PROGRAM

IEEE Brasil RFID 2014

Centro de Convenções - Espaço APAS

Sao Paulo - SP - Brazil
September 25, 2014

IEEE

RFID
IEEE Technical Committee on RFID

IEEE
Education Society
Chapter South Brazil - São Paulo

PATRONS

This is the first edition of this technical oriented Conference, designed to provide an excellent opportunity for researchers and engineers to communicate their advancement on RFID technology and its numerous applications.

IEEE BRASIL RFID 2014 will contribute to strengthen collaboration and partnership between research labs, public institutions and industry. This event is organized by the IEEE Education Society Chapter Campinas, linked to the IEEE South Brazil Section, and counts with the technical support of the IEEE Technical Committee on RFID (CRFID); and the patron support of Hewlett-Packard Brasil; CEITEC; and FIT - Institute of Technology.

IEEE BRASIL RFID 2014 is co-located with RFID JOURNAL LIVE! BRASIL, the industry's largest and most comprehensive conference and exhibition on RFID technology in Brazil.

For this first edition we received 28 submitted papers, 22 were accepted and 6 were rejected, it makes a rejection rate of more than 20%. Therefore, in this one-day event we will have 3 keynote presentations, 16 contributed talks and 6 posters, covering a variety of topics such as: Antenna Theory and Design, Chipless tags, Security and Privacy, Protocols and Software, IoT – Internet of Things, and several interesting applications.

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 2014!!

Hugo E. Hernandez-Figueroa
General Chair

Conference Organizing Committee

Hugo E. Hernandez-Figueroa, UNICAMP
General Chair

Renata Rampim de Freitas Dias, UNICAMP – RFID CoE
Technical Program Chair

Marli de Freitas Gomes Hernandez, UNICAMP
Finance Chair

Eduardo José Sartori, UNISAL
Publications Chair

Suely De Pieri Baladei, RFID CoE
Local Arrangements Chair

Reviewers

Hugo Enrique Hernandez-Figueroa, UNICAMP

Renata Rampim de Freitas Dias, UNICAMP – RFID CoE

Eduardo José Sartori, UNISAL

Lucas Heitzmann Gabrielli, UNICAMP

Luciano Prado de Oliveira, UNICAMP

Carlos Henrique da Silva Santos, IFSP – Itapetininga

Gilliard Nardel Malheiros Silveira, UNICAMP

Adriano da Silva Ferreira, UNICAMP
IT Support

Development of all-organic Antenna printed for passive UHF RFID application

Pedro Rebello
RFID CoE (Center of Excellence)
Flextronics Institute of Technology - FIT
Sorocaba - Brazil
pedro.rebello@fit-tecnologia.org.br

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

Vinicius Ferro
RFID CoE (Center of Excellence)
Flextronics Institute of Technology - FIT
Sorocaba - Brazil
vinicius.ferro@fit-tecnologia.org.br

***Abstract* - The purpose of this paper is to present a flexible conductive polymer antenna for passive UHF RFID using the inkjet printing technology. This all-organic antenna was used to assembly a RFID tag using the Alien Technology IC for UHF application in a strap package. Simulations were performed using the simulation software CST and their results were compared with the measurements, which were performed using an UHF TEM Cell and an UHF RFID reader. This article shows that the all-organic antenna can be functional and can be read by a UHF RFID Reader available on the market. These conductive polymer antennas are compared to antennas with the same design manufactured using a FR-4 and Copper.**

Keywords-component; Conductive Polymer, Inkjet Printing, radio frequency identification (RFID), ultrahigh frequency (UHF).

I. INTRODUCTION

RADIO FREQUENCY identification technology – RFID is an identification technology through radio signal using antennas and Tags to read and write information inside[1]. Currently this technology has been applied in the supply chain of high value among and many other uses and is presented as a possible alternative to substitute the process of barcode identification. However, one of the main obstacles to the adoption of this technology is the label's manufacturing (about tens of cents of dollars) [2]. This has been important for enterprises to prefer the barcode for items of low value. However, such a scenario is beginning to change with the emergence of a new branch of organic electronic. Among the characteristics of organic electronics is the structural flexibility of its molecules together in process of ink will allow that RFID tags could be printed directly on product packaging [3]. The low costs of materials and processes has potential for the label cost reduction (around units cents of dollars), making it even more interesting to item identification. Organic electronic coupled with RFID has great potential to replace the barcode in the future

II. RFID TAG ANTENNA

The antenna uses a T-Match configuration to achieve desired impedance for match with the IC (Integrated Circuit) in the desired frequency. For this application we used the Alien Technology IC for UHF application in a strap package.

The Figure 1 and 2 shows the antennas, where the antenna made of Kapton and Conductive Polymer has a dimension of 119x17 mm and a thickness of 0.020 mm the antenna made of FR-4 and Copper presents 113x17 mm and thickness of 0.035 mm.

Fig. 1. RFID Tag Antenna made of Kapton and Polymer.

Fig. 2. RFID Tag Antenna made of FR-4 and Copper.

This antenna designing for RFID tag had the main requirement to operate in. CST software helps to develop this antenna where it's composed of a conductive polymer that presents a conductivity of 50000 S/m and was built on a surface of polyimide film (Kapton) with relative permittivity 3.5 and loss tangent 0.02.

III. MANUFACTURING PROCEDURE

Inkjet printing is a technique could controllably depositing picoliter of ink on flexible substrates such as plastic and paper, directly, without physical contact, no wasted materials, and does not require the use of vacuum and high temperature. Currently many studies of manufacturing of RFID antennas trough of inkjet printing with Silver nanoparticle ink [4]. However, there are few studies antenna conductive polymer [5] and there are no reports in the global literature showing functionally passive UHF RFID tags with organic antennas. For printing was used a solution of copolymer PEDOT:PSS, the PH1000 of Clevios inc.. The solution was changed to obtain the ideal characteristics of an ink for inkjet printing, such as viscosity and surface tension. A significant increase in electrical conductivity of the printed film was necessary for the antenna to be functional. To do this it was added a doping [6] agent like an ethylene glycol or an organosulfur compound and proper heating treatment. We have got a significant increase in the conductivity of the material.

IV .RESULTS

A. Tag measurement

To performing the tests, it was used an UHF TEM Cell, which is a controlled propagation environment, where inside it, the mode of propagation is Transversal Electromagnetic (TEM). The Figure 5 shows how the tests using the RFID tags were realized.

Fig. 5**.** UHF TEM Cell used for measurements.

B. Measurement of Read Range based on the data acquired from tests performed at UHF TEM cell

For quantify the performance of the tag, the maximum read distance is the good manner for this. Considering the results obtained from the UHF TEM Cell, in which considering the minimum power of the Reader to turn on the tag and according to equation (1), given in [7-8], this is possible to determine the read range (in meters) of the tag.

$$r = h \cdot \sqrt{\frac{30 \cdot EIRP}{P_{min} \cdot L \cdot Z}} \quad (1)$$

Where, h is the inside length of the UHF TEM Cell, measured from the back to the front, $P_{\min}$ is the minimum power that the reader needs to use to active the tag, L is the loss of cables used and Z is the input impedance. The EIRP (Effective Isotropic Radiated Power).

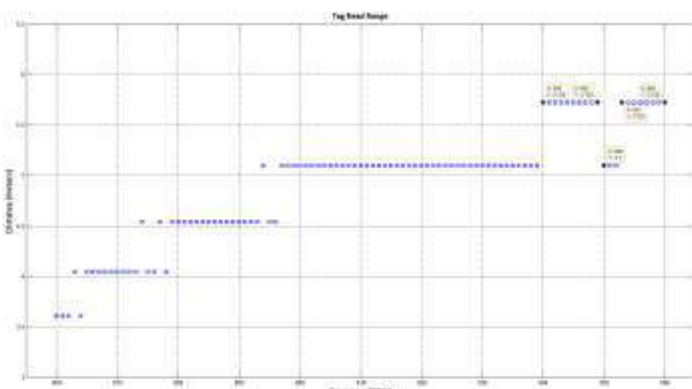


Fig. 6**.** Read Range of the Tag antenna made of Kapton and Conductive Polymer, considering *EIRP = 4W*.

As shown in the Figure 6, we can note that the Maximum read distance of the RFID Tag made of Kapton and Conductive Polymer presents:

r = 5,72 meters @ 940 MHz to 949 MHz and 953 MHz to

960 Mhz (totaling 16 MHz).

The Figure 7 shows of the reading distances of the tag made of FR-4 and Copper, considering EIRP = 4 W.

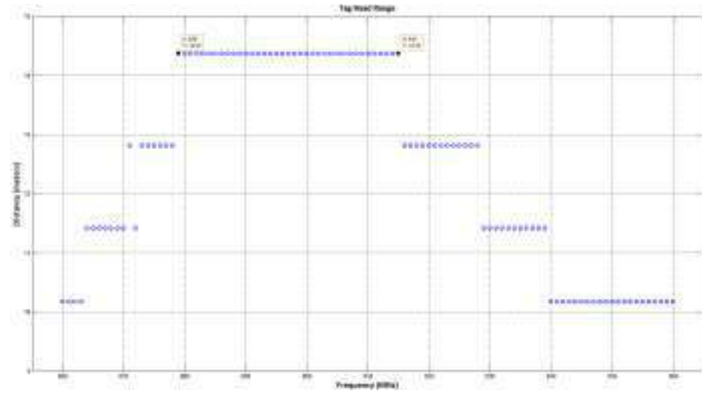


Fig.7**.** Read Range of the Tag antenna made of FR-4 and Copper, considering *EIRP = 4W.*

Analyzing the Figure 7 can be noted that the Maximum read distance of the RFID Tag made of FR4 and Cooper presents:

r = 14.37 meters @ 879 MHz to 915 MHz (totaling 36 MHz)

IV. CONCLUSIONS

In this paper, we introduced an innovative all-organic antennas for passive UHF RFID. These antennas are intended to be flexible and can conform to non-planar surfaces and also capable of being manufactured at a very low cost, making them perfect candidates to substitute metallic antennas where they are not viable. To comparison was also made one antenna copper on FR4 substrate, which there results from the simulation and measurements were similar. However, because of the need to print multiple layers of organic functional antenna is the lack of homogeneity could be the reason for differences between the results measured and simulated for the antenna efficiency subsequently impacting your gain, it may have directly affected the conductivity of the material. However the show is totally organic functional antennas with a chip UHF passive RFID.

REFERENCES

[1] K.. Finkenzeller, RFID Handbook: Radio-Frequency Identification Fundamentals and Application, 3nd ed: Wiley, 2004.

[2] A. Ustundag, The Value of RFID: Benefits vs. Costs, 2012, 182 p.

[3] H. Park, H. Kang, G. Cho, Fully roll-to-roll gravure printed rectenna on plastic foils for wireless power transmission at 13.56 MHz, *IOP Publishing*, no. 23, 2012, 6 p.

[4] A.L. Dearden, P.J. Smith, D.Y. Shin, N. Reis, B. Derby, and P. O'Brien. A Low Curing Temperature Silver Ink for Use in Ink-Jet Printing and Subsequent Production of Conductive Tracks. Macromolecular Rapid Communications, 26(4):315-318, 2005.

[5] [7] N. J. Kirsch, N. A. Vacirca, E. E. Plowman, K. R. Dandekar, A. K. Fontecchio, and T. P. Kurzweg, "Optically Transparent Conductive Polymer RFID Meandering Dipole Antenna," in Proc. of IEEE International Conference on RFID, April, 2009.

[6] Meng, H.; Perepichka, D. F.; Wudl, F., Facile Solid-State Synthesis of Highly Conducting Poly(ethylenedioxythiophene). Angew. Chem. Int. Ed. 2003, 42, 658-661.

[7] P. V. Nikitin et.al., "Sensitivity and Impedance Measurements of UHF RFID Chips", *IEEE Trans. MIT*, May 2009, pp 1297-1302.

[8] K. V. S. Rao et.al., "Antenna Design for UHF RFID Tags: a Review and a Practical Application", *IEEE Trans. On AP*, no.12, Dec. 2005, pp. 3870-3876.

Outlining Low Costs and Open Embedded Systems for RFID in Internet of Things Applications

Flavio Mania, Carlos Henrique da Silva Santos
São Paulo Federal Institute of Education, Science and Technology (IFSP), campus Itapetininga
Itapetininga, Brasil
{flavio.mania, carlos.santos}@ifsp.edu.br

Alexandre Alvaro
Federal University of São Carlos, campus Sorocaba
Computer Science Department
Sorocaba, Brasil
alvaro@ufscar.br

***Abstract*—This work aims to outline the use of low costs and open embedded systems in RFID based approaches designed to some Internet of Things (IoT) applications.**

***Keywords*—RFID; Internet of Things (Iot); Embedded System; Low costs.**

I. Introduction

The Internet of Things (IoT) might be defined as the identification of our daily objects, sensors or industrial devices interconnected to ubiquitously distribute their data in a global computer network, by some streamline technique to multicast informations about something or someone associated to a specific tag, which is usually integrated with any Radio Frequency Identification (RFID) based technology [1],[2]. From this perspective, there are a large number of efforts around the world to provide more security and cheaper solutions, such already reported in the literature [3],[4]. This work presents a brief introduction about open embedded system applications, focusing on Arduino toolkits, to enable low costs RFID device design to be applied in IoT area.

II. IoT and RFID Low Costs Based Device Design

Despite the RFID technologies costs have decreased and widely spread, the technology complexity and intellectual property have limited the design of new hardware approaches by the new startups. Furthermore, the business in this area is also limited by the recruitment of specialized work-power, the financial costs inherit to these hardware inspired projects and the not quick industrial acquisition of the RFID technologies [5],[6].

