'Open Source' known as Radiuino, working together with the reader module RFID, which will be responsible for obtaining the labels codes enabling the control of the products expedition. Being possible to issue lists of products and their contents. We will use elements of storage rule WMS as: Storage, inventory management, mailing products, expedition using FIFO, thereby improving productivity and the control of the goods ins and outs, better managing the flow of both products and materials information within the deposit or stock.

B. Computerized processes in the system

- Products:
  - Products inputs in stock;
  - Creation of RFID tags;
  - Making of products inventory;
  - Control of products expedition;
  - Addressing of Products
- User
  - Control of access and permissions;
  - Registration of users;
  - Generation of logs of changes;
- Tax records
  - Registration of CFOP, Fiscal classification and ICMS;
- Consultations
  - Products stock queries, product outputs;

C. Main Features

- Control of products via RFID tags;
- Users and access management;
- Conducting of inventory products outputs;
- Inputs and control of products address;
- Conducting inventory using RFID;

D. Possible Problem

There may be physical difficulty of the product storage location, for there cannot be obstacles that would prevent the communication of the plates and labels. Thus affecting the product label's reading, not returning the label code, thereby causing discredit to the reading equipment. A good solution would be investing in signal repeaters.

E. Restrictions

There will be partially implemented some rules of WMS, only major stock characteristics of the product. Other restriction is to have a place for appropriate inventory to use the RFID. We disregarded payment control rules.

F. Minimum System Requirements

- Server with processor QUAD CORE, 4GB memory, HD 500.
- Work stations with DUAL CORE processor or inferior, Minimum memory of 2GB, HD 80gb minimum.
- Module DK102 Radiuino with Be900
- Module RFID
- Programmer Module.

II. DEVELOPMENT ENVIRONMENT

The development environment will have as reference the Analysis, Design and Construction.
The tools used during the development of the project are listed in the following table:

Developer Tools	
Tool	***Description***
Microsoft Visual Studio 2010	Development in C #
SQL Server 2008	Database Management System
Arduino	Arduino development system
Crystal Reports	Reports Development

III. ABOUT RFID COMPONENTS

A. BEE900

In the design of the two modules were used BEE900. One with the development plate DK102, which is the data transmitter and the other on a controller connected to the computer, i.e. the receiver. This is responsible for transmitting and receiving packets data issued by the RFID.

B. UartBee

It is a converter that allows communication between a computer and a BEE900 device. It can be used as an inverter or as a firmware recorder. As a writer firmware, we programmed in C language in the Arduino application, the codes for BEE900 send and receive information, the UartBee makes the recording of these codes in each of the transmitters that are in an operable looping. While they are connected, they are always ready to transmit and receive information. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

C. RFID Uart 125 KHz

The module is designed to perform the reading of 125KHz Tags. It has a range of 120 meters (without barriers), and can be used in various kinds of controls.
When the RFID tag is passed on a maximum distance of 5 cm from the antenna, the data are sent by the transmitter BEE900 in a 52-byte packet, and received by the receiver BEE900, connected to the controller UartBee, which is in communication with the computer .
The RFID card is connected to DK102 plate, together with the BEE900 transmitter.

IV. ABOUT PROJECT

The project is aimed at increasing the efficiency of logistic operations, prioritizing a directed stock rotation, with methodologies FIFO. Agility in storage, automatic consolidation to maximize the usage of space in stocks. The system also directs and optimizes the available collection or the placement in the warehouse, based on real-time information about the status of the shelves usage and addressing products, obtaining maximum efficiency in monitoring the products, expedition of products using monitoring with input controlling batches. Gains with this implementation can be seen by the final time, resulting in a faster delivery of products for customers and the internal control of stock, leading to more reliability and integrity in the controlling of goods and the storage, in terms of efficiency in monitoring.

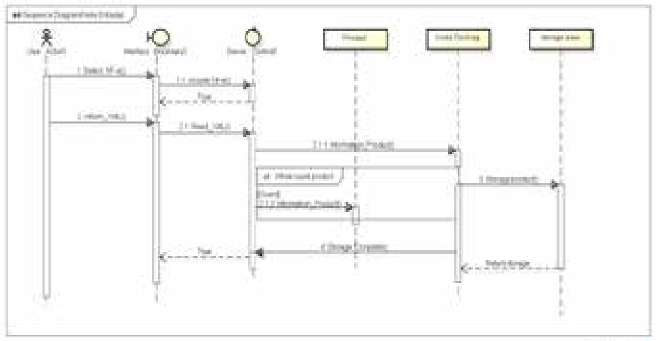

Fig. 1. Sequence Diagram – Cross Docking

Fig 1. Sequence Diagram (NFE)

- Selection of input info, performing a XML capture and generating a merchandise receipt recording.
  - Input validation by adjusting the non-compliance of products and new recordings for handling storage and expedition rules.
- Reporting XML for reading information on products and the supplier of products, addressing the particularities according to the vendor.
  - Reading XML for capturing product information and perform addressing intelligence according to the specific product.
  - Capturing product information and defining what address that these products should be stored.
  - Capturing products information and addressing manually, according to the expedition priority level and the strategic position in the stock.
- Product storage batch of the available address generation and according to the particulars of the product previously treated
- Storage completed, completion of the addressing service, generating products position map according to the input NF-held previously. Enabling product for booking order and expedition.

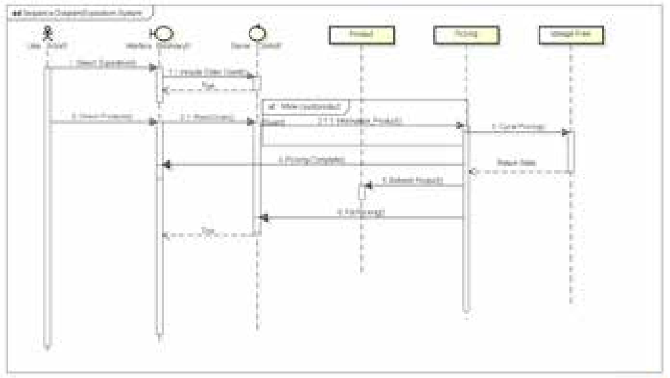

Fig. 1. Sequence Diagram – Picking

Fig 2. Sequence diagram (Expedition)

- Selecting expedition mode: capture customer orders and form a load or an expedition batch based on orders and the rules of validation of requests.
  - Input of requests of order: Orders input according to the order placed or order changes as per customers request, respecting stock previously held and stocks reservation
- Checking of products: Checking product inventory as per order requests and inventory compliance, and product reservations.
  - Reading order of products to generate an expedition batch service to match the required order.
  - Information products generating a service order and address availability in stock.
- Cycle of expedition: Cycle of flows of Inventory expedition, to suit the request according to the amount and volume requested. Return State: If the cycle or some plot-related service generates any non-compliance, it will occur a register of non-compliance according to the identified problem, in order to better control events.
- Upgrading product: Making of a procedure to use the amount set aside previously, and update address information and the stock of the product.
- Full Movement: Generated when the entire amount of requests are matched. Should be treated in a coefficient form and registering all movements after expedition.

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