However, the RFID and IoT integrations in Smart Cities, since traffic control until e-health systems have provided large scale and ubiquitous data interconnections to change information's between of them. It have motivated new business and R&D opportunities, supported by a close data collection cycle performed by some big data analytics applications, considering the raw data, information and knowledge [5]. Therefore, RFID is considered a global and one of the most priority technology necessary to improve a wide number of telecommunications and computers applications for IoT.

In Taiwan the IoT with RFID based technology platform by the fast SARS virus propagation, the governmental authorities anticipated the patients RFID based identification in hospital environments where some sensors were installed [7]. The IoT and RFID in heath control is also presented in [8], where a low cost prototype with a micro-controller based Arduino is presented to manage daily medicine time application and posology.

The Arduino toolkits, such as Raspberry and other low costs and open micro or electronic controller acquirement have widely been explored to decrease the prototype financial costs and hardware design [9]. In addition, the Arduino integration with Zigbee devices is simple and allows the wireless communication of these devices, such as presented i**n** [9] to automatize a house and communication their objects, being hardware level solution with low cost for the hardware layer in IoT. Zigbee is a wireless sensor network standard and widely explored for the low costs and plug-and-play approaches [10].

The Arduino and Zigbee has widely been explored in RFID based technologies for IoT, in Health [7], smart home [9] and other applications, such as in a prototype to control railways lines to prevent fatal accidents [11]. In this way, another open and low cost embedded controller is the Raspberry Pi commonly used as alternative in IoT applications with RFID based technologies [12].

Based on the Smart City concepts, a well know application is the relation between traffic control and people mobility, detaching accessibility technologies integrated with any mobile device to guide people with disabilities to interact with this smart environment [13]. On the other hand, it also contribute to provide a monitored security system, monitoring people and contributing to prevent some irregular actions [14].

From the vehicular perspective and RFID active devices informations for IoT with some embedded devices technologies, is the crash monitoring and prevention systems motivated by the constant increase number of vehicles in the metropoles and in theirs surroundings also interchanging data with some approaches to detect the drivers' health, where fatigue detector and front assist have usually been integrated to communicate with sensors in the automatized ways, in order to prevent some fatal accidents [15].

In rural environment there are products and new prototypes using these technologies to track animals, being used to localized lost ones or to just identify their location. From this successful applications, these system have been adapted for urban environments to monitor domestic animals equipped with any RFID technology that can easily detectable by any sensor network to return this pet location. This technology is acceptable by the low costs promoted by the integration of Arduino with a GPS and GSM shield to send messages with their location with more precision [16].

From this variety of business and applications, is possible to emphasize that the use of new technologies Internet of Things applications using RFID technologies can leverage the demand for new services, providing the possibility to create new demands that could be suppressed by an unimaginable number of startups. Since developing a custom RFID network based on Arduino to exchange data like collecting data from agriculture, control books network in a library, control river flow during the whole extension of the river until simple student presence control in a classroom are possible IoT-RFID applications. An example is Libelium[1], a company that has a set of IoT hardwares to deploy applications using sensors. In this context, it can enable the development of new services and products for these demand that can arise with the availability of a network deployed with low-cost sensors and some embedded open and low cost devices, such as the Arduino and its shields. These solutions provides acceptable scalable solutions that tends to provide new business opportunities [17].

In Brazil, the RFID market appears as an interesting national possibility to be an international player. It is motivated by the China hardware design procedures and foreign demands. However, the national logistic and the insertion of new RFID products is lower than the market necessity, which cannot be attribute to the governmental aspects, because it has offered financial support for innovative ideas and contributing with Brazilian entrepreneur [18]. Therefore, investments in RFID applications is interesting to be explored by companies and research institutions to provide novel technologies.

Furthermore, a wide range of applications of passive RFID tags have been integrated to provide more agility and people mobility in Brazil, as described in some news from RFID Journal Brazil [19], pointing out applications in vehicular portal, public transport cards to promote multiple access and soft control, personal identification in scholar or social environments or events. These are example of RFID passive technologies already in use in Brazil and could also integrated in some smart systems or IoT applications.

III. Conclusions

This work present a short and brief description about RFID devices based on Arduino Toolkits to provide low cost approaches for IoT for a variety number of applications around world, emphasizing the important integration between RFID and Arduino to design new prototypes and business in IoT, focusing in Smart Cities solutions. This convergence contributes to demonstrate the widespread number of research, new devices and recent demands described in the literature and required by business market, being an interesting way to attract investment to generate new business in Brazil. From the perspectives here presented, this work team group is designing a novel unmanned vehicle to detect active and passive RFID tags to publish in cloud computing.

[1]http://www.libelium.com/

Acknowldgements

The authors wish to thank the FAPESP for the partial financial support and Fitech (IFSP, campus Itapetininga) and Leris (UFSCar, campus Sorocaba) labs for the technical discussions.

References

[1] Welbourne, E., Battle, L., Cole, G., Gould, K., Rector, K., Raymer, S., ... & Borriello, G. (2009). Building the internet of things using RFID: the RFID ecosystem experience. Internet Computing, IEEE,13(3), 48-55.

[2] da Silva, L. G., S. Arismar Cerqueira, and C. H. da Silva-Santos. "Tri-band RF filters optimization using evolutionary strategy." *Microwave & Optoelectronics Conference (IMOC), 2013 SBMO/IEEE MTT-S International*. IEEE, 2013.

[3] Weis, S. A., Sarma, S. E., Rivest, R. L., & Engels, D. W. (2004). Security and privacy aspects of low-cost radio frequency identification systems. InSecurity in pervasive computing (pp. 201-212). Springer.

[4] Lee, S. M., Hwang, Y. J., Lee, D. H., & Lim, J. I. (2005). Efficient authentication for low-cost RFID systems. In Computational Science and Its Applications–ICCSA 2005 (pp. 619-627). Springer.

[5] Dohler, M., Ratti, C., Paraszczak, J., & Falconer, G. (2013). Smart Cities. IEEE Communications Magazine, 70-71.

[6] Wu, N. C., Nystrom, M. A., Lin, T. R., & Yu, H. C. (2006). Challenges to global RFID adoption. Technovation, 26(12), 1317-1323.

[7] Chen, Chia-Chen, and Ya-Fen Chang. "Smart Healthcare Environment: Design with RFID Technology and Performance Evaluation 2." *Performance Evaluation* 2 (2012): 3.

[8] McCall, Corey, et al. "RMAIS: RFID-based medication adherence intelligence System.", *Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE*. 2010.

[9] Hribernik, Karl A., et al. "Co-creating the Internet of Things—First experiences in the participatory design of Intelligent Products with Arduino." *Concurrent Enterprising (ICE), 17th International Conference on* IEEE, 2011.

[10] Tung, H., et al. "The Generic Design of a High Traffic Advance Metering Infrastructure Using ZigBee." (2014): 1-1.

[11] Bansal, Anand, et al. "RFID ZIGBEE Based Interplatform Train Tracking System." *India Educators' Conference (TIIEC), 2013 Texas Instruments*. IEEE, 2013.

[12] Cristian, Toma, Cristian Ciurea, and Ion Ivan. "Approaches on Internet of Things Solutions." *Journal of Mobile, Embedded and Distributed Systems* 5.3 (2013): 124-129.

[13] Nirbhavane, Megha, and Shashi Prabha. "Accident Monitoring System using Wireless Application." *safety* 3.4 (2014).

[14] El Amine, C. M., and O. Mohamed. "A localization and an identification system of personnel in areas at risk using a wireless sensor network." *Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2013 International Conference on*. IEEE, 2013.

[15] Hancke, Gerhard P., and Gerhard P. Hancke Jr. "The role of advanced sensing in smart cities." *Sensors* 13.1 (2012): 393-425.

[16] Ko, Chien-Ho. "RFID 3D location sensing algorithms." *Automation in Construction* 19.5 (2010): 588-595.

[17] Zaina, Luciana AM, and Alexandre Alvaro. "O Ensino de IHC Potencializando Ideias Empreendedoras.". *WEIHC*. 2013.

[18] Thober, Dario Sassi. "O Brasil pode ser o maior fornecedor mundial de tecnologia RFID". *V Workshop GESITI,* Campinas, 2007.

[19] RFID Journal Brasil. Availability: http://brasil.rfidjournal.com accessed on 08/31/2014.

RFID Solutions and Applications at Eldorado Research Institute

Fernando I. de L. Leite, Flávia C. da Costa and Ricardo T. Yoshioka
Design House Department
Eldorado Research Institute
Campinas – SP, Brazil
fernando.leite@eldorado.org.br

***Abstract* – This paper describes about RFID project development by Eldorado Research Institute. We have been working in many different RFID solutions and applications, such as, RFID chip development, tag/reader antennas, directional couplers and smart shelf, mainly in ASIC projects, such as, the ultra low power RFID chip EPC global Class-1 Generation-2, in 180nm technology and CMOS standard. With this background, Eldorado offers infrastructure of labs, equipment and human resources qualification in integrated circuit, in order to promote the microelectronic technology in Brazil.**

Keywords— UHF RFID tag antenna, Antenna reader, RFID chip.

I. INTRODUCTION

Eldorado is a Brazilian reference in research, development and innovation in the areas of software, hardware, processes, tests of electronic products, besides professional training. The Institute counts with a costumer portfolio that concentrate leading national and multinational companies, with cases in several economic sectors, such as banking, educational, governmental, health, energy, manufacturing, telecommunications and others. In this way, Eldorado have worked in developing RFID technology related with RFID chip, tag and reader antenna, including implementation of complete RFID system. The RFID chip is a device that presents challenges in executing complex design projects requiring specific technical expertise. For example in the RFID architecture was necessary to develop ultra-low power consumption. All these work related with RFID area has developed many people building capacity and specialist in RFID solutions and applications.

The remainder of the paper is organized as follows. Section II presents the ultra low power RFID chip design. Section III shows the tag antenna design. Section IV presents the development of the antenna reader. In Section V we present and discuss about the RFID systems and finally, we present the conclusion.

II. ULTRA LOW POWER RFID CHIP DESIGN

Actually, Eldorado is developing its own chip for RFID passive tag, in the 900MHz band, compatible with the UHF standard, EPC global Class-1 Generation-2, in 180nm technology and CMOS standard.

The RFID chip development for this kind of device has many challenges mainly due this ultra-low power consumption, this aspect changes the current standard project flow, both for digital, analog and RF design.

For the digital project design aspects the main concerns are related with area, frequency of operation and the intrinsic leakage from digital standard cells. The standard RTL design and verification flow must be adapted to consider the dynamic power consumption. The management of NVM (Non Volatile Memory) responsible for all stored information is very important due power consumption, mainly in the write procedures. This characteristic required project effort to well manage the power consumption of Digital System.

In the Analog side, the features for rectifier with better efficiency were one of the most challenging aspects, the small power supplied by the reader mixed with signal information, keeps this tradeoff situation a critical design.

At current project, aspects to characterize it at laboratory have been very exhaustive, collection of data crossing the main important variations like distance, voltage, signal sensitivity and power.

The picture of Silicon RFID chip (180nm) is shown below in Fig. 1; a) Project view; b) Microscope Semiconductor view.

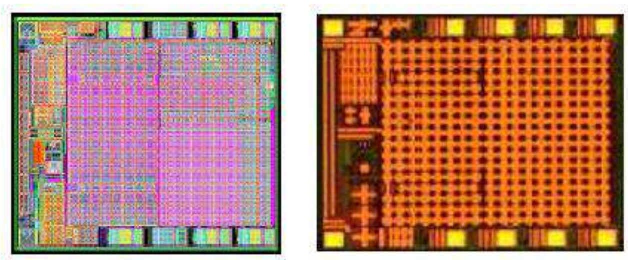


Fig. 1. a) RFID chip view; b) Microscope RFID chip view

III. RFID TAG ANTENNA DESIGN

Passive tags are designed with antennas optimized to extract maximum energy from the RFID reader signal while maintaining a communication link. The maximum efficiency is achieved by the perfect match between the antenna and the ASIC.

Eldorado group has been developing the RFID antennas that cover since UHF band (860-960 MHz) to microwave (2.45 GHz and 5.8GHz) [2].

The antenna design is showing dipole antenna to UHF RFID tag with a matching slot showed Fig. 2. The length and width of the T- matching part were changed to achieve the impedance matching. The T-matching is used to adjust the power transmission coefficient between the tag antenna and the chip. Simulations were carried out with CST Microwave Studio. A prototype was designed and tested to validate the simulations performed in this study. The target impedance of the prototype antenna is the conjugate of Z_a = 13.3 + j122 at 915 MHz. The antenna was fabricated using copper with thickness = 0.035mm on FR4 substrate, with the following specifications obtained from vendor datasheet: h=1.6mm, ε_r= 4.1, and tan δ = 0.002. The input impedance of the tag antenna for conjugate matching with the IC chip impedance is Z_a = 17.43 + j119.45Ω at the operation frequency of 915MHz with a S_{11} =-16.05dB. During the study, we observed that the antenna is sensitive to manufacturing process and the critic parameter to control is the real part of the antenna [1].

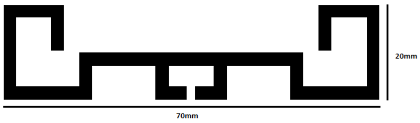


Fig. 2. Design of dipole antenna.

IV. Antenna Reader

A compact antenna for UHF band RFID reader was designed. The reader operating in the 915 MHz band is interesting due possibility of reading the tags for some meters. The RFID reader antenna was developed through computer simulations and used insulating material FR4 PCB of double layer of copper metal showed Fig. 3. The greatest difficulty in designing the antenna is related to narrow bandwidth. The experimental result of antenna designed showed that the value of return loss S_{11} =-39.05 dB. This antenna was used in the RFID system set of 915 MHz, which has shown a good response [2].

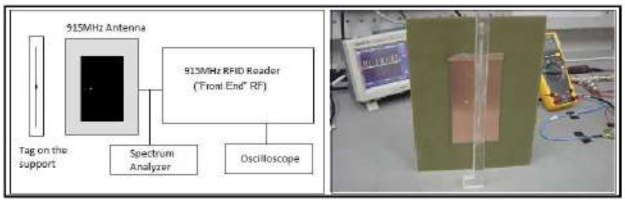


Fig.3. RFID Reader: a) RFID 915MHz System; b) 915MHz antenna Reader.

Eldorado developed in cooperation with Unicamp, directional couplers in the 915 MHz, 2.45 GHz and 5.8 GHz. The directional couplers are important devices in circuits of microwaves are used to obtain a part of the energy of the signal that are propagates. This sampling of energy serves mainly to monitor their behavior. The main parameters of the coupler were measured in the Network Analyzer and proved to be very promising and very close to the simulated.

V. Systems

RFID technology provides a lot of business that allow to identify individual products and components, and to track them throughout the supply chain from production to point-of-sale. Readers can range in size from a hand-held device to a 'portal' through which several tagged devices can be passed at once, for example on a pallet.

Eldorado has developed a RFID inventory system in the 915 MHz band based on EPC Global standard. For example, specific developed shelf can read identification of more than 400 samples with a reader. The tag information collected in the shelf can be sent remotely through the internet or wireless network (Wi-Fi or cellular carrier networks) to a central data control system or to another location. A photo of the RFID smart shelf is shown in Fig. 4.

Fig.4. RFID Smart Shelf

VI. Conclusions

Eldorado Research Institute is a technological solution provider in Semiconductor, Hardware and Software and has developed important ways for RFID technology such as RFID chip, tag/reader antenna, directional couplers and smart shelf. Therefore Eldorado may offer system solutions for all stages of RFID, since development consulting services, portals, chips and antenna design. Finally, Eldorado is an important Institute that contributes in this area developing hard skills and specialist to provide solutions to complex RFID systems.

References

[1] F.C. Costa, E.R.de Lima, R. T., Yoshioka, J.E. Bertuzzo and J.Koeppe “Impedance Measurement of Dipole Antenna for EPC Global Compliant RFID Tag”, Microwave & Optoelectronics Conference (IMOC), 2013 SBMO/IEEE MTT-S International , 4-7 Aug. 2013.

[2] G. N. M. Silveira, J.A. Moretti, H. E. H. Figueroa, R. T. Yoshioka, J. E. Bertuzzo and L. L. R. Bravo,“Exploring Dual-Band RFID Tag Antennas by Means of Asymmetric Dipoles”, Microwave & Optoelectronics Conference (IMOC), 2011 SBMO/IEEE MTT-S International, Oct. 29 Nov. 1 2011.

[3] J.A. Moretti; G. N. M. Silveira.; H. E. H. Figueroa, J. E. Bertuzzo, R. T., Yoshioka, “Pesquisa e desenvolvimento em RFID no Instituto Eldorado” Em: Fabiano Hessel; Reinaldo Villar; Renata Rampim; Suely Baladei. (Org.). Implementando RFID na cadeia de negócios: tecnologia a serviço da excelência. 1ed.Porto Alegre. : Edipucrs. 2009.v. 1, p. 295-300.

Methodology for choosing Piezoelectric devices

Using piezoelectric energy harvesting to feed massive use of RFID tags

Shieh, P.J.; Azana, N.T.; Santos, T.E.A.; Martins, A. V.; Dias, N. L.
DMI: Division of Information Display
CTI Renato Archer
Campinas, Brazil

Xavier Jr., A.L.
Automated Optical Inspection Division
Centro de Pesquisas Avançadas W.von Braun
Campinas, Brazil

***Abstract*— In the context of the Brasil-iD project, this paper proposes a methodology for choosing piezoelectric devices for energy harvesting RFID tags. The proposed methodology guides the search for important device parameters, starting with the capture of their electrical response. By manipulating data, explicit and implicit knowledge of important piezoelectric information was obtained. This methodology also considers the usage scenarios by collecting information about: vibration signatures, frequencies and amplitudes characterization, variety of vehicles types, roads pavement conditions, vehicle accelerations and speeds.**

***Keywords—piezoelectric; energy harvesting; RFID; windshield vibration*[1]**

I. BRASIL ID PROJECT

Brasil ID [1] is a recently created Brazilian initiative to tag a large amount of goods and products in circulation in Brazil, making extensive use of RFID technology. Large scale applications of RFID of this type also require a new model of service where customers can benefit from the potential use of the technology. Within this context, the massive association of RFID tags to vehicles in circulation has some challenges. Tolling application in the country already employ a variety of different RFID technology. As a consequence, Brasil ID base for vehicle tagging will very closely follow models already introduced by the tolling systems. The aim is to simplify and concentrate the tax process in an electronic document carried by the tag and represent a given tax collection transaction during a vehicle passage by a single number that is exchanged between tag and reader. On the other hand, RFID inspection of product and goods would be made by passive tags. However vehicle tags are largely dependent on batteries with a limited lifespan. Batteries provide the necessary tag sensitivity to guarantee a large reading zone and high reading probability regardless the vehicle speed. Energy Harvesting (EH) solutions are therefore viewed as promising ways to circumvent the problem of battery obsolescence in case of all vehicle in the Brazilian commercial vehicle fleet become associated to RFID transponders. Among EH techniques, piezoelectric devices extract useable electrical energy from mechanical vibrations [2]. To develop an EH system, to feed a RFID tag within the context of Brasil ID Project, the existence of a large number of providers of piezoelectric devices [3] complicates the choice of a suitable model, as the most technically and economically feasible.

II. PIEZOELECTRIC TEST SYSTEM

A special structure was designed and built to test piezoelectric devices as a way to ensure standardization of test conditions. Fig.1 shows the different modules that are responsible for generating vibration signals, checking mechanicals movement and measuring the response of piezoelectric devices.

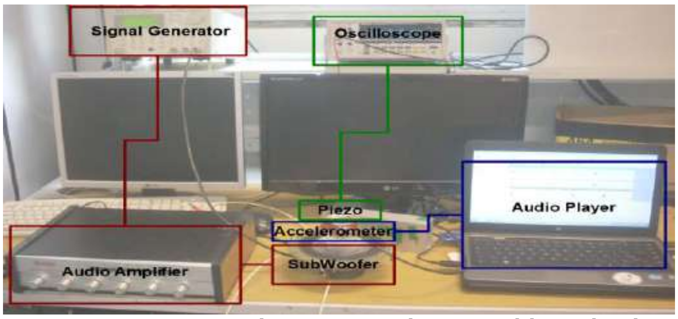


Fig. 1. Test System - signal generator supplies sinusoidal signals; player reproduces audio files; audio amplifier; mechanical vibration structure (commercial subwoofer - 6Ω/50W); accelerometer, to check the mechanical vibration; piezoelectric device and oscilloscope.

The Test System was verified and validated between 15Hz to 400Hz to check the frequency and amplitude of the mechanical signal.

III. WINDSHIELD VIBRATION CHARACTERIZATION

Considering that the RFID tag will be usually attached to the windshield, their vibration signatures need to be known. The windshield vibrations are composed of different frequencies and amplitudes that are mainly influenced by different factors: vehicle type, pavement surface, speed, acceleration, and others.

An accelerometer (Slam Stick VR001), with sample rate of 3200 Hz, was used to characterize the windshield vibration. The accelerometer was glued to the windshield of three types of vehicles: bus, truck and car. The measurement was conducted in different situations: stopped with motor on, in

We would like to thank CNPq and FINEP agencies (contract # 01.11.0011.00) for funding the project

the traffic city and on a road at different speeds. Overall, 70 samples were taken of windshield vibrations of one truck, two different busses and three models of cars. While the accelerometer provided measurements for the three axes (x, y and z), we read only the acceleration of the z axis, to reproduce them in the test system. For all z samples, a MatLab plot was made showing the evolution of the frequency and amplitude of acceleration during the test. 14 samples were chosen to represent different scenarios for windshield vibrations in vehicles.

As we can see in Fig.2, the vibration scenarios generated by the vibration profile can be used to standardize the test of different piezoelectric devices.

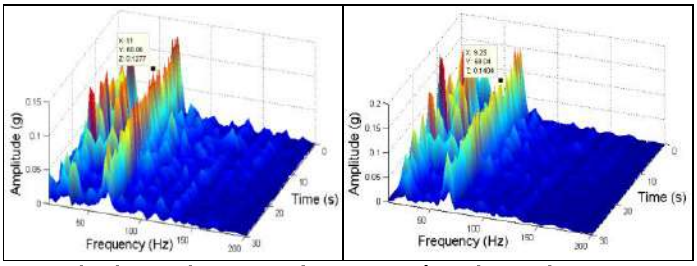


Fig. 2. The chosen vibration samples were transformed, via LabView, in wav format files. On the left, a sample of the windshield vibration for a truck at 80 Km/h. On the right, the corresponding plot generated by the Test System playing the wav file.

IV. PIEZOELECTRIC FLAT CHARACTERIZATION

Electrical power generated by piezoelectric materials depends on the vibration characteristics, piezoelectric material and dimensions, environment temperature, mounting configuration, etc. Each piezoelectric device has a natural frequency where the maximum response if offered.

The Piezoelectric Test System was used to characterize 16 piezoelectric devices divided in two groups of 10 polymers and 6 ceramics, mounted in the cantilever configuration. The tests determined the natural frequency of each device and estimated the power level they provide when subjected to a sinusoidal mechanical excitation. Each piezoelectric device was subjected to sinusoidal mechanical vibrations of frequencies ranging from 15 Hz to 300 Hz, since the main windshield vibrations have a frequency spectrum with relevant amplitudes up to 150 Hz.

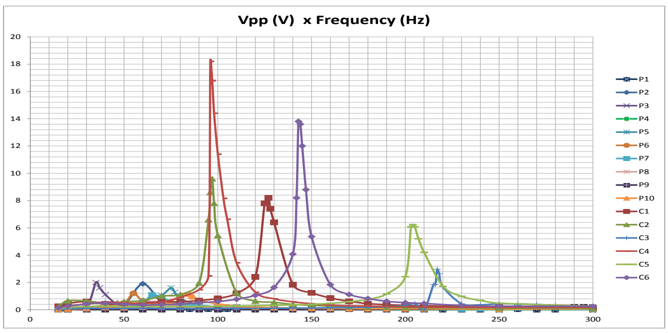


Fig. 3. Voltage generated by each piezoelectric device when stimulated by mechanical vibrations of different frequencies.

Fig. 3 shows that the tested ceramic devices can generate voltage several orders of magnitude larger than their polymers counterparts and the evaluated polymer piezoelectric device responses have natural frequencies well within the windshield vibration range, between 15 Hz and 100 Hz, while ceramic devices showed a poorer response.

The typical output of a piezoelectric device is an alternate current waveform in response to deflection in both directions. For EH applications, this output needs to be converted into a direct current, and the use of a bridge rectifier implied that P1, P4, P8 and P9 should be eliminated from the next step.

V. PIEZOELECTRIC SCENARIOS CHARACTERIZATION

To complement the piezoelectric characterization, 14 different windshield vibration scenarios were tested reproducing the vibration of real windshield vehicles, as a way to get more information for using them in real vehicle transport scenarios. Conceptually, the test would be made with the factual load, if well known. In this case, the measurement equipment (oscilloscope) acts as a load of 1MΩ.

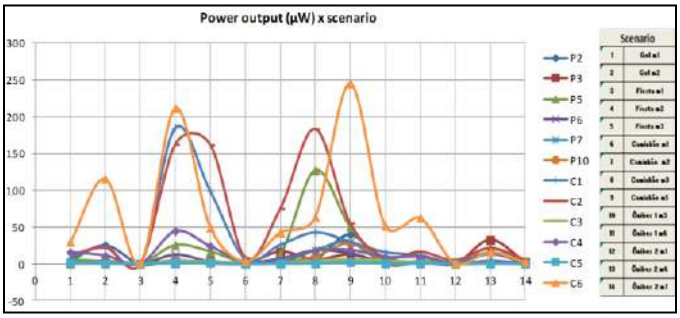


Fig. 4. Electric power provided by each piezoelectric when feed by mechanical vibrations of audio files reproducing the 14 scenarios of windshield vibrations.

For the majority of piezoelectric devices tested, the resulting output power were very small, but there were some types that provided a considerable level of electric power in some scenarios, being therefore recommended as promising EH systems.

VI. CONCLUSION

Considering the power requirement of a typical RFID chip used in the Brasil-ID Project, the most suitable devices are P2, P5, C1, C2, C4, C6 that will be analyzed deeply in the future.

The proposed methodology has been applied to the strategic evaluation of piezoelectric devices as source of energy harvesting for RFID transponders in the context of tagging commercial vehicles in the Brazil ID Project [1], exploring possible usage scenarios, especially those involving attaching tags to vehicle windshields.

REFERENCES

[1] BRASIL ID Project. http://www.brasil-id.org.br.

[2] Marzencki M., Ammar Y. and Basrour S. "Design, fabrication and characterization of a piezoelectric microgenerator including a power management circuit". Eda Publishing DTIP 2007.

[3] Harrop P., Das R. "IDTechEx Report: Energy Harvesting and Storage for Electronic Devices 2010-2020". IDTechEx. Ltda.

Approach to the development of RFID applications as a service using multi-tenant architecture

Bruno Dias Leite
DC, UFSCar
FIT
Soracaba,Brazil
bruno.leite@dc.ufscar.br

Tiago Pomponet do Carmo Santos
FIT
Sorocaba, Brazil
tiago.santos@fit-tecnologia.org.br

***Abstract* - Software as a Service SaaS is a distribution model in which the service providers can support many customers (tenants) in the same time using the same infrastructure of hardware and software. The tenants take advantage from low initial investment since there is no need to acquire hardware to run the software. RFID software is applicable in many scenarios and the high variability of business rules could make each application unique. This study presents an approach to the development of RFID applications as a service using multi-tenant architecture and techniques able to manage the variability of tenant's requirements in execution time. A viability study of this approach indicates that SaaS can be effective in the distribution of low cost RFID applications.**

Keywords – RFID, SaaS; Multi-Tenant;

I. INTRODUCTION

Software as a Service (SaaS) is a distribution model that focuses in low cost deployment and on demand support. SaaS allows small businesses to hire robust information systems with the payment of a monthly fee. The adoption of SaaS provides a series of advantages to the service consumers as such: reduction of deployment costs, quick maintenance and software evolution. From the perspective of the service provider, the reduction of operational costs favors the offer of SaaS to a bigger demand of consumers. Although the SaaS benefits justifies the increase of this market, many challenges of tenant's customization in high variability systems are yet to be solved.

One solution to reduce SaaS execution costs, as such energy and hardware, is to use the Multi-tenant (MT) architecture. This architecture was created to share SaaS instances by more than one tenant simultaneously. The sharing is possible through data partitioning mechanism that restricts information of a tenant to the other tenants. However, the MT architecture can be a challenge, since the tenant's functional and non-functional requirements may vary. To meet the greatest number of tenants with the MT architecture, it is necessary that SaaS is customizable according to each type of application [2] [3]. Customizations of SaaS can be related to user interfaces, data, processes and permissions [3] [4] [5] [6].

The following section presents the motivations for the use of SaaS in conjunction with RFID technology. In Section 3 are presented the main features of RFIDaaS application along with the techniques used for different types of customization. Section 4 describes a feasibility study conducted in the RFIDaaS manufacturing line from HP.

II. MOTIVATION

The majority of RFID applications have a higher cost of deployment and development when compared to traditional software. The high cost of investment in hardware (RFID readers, cabling, antennas and tags) associated with skilled labor, restricts the access to this technology by small and medium businesses. SaaS can be a model for the spread of RFID technology to those companies. However, the high variability of applications needs to be treated in a effective way to get all benefits from MT architecture. The main goal of this approach is to develop RFID applications as a service (RFIDaaS) able to support tenant's requirements using software techniques.

III. RFIDAAS

Products and assets identified by radio frequency must be associated with an Electronic Product Code (EPC). Along with the supply chain, produced and marketed items are moved between business units, eg, storage, receipt, storage, etc. The data obtained through RFID in every business step [7] can provide information about the location and status of items at a given time and space. The information extracted from these data allow the traceability of items.

The RFIDaaS was developed for the traceability of items in the supply chain, being responsible for performing RFID processes and to capture business operations made by the tenants. In the following, the types of customization available in RFIDaaS and the techniques applied are presented:

- **Data**: dynamic addition of extra fields associated with forms of business steps. Thus, fields can be defined by the tenant according to their needs.
- **Processes**: mechanism for dynamic creation of RFID processes. Thus, tenants are responsible for defining the processes used in the traceability of items, according to the business steps that they are composed.
- **User Interfaces**: parameterization of interface components such as buttons, colors and pictures of tenants. Components can be customized whenever a tenant wishes to change the visual identity of SaaS.
- **Permissions**: identification of the tenant who owns the record stored in the database. This technique ensures that the information referring to the tenant is not accessible to other tenants of the service.

IV. CONCLUSION

To evaluate this approach, usage scenarios for RFIDaaS were defined. Each scenario describes business rules for HP factories that deals with the production of cartridges, printers and desktops. The scenarios simulates the actual behavior of the tenants of the service in a packaging process. In this process the items identified by RFID should be associated with the container in which they will be packaged.

TABLE I. SCENARIO A - CUSTOMIZATION OF DATA TO THE PACKING PROCESS.

Form information	**Tenants**	
	Factory A	***Factory B***
Default	***X***	***X***
Pallet ID	***X***	
Part Number		***X***

Whereas the variability of the requirements of the HP factories: cartridges production (Factory A); printers production (Factory B) as observed in Table 1, the form information are distinct and should be treated individually. The extra fields technique was used to resolve the conflicts in requirements, so both factories are treated as tenants and Pallet ID and Part Number fields are considered extra fields of Factory A and Factory B, respectively.

TABLE II. SCENARIO B - CUSTOMIZATION OF PROCESS TO THE PACKING PROCESS.

Business rules	**Tenants**	
	Factory A	***Factory B***
Associate items to the container (default)	***X***	***X***
Allow packing for equal products	***X***	***X***
Allow packing for different products		***X***

Similar to scenario A, the factories considered in scenario B have different requirements. However, the variation of the requirements is related to the business rules that compose the packaging process. In this case, the treatment of variability was done through the creation of RFID processes. In The tenant identified by "Factory A", the business step "inspecting" was added to the process. Thus, this step became responsible for assessing whether the items aggregates in the container belong to the same product.

Other scenarios simulates the behavior of RFIDaaS for customization of interface and permissions. The analysis of the simulations showed the viability of this approach in the development of applications of RFID as service. The techniques used in the treatment of customizations attends the variability of the requirements of tenants, retaining the advantages of SaaS for distribution of low cost RFID software.

REFERENCES

[1] Taurion, Cezar Cloud computing : computação em nuvem : transformando oinformação / Cezar Taurion. — Rio de Janeiro : Brasport, 2009. mundo da tecnologia da Bibliografia. ISBN 978-85-7452-423-8 1 . Computação em nuvem 2.

[2] Zhang, K.; Zhang, X.; Sun, W.; Liang, H.; Huang Y.; Zeng L.; Liu X. A Policy-Driven approach for Software-as-Services customization. In E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services, 2007. CEC/EEE 2007. The 9th IEEE International Conference on, p. 123–130, IEEE Computer Society, 2007.

[3] Mietzner, R.; Metzger, A., Leymann, F.; Pohl, K. Variability modeling to support customization and deployment of multi-tenant-aware software as a service applications. In Proceedings of the Workshop on Principles of Engineering Service Oriented Systems (PESOS '09), p. 18–25, IEEE Computer Society, 2009.

[4] Kitano, T.; Iguchi, K.; Koyama, K. Generating Robust XPaths for Service Customization. 2010 6 th World Congress on Services, n. 1, p. 166-167, 2010.

[5] Ruehl, S. T., Andelfinger, U. Applying software product lines to create customizable software as a service application. In Proceedings of the 15th International Software Product Line Conference, vol. 2, p. 1–4. ACM, 2011.

[6] Zainuddin, E.; Gonzalez, P. Configurability, Maturity, and Value Co-creation in SaaS: An Exploratory Case Study. In: ICIS 2011 Proceedings, 2011.

[7] Core Business Vocabulary: GS1 Standard. GS1 Global, 2014. Versão 1.1, Maio 2014. Acesso em: 19/05/2014. Disponível em: <http://www.gs1.org/gsmp/kc/epcglobal/cbv/

The Dirac-Delta Functions for Signal Path-Loss Modeling at Mid-Sized Urban Areas

Huber Nieto-Chaupis
Universidad Nacional de Ingeniería - IIFIEE - Rímac - Lima
Universidad de Ciencias y Humanidades - Dirección de Investigación - Los Olivos - Lima

***Abstract*—A study of the impact of using the Dirac-Delta functions with polynomial argument for modeling the signal path-loss in mid-sized urban areas is presented. From the fundamental "spike" property of the Dirac-Delta functions, or simply Delta, the formulation of nonlinear input/output (I/O) integrals with unknown parameters applied to a scheme of urban zone containing buildings and delimited areas was empathized. The modeling assumes that the Delta function contains a polynomial argument and unknown parameters. The extracted parameters through Monte Carlo steps, would serve to measure the signal intensity degradation over the mid-sized urban areas. The obtained results are compared with the well-known models like Okumura-Hata thereby yielding a discrepancy of order of up to 5%, roughly.**

***Index Terms*—Dirac-Delta Functions, Path Loss Modeling**

I. Dirac-Delta Functions in a Nutshell

One of the most notable applications among the diverse properties of the well-known Dirac Delta function, or simply Delta function is that of the trivial convolution integral written as $f(t) = \int_{-\infty}^{\infty} f(\tau)\delta(t-\tau)d\tau$ where the Delta function argument depends linearly on $t - \tau$ [1]. An interesting extension of the Delta function considers a nonlinear argument which gives rise to the so-called 'spike' property,

$$\delta\left[f(\tau)\right] = \delta\left[\prod_{i=1}^{N}(\tau - a_i)\right] = \sum_{i=1}^{N} \frac{\delta(\tau - a_i)}{\frac{df(\tau)}{d\tau}\ |_{\tau=a_i}} \quad (1)$$

where $f(\tau) = (\tau - a_1)(\tau - a_2)...(\tau - a_{N-1})(\tau - a_N)$ is a continue function whose zeros are denoted by $a_1, a_2, ..., a_{N-1}, a_N$. For instance $f(t) = \int f(\tau)\delta(t^2 - \tau^2)d\tau \approx f(t)/2t$ that makes us to conclude preliminarily that the case where the integral consists of $\delta(t^m - \tau^n)$ the resulting convolution integration acquires the form $f(t)/t^{n-1}$, thereby demonstrating that the resulting integration depends on $1/t^{n-1}$. It is also possible express $f(\tau)$ as $f(t, \tau)$ thereby suggesting to rewrite (1) in a more general manner

$$\delta\left[f(t,\tau)\right] = \begin{cases} \delta\left[\prod_{i=1}^{M}(t - \tau - a_i)\right] & \text{uniform} \\ \delta\left[\prod_{j=1}^{N}(\gamma_j t - \rho_j \tau - a_j)\right] & \text{composed} \end{cases} \quad (2)$$

where has been coined the terminology 'uniform' and 'composed'. Clearly the first case obeys to a simple definition of the Delta function where the argument depends on the shift or delay given by the a_i parameter. The second case involves γ_j and ρ_j parameters which are adjudicated to the coefficients of the variables t and τ, respectively. It serves to propose a methodology of system identification, in the sense that these parameters might play the role as the system parameters. For instance, consider the I/O integration with Delta functions based on the composed case as given by Eq. 2, so that the I/O integral reads

$$I(t) = \int_{-\infty}^{\infty} \delta\left[\prod_{j=1}^{N}(\gamma_j t - \rho_j \tau - a_j)\right] \mathcal{N}(\tau - \alpha_{11})d\tau \quad (3)$$

where I the resulting intensity signal and N runs over the maximum value of grade of polynomial. For instance, we attempt to set a particular case when the system is order N=3. The set of parameters are presented for three different cases, $\alpha_{11} = 0$, $\gamma_1 = \gamma_2 = \gamma_3 = 1$, ρ_1=[6,0.2,6], ρ_2=[10,0.85,0.75], ρ_3=[0.7,0.6,0.5], a_1=[11,10.5,11], a_2=[13,12,t'], and a_3=[1.2,1,0.3], and the resulting in the curves plotted in Fig. 1 (a-c). For this end, $\mathcal{N}(\tau) \approx J_2^2(\tau)$ the square of second-order Bessel function. The apparition of successive dips can be interpreted as the degradation of signal amplitude by effect of path loss along

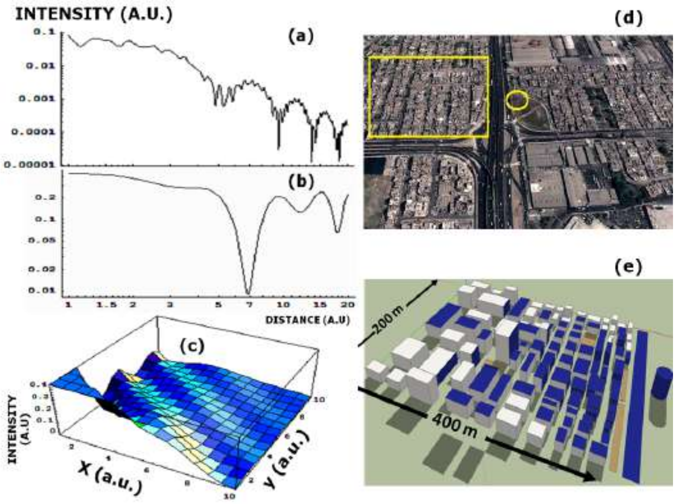


Fig. 1. Resulting spectra obtained with I/O Delta integrals: (a) Curve with dips in 8, 18 and 20 a.u. and reduction of intensity in up to 10^{-4}, (b) curve with only one dip at 7, and (c) 3D plot with gradual intensity degradation for $10{\times}10$ a.u.^{2}. (d) View of mid-sized area in Los Olivos, Lima, taken from Google-Earth. (e) Simulation of mid-sized zone and the most favorable areas of signal reception.

the wave emission direction [2]. This case can be interpreted as the presence of multiple obstacles which are associated to a large path loss and with high values of ρ_j parameters. In Fig. 1 (c) $t \to x$ and $t' \to y$ and the resulting 3D plot shows the degradation of signal along an area given by 10×10 a.u.^{2}. Clearly the independent variables are connected to distances.

II. Testing Dirac Model with Monte Carlo Simulation

The Dirac formalism is tested in a mid-sized urban area located in Los Olivos north part of Lima city. In Fig. 1 (d), aerial view of a mid-sized area with the zone under study (yellow rectangle) and a base station in the right side (yellow circle) are shown. The signal reception is simulated by keeping geometric features and terrain morphologies. It is done with the assistance of Google-SketchUp. The suburb under study contains rectangular dimensions of 400 m$\times$ 200 m. Indeed, the base station (cylindric form) is 50 m. in front. The urban simulation contemplates up to 103 blocks and heights ranging between 2.5 m and 25 m. For simulation base station length are ranging between 20 and 40 m. In addition, the signal strength received at end users is simulated through the Monte Carlo step. It is because the stochastic character of the spatial propagation inside the suburb that justifies the usage of this method. Consequently, for simulation criterion 80 Km^2 area is thus divided in 20×10 portions which does not necessarily fits with the blocks location. In this way, 200 blocks and their location are spatially defined, as well as individual strength signals are assigned to them, in according to the far-field antenna case. For this exercise is assumed that the base station gain is of order of -70 dB. Furthermore, nominal distance d_q is associated to the signal strength by means the relation I_q=$M/(d_q+\Delta d_q)^4$ with Δd_q the attained error and M normalization constant. One can note that this expression has the form of the resulting integration of a Delta convolution. With this in hands, up to 200 values of signal strength were generated. In order to operate the Monte Carlo step, a Gaussian probability distribution function g(d_q) =R exp(-$(d_q - \Delta d_q)^2/\Delta d_q^2$) with R normalization constant, is established. It implies that Δd_q absorbs the random character. In this way is asked if $I_q >$ g(d_q) which should guarantee the event acceptance. If it is true then $q \to q+1$ and I_{q+1} the nominal distance is saved and a new set of random numbers is generated. The obtained errors satisfy the relation $\bar{d} < \Delta d_q$, where $\bar{d}$ the statistical error. As consequence up to 15 possible scenarios have been selected because their highest probabilities. The average Base Station (BS) height turns out to have 26 m. The resulting scenario is depicted in Fig 1 (e). Now we transcribed this result into an integral containing a Delta function with a polynomial argument by which would resemble the full mechanism among the transmitter, communication medium and receiver:

$$P_L = \mathcal{A}\mathrm{Log}\left\{\int_{-\infty}^{\infty}\delta\left[\prod_{j=1}^{3}(\gamma_j t - \rho_j \tau - a_j)\right]\mathcal{N}(\tau)d\tau\right\} \quad (4)$$

TABLE I
Path-Loss (dB) of a 1.5 GHz signal, for Known Models and Dirac Delta Model

Run	Free Space	Okumura Hata	Hata	Cost-123	Dirac Delta Composed
3	90	103	110	105	104
15	91	102	115	109	106
37	91	111	111	110	108
44	91	110	117	107	103
58	90	104	109	106	98
60	91	116	110	111	99

where $\mathcal{A}$=45. It was assumed up to N=40 obstacles but 3 of them locate at 21, 55, and 137 m., have presented influence on the signal degradation. These values are correlated to the dips as shown in Fig. 1. (a). It might be an interesting advantage of model, since we can predict path-loss with algorithm of Eq. 4. The extracted parameters average values $\mathcal{Q}$=3, γ_1=20.9, γ_2=-2.3, γ_3=28.6, ρ_1=-3.2, ρ_2=35.1, ρ_3=20.1, a_1=-1.2, a_2=20.4, a_3=39, that constitutes a 9-parameters system. All of them enter in Eq. 4 for integral evaluation and logarithm operation. In order to compare it with known models in Table I are listed the quantitative differences among them for equal input values. According to the Monte Carlo simulation, base station height of 26 m. $\pm$ 1.5 m., is considered. The coverage distance is of 500$\pm$ 10 m. However, we assume that the nominal suburb length is near to 1 Km. Threshold values are inside the valid range of models [3]. It is interesting that the proposed model fits well the mean values of models as for example occurs in the run 37. In effect, here the height of 28 m, coverage distance of 0.5 Km, height receiver of 20 m, and received signal of -76 dB was obtained. For other runs, errors beyond 5% appears to be consistent with the known models [4]. It is exemplified in the run 37 whose differences with the Okumura-Hata model is of order 2.7%. It is because the receiver got up to -68 dB because the height antenna of 28 m. In addition, the Delta model appears to be congruent with well-used models, but a discrepancy of order of 5% in average is encountered.

References

[1] Hoskins R. F., Delta Funtions: Introduction to Generalized Functions 2nd Edition, Int. Specialized Book Service. Won Mee Jang, Quantifying Performance in Fading Channels Using the Sampling Property of a Delta Function, Communications Letters IEEE, Vol 15, pp.266-268 (2011).

[2] Erceg, V., et.al., An empirically based path loss model for wireless channels in suburban environments, Selected Areas in Communications, IEEE Journal on, Vol. 17, No 7, 1999. pp. 1205 - 1211. Morten Jacobsen, Msc thesis, Aalborg University Denmark, Modeling and Estimation of wireless multi-path channels, 2009.

[3] Sarkar, T.K., Ji, Z., Kim, K., Medouri, A., Salazar-Palma, M.: A Survey of Various Propagation Models for Mobile Communication. IEEE Antennas and Propagation Magazine 45(3), 5182 (2003). Yixi, X., Lavergnat, J., Mon, J.P.S., et al.: Microwave and Millimeter Wave Propagation. International Academic Publishers, New York (1995).

[4] Uchida, K., et.al., Interpolation of communication distance in urban and suburban areas, Antennas and Propagation (ISAP), 2013 Proceedings of the International Symposium on, Vol 2, 23-25 Oct. 2013, pp. 873 - 876. Ohira, T., et.al., A study of mobile path loss estimation models for a sloping terrain area in cellular systems, Communications (APCC), 2012 18th Asia-Pacific Conference on, 15-17 Oct. 2012, pp. 472 - 477.

RFID Tag Tests: Comparison Between GTEM cell and Anechoic Chamber Results

Alessandro Luz – RFID CoE, Flextronics Institute of technology – Brazil
Fabíola Costalonga – RFID CoE, Flextronics Institute of technology – Brazil
Email: alessandro.luz@fit-tecnologia.org.br; fabiola.costalonga@fit-tecnologia.org.br

Abstract – This article presents a comparison between UHF RFID Tag performance tests realized in two different RF environments. It will describe the methodology used in both tests, technical comparison between tests realized on TEM cell (Transversal Electromagnetic cell) and UHF Anechoic chamber and presents the tests results in order to compare these environments test for RFID Tag performances.

Keywords-component: RFID, GTEM cell, UHF Anechoic chamber.

I. Introduction

Radio frequency identification (RFID) is a technology that uses a code modulated by a RF signal to read and write products information in a memory inside of a microchip connected to a RF antenna (this set will be called TAG during this article). This information can be use to control products movement in an industry and track this product during life cycle wherever it is worldwide. Some parameters, as a maximum read range or frequency response are used to choose the right tag model for each application. As any commercial protocol communication, RFID devices must have a standard behavior, usually dictated by an expert committee in that subject. ISO, Class 0, Class 1, and Gen 2 are examples of standard references for RFID technology.

The practical tests of RFID, where standard parameters are measured, must be realized in a RF controlled environment to ensure that an external interference or a signal reflection will not cause any influence in the tests results. The EPCGlobal standard that regulates de tests conditions, recommend a Anechoic chamber to realize the tests. As the Anechoic chamber, TEM cell is developed to ensure a controlled environment conditions. Some differences between these environments tests can be highlighted like: the size, the frequency response, path loss and the test cost in order to identify Tag characteristics. The results will show how much representative is the influence of these differences in RFID tag performance tests. Use a GTEM cell for a no accredited test instead of Anechoic chamber can decrease a develop time and costs.

II. TEM/GTEM Tests

The GTEM cell (Gigahertz Transversal Electromagnetic) is a TEM waveguide with the upper frequency limit extended to the GHz range. GTEM cell has a pyramid format and is constructed whit a grounded metal plates connected a coaxial connector with 50 ohm characteristic impedance. The RF signal is introduced inside the chamber through this connector and the electromagnetic field is distributed around the equally inside the cell. The center conductor of the coaxial terminal is connected to a conductor plate that establishes another connection to a resistor matrix located in base of the cell. Without the center conductor this construction would be similar to a simple wave guide. A schematic example of GTEM cell is shown on Figure 1.

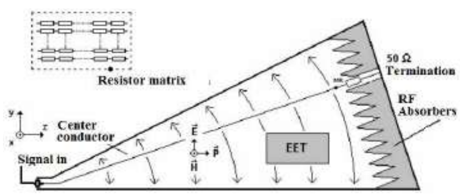


Figure 1 – Schematic GTEM

III. Anechoic Chamber

The objective of an anechoic chamber is simulating an open site area. Open site area is an ideal ambient for RF tests, which requires a big area free of RF interferences, it is not as practical as an anechoic chamber. Basically an anechoic chamber is constructed with shield material to attenuate the external interferences and covered inside with no reflective material, the RF absorbers. The operation frequency range and attenuation level depends on the material used in the chamber construction and absorber format.

Figure 2 – UHF Anechoic chamber for RFID test like Static test accredited by EPC global

IV. Method

The tests purpose is to find the minimum power tag turn on, it means that, the tests will start reading the tag with a maximum interrogator power and the transmitted signal power will be decrease until the Tag stop answer. The tests method defines the steps used to ensure the results confidence. Same tag, same reader and same measure equipments were used in the two cases to replicate the tests as close as possible. The mean difference is the objects under comparison, is important to mention that was used a linear antenna inside the anechoic chamber.

The test setup was based on de EPCGlobal Static Test method for applied tag performance testing Ver.1.9.5 . It doesn't mean that the test was compliance with the standard. Was used as a reference the conditions to evaluate the environment, the reader set, the method to measure and attenuate the transmitted signal and to calculate the power defined as a Pturn on.

All losses that could interfere in the results was measured and used as compensation. GTEM cell and Anechoic chamber was validated measuring the noise inside in the test frequency band. The reader was set to transmit in a fixed frequency and in the maximum power, three frequencies was tested 902.25MHz, 915.25MHz and 927.25MHz. A directional coupled is used to derivate a part of the transmit power in order to monitor the transmitted power with a spectrum analyzer. The transmit attenuator is used to decrease the power until achieve 50% of the read rate or less, the read command was sent 50 times for each step attenuation, that occur in steps of 1dB. The saved measure as a result is the transmitted power before the tag stop to answer or achieve less than 50% reading, plus measured losses minus transmitter antenna gain.

Figure 5 represent the GTEM setup test and Figure 6 the anechoic chamber setup test. In the anechoic chamber scenario the distance "D" was 1m and de distance "d" was the same of measured inside GTEM.

The tests were replicate in two different tags in an effort to validate the results. Was considered as Tag1 the a Avery Denison model and the other was called Tag2 a Brazilian project made by Valid, both in a UHF band.

Figure 3 – Tag 1

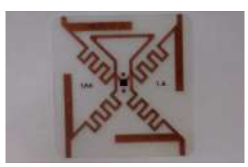


Figure 4 – Tag 1

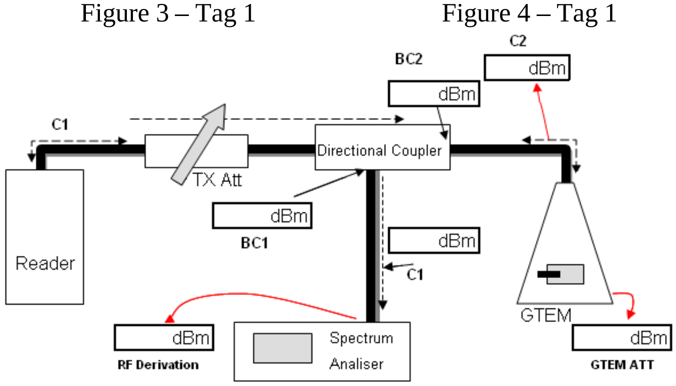


Figure 5 – The test scenario using GTEM

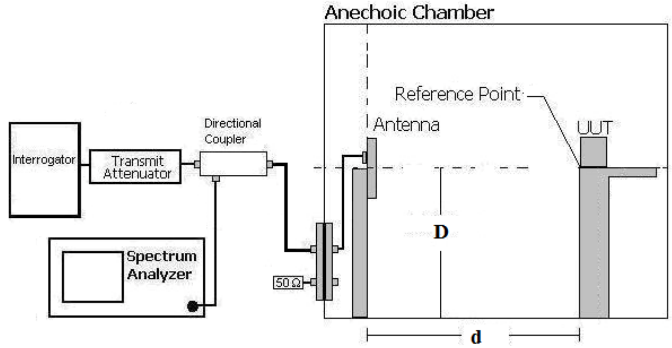


Figure 6 – The test scenario using Anechoic chamber

The tag under test was rotate 360º in steps of 45º in both tests. It was choose as the 0º the position where tag had better answer, the tag rotate counterclockwise until achieve 315º. Figure 7 show the tag position in 0º and the rotate direction inside the GTEM cell, Figure 8 show the rotate direction inside anechoic chamber, this position was faced to the antenna.

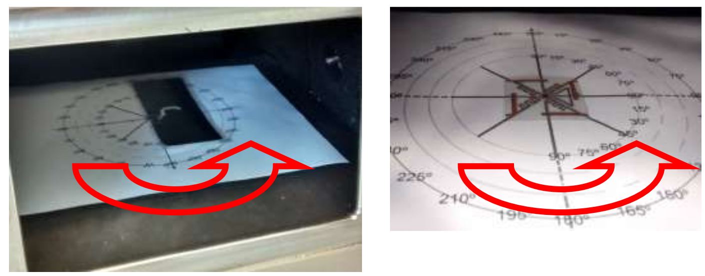


Figure 7 – Tag position=0º_GTEM test

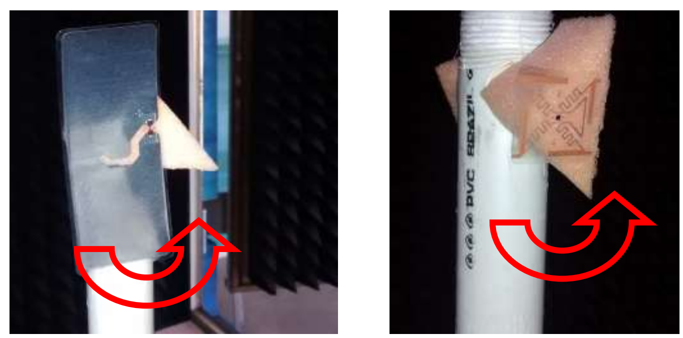


Figure 8 – Tag position=0º_Anechoic chamber test

V. Results

The test results on GTEM cell and anechoic chamber had a significant dispersion values in some angles, it mean that the minimum tag power turn-on had different results when it is rotated with respected to transmission antenna, although both environment tests had same trend.

However, it is important to mention that for the Angle 90º and 270º, the two environments test: GTEM and Anechoic had some similar results for sensitivity RF power, it is shown on Figure 9 and Figure 10, even if the tag 2 does not answer as good as tag 1, it happen in both tests.

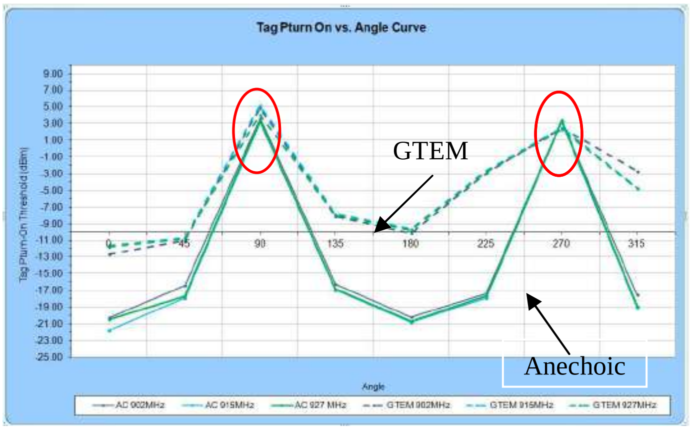


Figure 9 – Test result using Tag 1

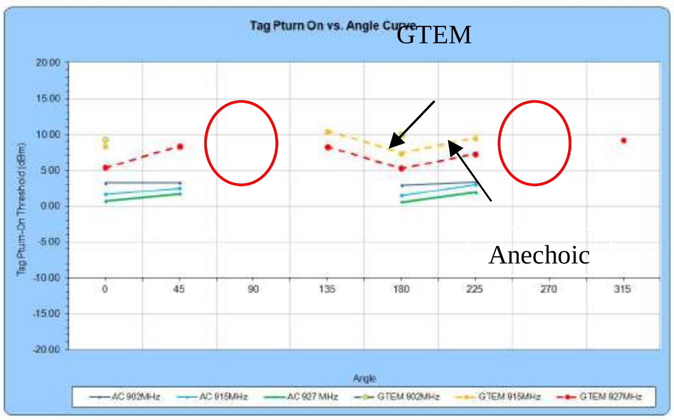


Figure 10 – Test result using Tag 2

VI. Conclusion

This paper, demonstrate that is possible to make a pre compliance RFID Tag validation. The comparison is relevant because the GTEM cell is a small size device, that generates a consistent Electromagnetic field for testing RFID tags and demands few space, less investment, fast setup configuration, and it is a very convenient for Antenna development and RFID Application use.

Even the results are not equal is possible to assume that there is a correlation, but GTEM cannot be used for a standardized test.

The Standard IEC 61000-4-20 define some tests and measurements techniques in transverse electromagnetic (TEM) waveguide for Emission and immunity testing, this standard reinforces that GTEM can be used as a option for Anechoic chamber , this paper is dedicated for RFID tests.

References:

[1] WEINZIERL, D. and RAIZER, The transmission line modeling method (TLM) applied to the simulation of TEM CELL and Shielded enclosures, Journal of microwaves and optoelectronics, 2006.

[2] WEINZIERL, D. e RAIZER, Study of electromagnetic compatibility (EMC0 test chambers using the transmission- line modeling method (TLM), Federal university of Santa Catarina doctor degree, 2004.

[3]Heuvelman, Wilmar and Janssen, Rick, FEM Modeling of Gigahertz TEM Cells for Susceptibility Analysis of RFID Products, European Microwave conference, 2012

[4] A GTEM BEST PRACTICE GUIDE – APPLYING IEC 61000-4-20 TO THE USE OF GTEM CELLS, A. Nothofer, M.J. Alexander, National Physical Laboratory, Teddington, UK, D. Bozec, D. Welsh, L. Dawson, L. McCormack, A.C. Marvin, University of York, Heslington, UK

[5] Research on the directivity test of RFID tag in GTEM cell - Ji Li ; Sch. of Inf. & Commun. Eng., Beijing Univ. of Posts & Telecommun., Beijing, China ; Shu-fang Li ; Zhong-liang Zuo ; Jian-xiong Li

[6] EPCglobal Static Test Method for applied tag performance testing Rev 1.9.5

[7] IEC 61000-4-20 ed2.0 Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides.

[8] Nikitin, Pavel, UHF RFID Tag characterization; overview and stat-of-the-art.

[9] K. V. Seshagiri Rao, Nikitin, Pavel, Member, and Sander F. Lam, Antenna Design for UHF RFID Tags: A Review and a Practical Application, IEEE transactions on antennas and propagation, vol. 53, no. 12, December 2005

[10] EPCGlobal Static Test method for applied tag performance testing Ver.1.9.5, 2008

Numerical Determination of Frequency Guard Band Resonances for Chipless RFID Tags

Gilberto T. Santos-Souza
School of Technology
University of Campinas - UNICAMP
Limeira – SP, Brazil
g081491@dac.unicamp.br

Leonardo L. Bravo-Roger, *Member, IEEE*
Telecommunication Division School of Technology
UNICAMP
Limeira – SP, Brazil
leobravo@ft.unicamp.br

***Abstract*—This paper presents a numerical study to show the frequency guard band effect in the design of spiral resonators coupled in 50Ω microstrip line for encoding Chipless RFID Tags in S-band. Simulations in the HFSS version 15 software were performed for this study.**

Keywords—Chipless RFID Tag, Resonator, Frequency Guard Band

I. INTRODUCTION

In the Chipless RFID Tags systems, the resonators are responsible for encoding data, where each resonator represents one bit. The function of these resonators are to create a low impedance path through 50Ω microstrip line, the resonator and the ground, when it works in its resonance frequency, creating a short-band effect in this frequency due to its internal resistance. The inductances [1] and capacitances [2] of the resonator are the parameters that define its resonance frequency by E.1:

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

Basically, these resonant frequencies are tuned by changing the resonator's length. The increase of the resonator's length will be also increase the inductance and capacitance, lowering the resonant frequency.

In the literature is possible to find several Chipless RFID Tags technologies [3-4], but none exist a study of frequency guard band for cascaded resonators. To avoid reading errors, each resonator should resonate or not in the frequency for which it is designed. For reasons of limited spectrum, it is desirable that the resonant frequencies of the resonators are close, this means larger number of bits in the same band. However, adjacent resonators can resonate in the same frequency resulting in read errors from the ID Tag. At S-band, typically each resonator occupies 20MHz of bandwidth, approximately. This article shows how to design a six bits Chipless RFID Tag in the substrate Taconic TLX-0 ($\varepsilon_r = 2{,}45$, $\delta = 0{,}0019$ e h = 0,787mm) with a frequency guard band that avoids interference in the resonances. This study can be also used for other binary classifications of Chipless RFID Tags in the S-band.

Department of Microwaves and Optics (DMO), School of Electrical and Computer Enginnering (FEEC), University of Campinas (UNICAMP).

II. DESIGN OF CHIPLESS RIFD TAG

Fig. 1 illustrates the parameters construction of the spiral resonator. The design of the Chipless RFID Tag is shown in Fig. 2, where L_1, L_2, L_3, L_4, L_5 and L_6 are the different lengths of the resonators to tune its resonance at different frequencies, respectively.

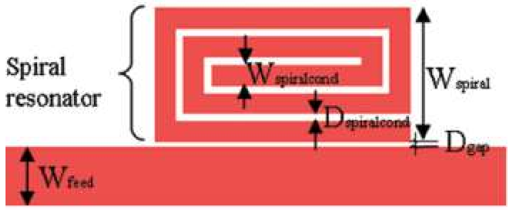


Fig. 1. Spiral resonator [3]: $D_{spiralcond} = 0.3mm$, $W_{spiralcond} = 0.8mm$, $W_{spiral} = 5.2mm$, $W_{feed} = 2.26mm$ and $D_{gap} = 2.26mm$.

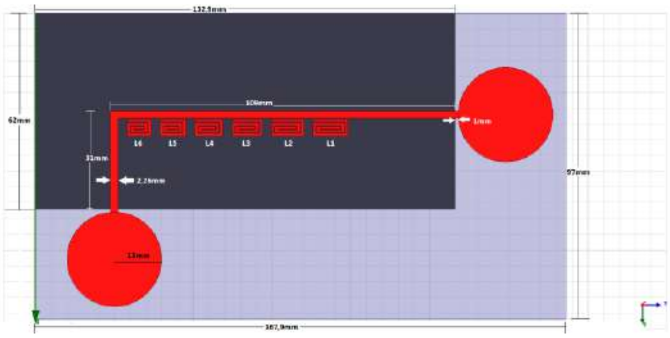


Fig. 2. HFSS model for six bits Chipless RFID Tag.

III. RESULTS

To simplify the analysis of the results, the Tag's antennas are removed from the simulation model and replaced by ports that feed the RF transmission line. Table I shows the resonators's lengths values in millimeters (mm) to two different designs.

TABLE I. LENGTH PARAMETERS OF THE RESONATORS IN MILIMETERS

PROJECTS	L1	L2	L3	L4	L5	L6
1	10,1	9,7	9,1	8,7	8,4	8,1
2	11	10,2	9,4	8,7	8	7,5

In Project 1, there are resonant frequencies very close to adjacent resonators. The Project 2 shows a case where the resonances are separated by frequency guard bands appropriates. The six resonances obtained in the Project 1 when multiresonator is excited with a frequencies sweep in S-band are shown in Fig. 3 Analyzing the second and third resonances (corresponding to the resonator length L_2 and L_3), observed a separation of only 78MHz between their central resonance frequencies. Fig. 4 shows the magnetic distribution field of the multiresonator when is energized only with the resonance frequency of the resonator length L_2 (2.076 GHz). Clearly observed that the resonator length L_3 also is resonating at this frequency and absorbing energy from the line, which could cause a reading error in the Tag code.

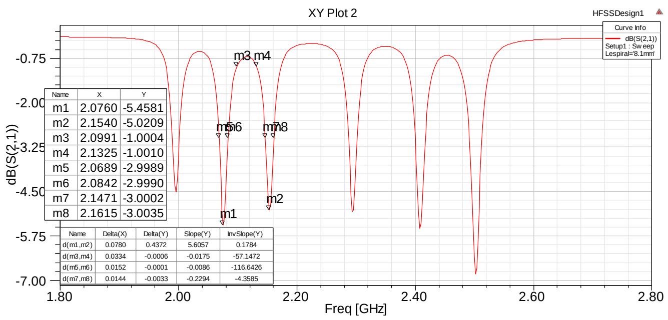


Fig. 3. Project 1: Six bits Chipless RFID Tag resonances.

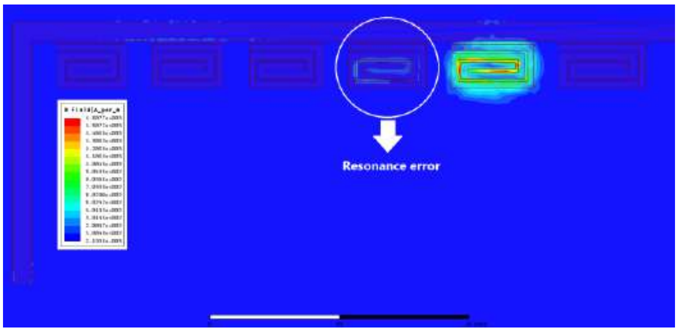


Figure 4. Resonance error of Project 1 at 2.154GHz.

Obviously a solution to this problem is to increase the frequency guard band between adjacent resonances. However, excessive separation is unacceptable due to restrictions on spectrum use. This paper proposes to obtain appropriate values for frequency guard bands in the design of this type of Tags in S-band using numerical simulations. The simulations corresponding to multiresonator in the Project 2 are shown in Figs. 5 and 6. The Fig. 5 shows a better distribution of resonances within the S-band, wherein the lower frequency guard band resonances now occurs between the lengths of the resonators L_1 and L_2, with a value of 162MHz.

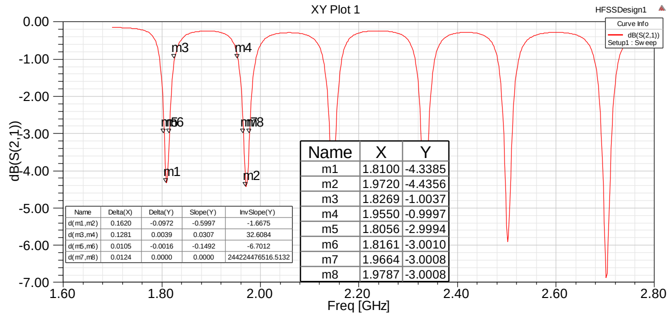


Fig. 5. Project 2: Six bits Chipless RFID Tag resonances.

Fig. 6 shows that when exciting the Tag with the resonant frequency of the resonator length L_2, whose value is 1.97 GHz, only it resonates, there is no resonance in the adjacent resonators.

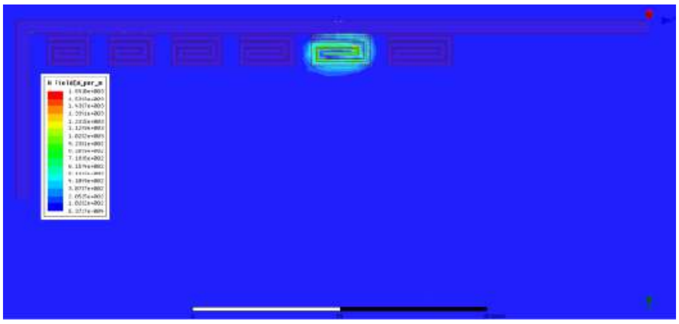


Fig. 6 . Resonance of Project 2 at 1,972GHz.

An analysis to all other resonant frequencies of the other five resonators was also performed, yielding similar results.

IV. Conclusion

This work showed the importance of simulating the coupling between adjacent resonators, in the design of chipless RFID Tags, for frequency guard band values appropriate enabling accommodate the largest possible number of bits in the band operation of the Chipless RFID Tag, avoiding spurious resonances that cause errors in reading of the ID.

References

[1] Z. Hejazi, P. S. Excell, Z. Jiang, "Accurate distributed inductance of spiral resonators", *IEEE Microwave and Guided Wave Letters* , vol. 8, no. 4, pp: 164–166, April 1998.

[2] Z. Jiang, P. S. Excell, Z. M. Hejazi, "Calculation of distributed capacitance of spiral resonators",*IEEE Transactions on Microwave Theory and Techniques*, vol. 45, no. 1, pp: 139–142, January 1997.

[3] S. Preradovic; N. C.Karmakar "Multiresonator-Based Chipless RFID, Barcode of the Future" Springer (2012).

[4] Y. F. Weng, et al. "Design of Chipless UWB RFID System using a CPW Multi-Resonator". The University of Hong Kong, 2013.

T-Matching Variation Effect of RFID Tag Antenna for 915MHz

Flávia C. da Costa, Ricardo T. Yoshioka,
Eduardo R. de Lima and Fernando I. de L. Leite
Design House Department
Eldorado Research Institute
Campinas – SP, Brazil
flavia.costa@eldorado.org.br

***Abstract*— In this paper, a miniature antenna for a passive UHF RFID tag is designed. The simulation is carried out by using CST Microwave Studio program based on the Finite Integral Technique (FIT). The T-Match dimensions were optimized and evaluated using the CST Microwave Studio and S parameters of the fabricated antenna were measured using a two-port VNA. A calibration procedure was used to correct the error that the material specifications can cause in the impedance results. Moreover, the proposed antenna is simple structure, low profile and easy fabrication.**

***Keywords*— UHF RFID tag antenna, T-match, Impedance measurement.**

I. INTRODUCTION

Radio frequency identification (RFID) has increasingly gained the attention of industrial and academic societies because of its widespread applications. When implementing an RFID system, it is often desired to have a compact tag with minimal detuning of its performance due to the loading of identification object, and extend the reading range without increasing reader's power.

An RFID tag, which is also called an RFID transponder, consists of an integrated circuit containing a processor and memory combined with an antenna. The integrated circuit is usually placed between the terminals of a balanced tag antenna [1]. Most UHF (Ultra High Frequency) RFID tags are dipoles or some variation of it and thus have characteristics similar to that of a dipole. The performance of current RFID tags is therefore limited near such materials.

The range and scalability of RFID systems are strongly dependent on the operating radio frequency of the systems. It is well known that when the RF output power of the reader and its antenna gain are fixed, the performance of the RFID tag relies mainly on the conjugate match condition between chip and antenna [2]. RFID UHF bands vary in different countries and include frequencies between 860 MHz and 960 MHz (EPC global standard). Most popular UHF RFID standards are ISO 18000-6B and recently ratified EPC Gen2.

A successful antenna design must satisfy a conjugate impedance match condition. This impedance varies depending on the fabrication technology, the chip design and the chip packaging. However, it is difficult to accurately predict the impedance of the tag antennas in real environments due to the complicated application scenarios and the uncertainty of the electrical properties of the attached platforms. Impedance modeling with 3D electromagnetic (EM) simulations in conjunction with experimental method is an effective way to characterize the tag antenna impedance. CST Microwave Studio (MWS) uses the FIT (Finite Integration Technique) method for analysis of electromagnetic fields in time and frequency domains [3].

Most of the antennas for UHF omnidirectional tags are commonly fabricated as modified printed dipoles. The design goal is to achieve the inductive input reactance required for the microchip conjugate impedance matching, and to miniaturize the antenna shape. Several tricks are used, and the resulting tags sometimes exhibit charming and nearly artistic lay-outs [4].

In this paper, we present the effects that the variation of the length of the T-match that changes the impedance of the antenna. This background gives the knowledge to understand the optimization of the antenna in terms of shape and length in the operational band. The impedance of the proposed antenna is match at 915 MHz. The antenna has a simple structure which requires only a single layer of metallization on a dielectric substrate, enabling one to fabricate it with ease. The simulation and experimental results are compared and a good agreement is observed. The effects of parameters are presented and discussed.

II. DESIGN AND STRUCTURE OF TAG ANTENNA

Passive tags are designed with antennas optimized to extract maximum energy from the RFID reader signal while maintaining a communication link. The RFID ASIC impedance is non-linear regarding the frequency, i.e. the impedance varies with the input frequency. The impedance of balanced antennas cannot be measured directly using measurement instruments, since these instruments are terminated with un-balanced ports such as coaxial ports. When a balanced antenna is connected to an un- balanced test port, the currents fed to the two radiators of the antenna are unequal. Thus, impedance of the balanced antenna cannot be characterized correctly.

The RFID antenna must have suitable gain while also providing a good match between the chip and tag antenna. This results in a minimal amount of power reflected when the antenna transports power to the chip. Power reflection coefficient is defined as (1):

$$S_{11} = \frac{Z_a - Z_c^{\ *}}{Z_a + Z_c} \qquad (1)$$

Where $Z_a = R_a + jX_a$ is the complex impedance of the antenna and $Z_c = R_c - jX_c$ is the complex impedance of the chip.

The proposed antenna structure is shown in Fig. 1. The antenna designed in this work is a dipole with a matching slot. T-match acts as an impedance transformer. For the case of half-wavelength dipoles, the resulting input impedance at the T-match port is inductive, while for smaller dipoles, the total input impedance can be both capacitive and inductive. The T-match geometry can be also embedded within the main, yielding a compact structure.

The T-match basically has three critical parameters: the length of the T-match (L_t), the width of the secondary trace W_1, and the distance between the two traces. The geometrical parameters can be adjusted to match the complex chip impedance Z_{chip} [4]. In this paper, we changed the length of the T- matching to achieve the impedance matching. It is used to adjust the power transmission coefficient between the tag antenna and the chip. Simulations were carried out with CST MWS. Prototypes were designed and tested to validate the simulations performed in this study. The target impedance of the prototype antenna is the conjugate of a RFID Chip with $Z_{chip} =$ 13.3 - j122 at 915 MHz. The antenna was fabricated using ROGER 4350B with the following specifications obtained from vendor datasheet: h=1.524mm, t= 35µm, and tan δ = 0.0037. The the parameters (units in mm) are: W = 80, L = 20, W_t=5 and L_t=17.2.

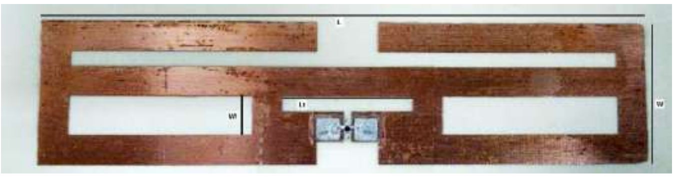


Fig.1. Design of the antenna.

III. IMPEDANCE MEASUREMENTS RESULTS

Port extension method was used to validate the measurement methodology of the antenna. It was used the two-port VNA and a test fixture, to measure the S parameters.

In the measurement setup was used the two-port VNA and a test fixture, to measure the S parameters. The two fixture SMA connectors are connected to the VNA through the test cables. The other end of the test fixture is connected to the test antenna. The test fixture is constructed by using two semi rigid coaxial cables with a length of 100 mm and an outer conductor diameter of 2.2 mm. The coaxial cables are soldered together on their outer conductors. The other end of the fixture is open with the small extensions of inner conductors to form the tips to connect the antenna under test [4].

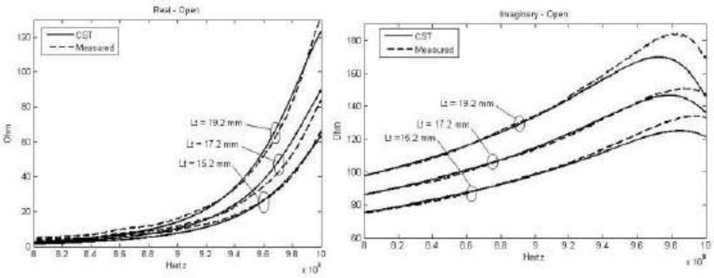


Fig.2. Effect of the L_t on the impedance of the antenna.

Fig. 2, shows the input impedance of the antenna on an ROGER substrate. Both the real and imaginary parts of impedance are shown, and in order to demonstrate the measurement accuracy CST MWS simulation results are compared with the measured results. As shown in Fig. 2, the T-Match length (L_t) affects both the resistance R_{ant} and the reactance $X_{ant.}$ From the above observation, it is noted that it is possible achieve the desired impedance adjusting the W_t or L_t parameters.

The antenna was designed to work ate 915MHz and the target impedance is the conjugate of Z_{chip} = 13.3 –j122Ω. The impedance matching for that frequency was achieved when L_t = 17.2mm, with Z_a = 13.97 + j121.12Ω and S_{11} = 27.84dB. The reader range was 3m.

IV. CONCLUSION

We presented the effects that the variation of the length of the T-match that changes the impedance of the antenna. The proposed antenna is matched with the variation of Wt. The T-Match length (L_t) affects both the resistance R_{ant} and the reactance $X_{ant.}$ The antenna was designed and fabricated on a Roger substrate. The input impedance of the tag antenna for conjugate matching with the IC chip impedance is 13.97 + j121.12Ω at the operation frequency of 915MHz with reader range of 3m.

REFERENCES

[1] T. C. Chau , B. A. Welt , and W. R. Eisentadt, “Analysis and Characterization of Transponder Antenna for Radio Frequency Identification (RFID) Systems”, Packaging Technology and Science, Vol. 19, no.1, pp.33-34, 30 Nov. 2005.

[2] P. V. Nikitin, K. V. S. Rao, S. F. Lam, V. Pillai, R. Martinez, and H. Heinrich, “Power reflection coefficient analysis for complex impedances in RFID tag design,” IEEE Trans. Microw. Theory Tech., vol. 53, no. 9, pp. 2721–2725, Sep. 2005.,

[3] CST – Computer Simulation Technology, CST Microwave Studio 2014 user manual, 2014, http://www.cst.com

[4] Marrocco, G. “The Art of UHF RFID Antenna Design: Impedance-Matching and Size-Reduction Techniques”, IEEE Antennas and Propagation Magazine, Vol. 50 , pp. 66 – 79, Feb. 2008

[5] Costa, F.C., de Lima, E.R., Yoshioka, R.T. ; Bertuzzo, J.E., Koeppe, J., “Impedance Measurement of Dipole Antenna for EPC Global Compliant RFID Tag”, Microwave & Optoelectronics Conference (IMOC), 2013 SBMO/IEEE MTT-S International , 4-7 Aug. 2013.

Challenges to the use of RFID in wood crossties

Alessandro S. Santos, Henrique F. Puhlmann, Leandro Avanço, Maria J.A.C. Miranda, Matheus Jacon, Mauro K. Noda, Sergio Brazolin, Takashi Yojo, Victor Mancini
Institute for Technological Research of the State of São Paulo - IPT
São Paulo - Brazil

Carlos E. Cugnasca, José K.C. Pinto
Escola Politécnica
University of São Paulo - USP
São Paulo - Brazil

Veltan E. Martinnelli Jr, Antonio C. Santos
Department of quality of materials
São Paulo Company of Metropolitan Trains - CPTM
São Paulo - Brazil

***Abstract* - This paper presents the challenges to the use of RFID in Brazilian wood crossties considering factors related to mechanical, physical, drying properties, aspects of anisotropy and hygroscopicity. The challenges to using RFID in this material consider dielectric loading, encapsulation for resisting the natural efforts within wood, and design for automation.**

Keywords - RFID; wood; sawn wood, crossties, trains, dieletric constant

I. Introduction

Supply chains have been instrumented with Radio-frequency Identification (RFID) to improve control and efficiency, as well as to allow traceability of products. In warehouse, the identification of pallet wood with the insertion of tags has become a viable alternative for various scenarios [1]. However, when the idea involves the tracking of "sawn wood" other aspects have great significance for RFID application [2]. For example, wood from Amazonian trees when not handled properly, be it in transport or storage, can be considered environmental crime.

Physical characteristics of the wood itself may limit the transmission power of radio signals, hinder tag insertion, and can cause structural damage to the tags, due to the strain of natural wood throughout its life cycle, be it in logs or as manufactured wooden sleeper parts for the railway industry.

Another factor is the type and species of trees found in Brazil, which are different from the types found in regions of the northern hemisphere. Therefore, the traceability of such material imposes new challenges to the RFID research field.

II. Wood Complexity

The appearance and characteristics of wood are determined by their cellular structure, and as it is a product of nature, pieces taken from the same tree may have different properties depending on their location and position of the fibers in relation to a given system of axes.

In addition to this individual aspect, the physical and mechanical properties of wood change greatly between species; among the variety of species, we can observe woods with apparent densities ranging from 200 kg/m^3 to 1100 kg/m^3. Therefore, the selection of wood species for a particular use depend on the analysis of these properties and the expected durability, compared to internal forces and action of organisms that degrade wood [3].

The factors related to mechanical and physical properties must be considered in RFID application to wood crossties, because wood is an anisotropic and hygroscopic material in some way.

Generally, wood is considered dry when its moisture content is in equilibrium with the relative humidity and temperature of the environment. In this situation, the dimensional movement of wood is smaller compared to the wood in green state (saturated water), i.e., when its moisture content is above the saturation point of fibers (PSF).

In natural or artificial drying processes, below the PSF, the wood loses or gains water contained in the cell wall, depending on the environmental condition; therefore, its dimension changes and causes deformation. Due to its anisotropy and gradient drying, this deformation will cause internal stress that can reach intensity of up to 100 daN/cm^2 which is more than the wood strength in tension perpendicular to the fiber and, consequently, the wood will crack and split.

Therefore, to ensure the integrity of the RFID tag applied and the signal reading, knowing the properties and behavior of wood material in the environment of use are fundamental.

III. Challenges to RFID

Several categories of tags can be selected, each one with particular characteristics, advantages and disadvantages. In logistics, the UHF band (860-960 MHz) is one of the most used, especially for inventory control and product tracking. In these cases, the main advantages are low cost, high reading speed and maximum reading distance (up to 10 m, approx.).

There are RFID tags that can be used to identify several kinds of products. Currently, the readability and range of RFID tags are especially affected by fluids and metals, reducing their reliability [4]. The humidity and amount of water in a log of wood decrease the RFID tag antenna efficiency, which requires a stronger radio frequency (RF) signal to operate. The backscattered signal strength is proportional to the amount of water in the wood, and as it increases, the RFID tag antenna operates with lower efficiency due to ohmic losses and changes in input impedance (both the real and imaginary parts of the wood dielectric constant increase).

Simulations are useful to evaluate the propagation of the signal emitted by a reader in the hole made in a piece of wood for placing a tag (Fig. 1).

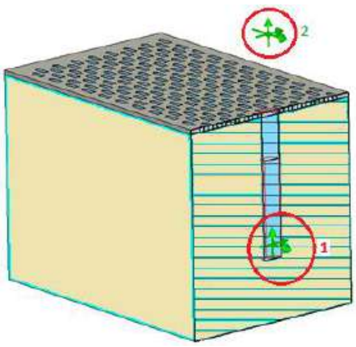


Fig. 1 – Hole in a piece of wood with a tag.

For that, wood characterization is important in assessing the conditions for reading the tags implanted in it, and the choice of material to be used to close the hole, which must have characteristics similar to those of the wood.

An empirical determination of the relative dielectric constant (εr) and the tangent loss factor (tan δ) of some types of wood commonly used in railway sleeper tracks were performed, using electromagnetic resonance process. A copper microwave cavity was constructed, filled in with a sample of wood, to resonate near in the frequency band of interest (902-928 MHz). Table 1 shows the results for five types of Brazilian wood.

Table 1 – Relative dielectric constant of some types of Brazilians woods.

wood	density (kg/m³)	εr	tan δ ($x10^{-3}$)
Guatambú-amarelo (*Aspidosperma*sp. Apocynaceae)	636	10 - 11	6.5
Jatobá (*Hymenaea* sp., Leguminosae)	1022	12 - 13	9.0
Pinus (*Pinus* sp., Pinaceae)	539	9 - 10	2.0
Cedrinho (*Erisma uncinatum*, Vochysiaceae)	548	9 - 10	8.0
Ipê (*Handroanthus* sp., Bignoniaceae)	1093	9 - 10	2.0

Fig. 2 shows a graph which allows evaluating this signal attenuation inside woods with εr = 12 (commonly used in railway sleeper), which is approximately 12 dB.

IV. Services and Scenarios for Traceability

The application of RFID technology in wood crossties is an interesting case study in the logistics area. All the stages of the life cycle of wood crossties should be monitored: the authorized tree cutting, processing at the sawmill, storage in stock, installation, and disposal towards the end of its useful life.

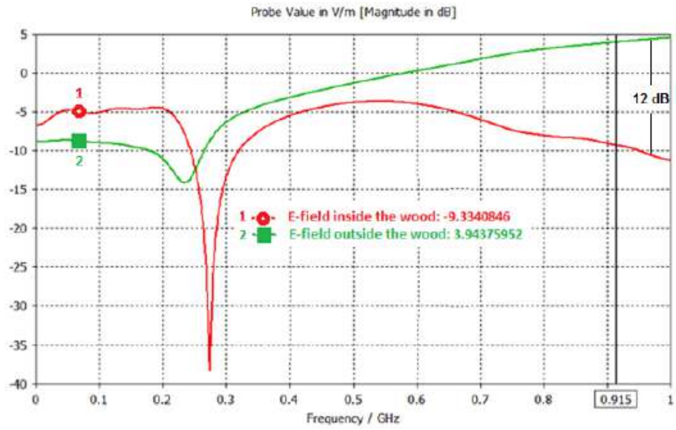


Fig. 2 – Signal attenuation for woods with εr = 12 (Jatobá).

Automation and control of incoming and outgoing stock can bring important benefits, such as increased flexibility and minimization of errors, besides enabling wood crossties monitoring, contributing to a more precise planning of replacements and disposal [5].

V. Conclusions and Future Works

The use of RFID tags in sawn wood, such as crossties, can bring many benefits, both for logistic processes and for traceability. However, there are many challenges to overcome due to the adverse conditions of use, especially moisture, impact, vibration and wood deformation.

As future works, we can highlight the selection of the most appropriate tags, and research on the best ways to install them.

Acknoledgments

The authors wish to express their profound gratitude to Dr. Marcelo B. Perotoni, from the Federal University of ABC, São Paulo, Brazil, for his help in carrying out the simulations.

References

[1] S. Shen and D. Wang, "Research on Warehouses Management Based on RFID and WSN Technology," in *2nd International Workshop on Database Technology and Applications (DBTA)*, 2010.

[2] F. Ohnimus, J. Haberland, C. Tschoban, I. Ndip, K. Heumann, C. Kallmayer, S. Guttowski and K. Lang, "Design and characterization of a small encapsulated UHF RFID tag for wood log monitoring," in *Loughborough Antennas and Propagation Conference (LAPC)*, Loughborough, 2010.

[3] Institute for Technological Research of State of São Paulo, Catalog of Brazilian woods for construction(in portuguese), São Paulo: IPT, 2013, p. 103.

[4] M. Rata, G. Rata, A. Graur and V. Popa, "The influence of different materials in 13.56 RFID system," in *1st Annual RFID Eurasia*, 2007.

[5] V. E. Martinelli and C. E. Cugnasca, "Logistics Process Control for Wood Sleepers with Adoption of RFID - A Precondition For Environmental policy," São Paulo, 2013.

Differential Power Calculation to RFID UHF Passive Tags Characterization

A.C. de Souza and T.P. Vuong
University of Grenoble-Alpes,
Grenoble, France
coelhoda@minatec.inpg.fr

Y. Duroc
University Claude Bernard Lyon 1
Villeurbanne, France

A. Luce
Laboratoire national de métrologie et d'essais
Trappes, France

***Abstract*— This paper describes a new method to characterize commercial UHF RFID passive tags in the near-field and far-field zones of the reader antenna. This method is based on the tag's performance on power activation in several distances. Different kind of commercial tags were performed, and from measurements results, the differential power calculation is introduced in order to investigate the evolution of power requirements to activate the tag in the near and far field regions. According to tag's antenna geometric features and the differential power result of each one it is possible to classify the tag in two different families.**

Keywords—UHF passive tags characterization; near and far field measurement; differential power activation; RFID

I. INTRODUCTION

The RFID (Radio Frequency IDentification) has become one of the emblematic wireless technologies and has quickly been developed for real-time identification in several fields. Among the frequency bands used in RFID applications, the UHF band (Ultra High Frequency, 860 MHz to 960 MHz),is the one that mobilizes the essential of R&D and large part of the applications. One of last advents, the Near-Field (NF) UHF RFID has attracted many attentions because of its versatility in gathering the advantages of UHF systems and robustness to environmental effects of HF (High Frequency) systems.

Among the issues for achieving efficient UHF RFID systems, it is well-known that the characterization of passive tags is a key aspect. The actual methods of characterization of commercial passive UHF RFID tags [1]-[5] are based on the minimum required transmit power (P_{RE}) to read a tag, and on the backscattering signal strength from the tag. But these methods are only carried out in Far-Field (FF) zone. Relatively few research works have been proposed for the characterization of UHF RFID systems in the case of NF zone [6]-[9]. Recent studies [6]-[10] showed that performance of UHF RFID systems relies on the electromagnetic coupling (EC) between the reader antenna and tag antenna on all field zones. [11] suggests the analyses of magnetic field strength to evaluate the systems in near-field range, but the norm does not give any further detail about the method (formulas and calibration technic) to be used.

This paper proposes a new method to characterize, evaluate, and compare commercial UHF RFID tags by means of the differential power (DP) calculation. The DP is the power needed to activate the tag at a given distance in relation with the power needed to activate the tag at the referential distance. This approach contributes to overcome the lack of experimental procedure to evaluate UHF tags in the NF zone, and it represents the originality of the work. The proposed method is carried out in NF and FF. Results highlight the correlation between the tag designs (geometry and size of the antenna, type of chips) and tag performance on minimal power activation in function of the read range.

II. MINIMUM POWER ACTIVATION OF RFID PASSIVE TAG

The RFID passive systems are highly dependent on the emission power sent by the reader. This power essentially supplies all operational energy to the bi-directional communication between reader and tag. The tag turns on operation mode when P_{RE} is high enough to overcome losses in air, interferences and to reach the tag with a value superior or equal to the sensitive power ($P_{Tsen.}$) of the tag's integrated circuit (IC).

The minimum power activation (P_A) is defined as the lowest value of power available at the tag's antenna to wake up the IC. The P_A depends on some factors linked to antenna quantities of reader and tag, and to the environment conditions (proximity to any detuned objects like metal and plastics). The antenna quantities are separated in three categories: circuit (impedance matching coefficient, Q factor), physical (dimensions, geometries, orientation) or radiation (gain, polarization, radar-cross section (RCS)).

The P_A can be estimated at FF conditions by using Friis formula as described in [1], [7], [9] and [12]. But in NF cases, it requires more complex knowledge about the current distribution in both antennas and coupling coefficient [7]-[9]. A simplest way to analyze the effects of the physical features of tag antennas on the P_A is to evaluate the minimum differential P_{RE} to activate the tag. The differential power corresponds to the additional required power to wake up the tag at another distance relative to the first one.

III. CLASSIFICATION OF UHF RFID PASSIVE TAGS

The UHF RFID passive tags can be classified into three families:

A. *Near-Field Tag (NF tags)*

The tag antenna is a loop of very small dimensions, smaller than $\lambda/10$. Reader and tag are magnetically coupled and can be modeled by associated coils as in a transformer system.

B. *Hybrid Tag (HB tag)*

This type of tag is performed to work in NF and FF zones. Their antennas are usually composed of a small meandered dipole and a loop-matching structure at the center. The loop structure also contributes to the performance of the tag in the NF reactive zone [9]. The meanders help to minimize the antenna dimensions, and are easily tuned. On the other side, the hybrid tag has low gain.

C. *Far-Field Tag (FF tag)*

The antennas of FF tags are mostly shaped of dipole-like antenna or folded dipole. To improve the antenna gain and RCS, some designs present a large metallic area joined to the dipole. They also have a loop-matching network at the center.

TABLE I. MAIN FEATURES OF STUDIED TAGS

Tag	Geometry	Size (mm²)	$P_{Tsen.}$ (dBm)	Family
Tag1[13]		22 x 22	-14	HB
Tag2[13]		44 x 10	-14	HB
Tag3[14]		40 x 18	-18	HB
Tag4[14]		49 x 30	-18	HB
Tag5[13]		70 x 17	-14	FF
Tag6[13]		95 x 8	-14	FF
Tag7[13]		93 x 19	-14	FF
Tag8[13]		44 x 46	-14	HB

IV. METHOD OF CHARACTERIZATION

A. *Experimental Test*

In the experimental tests, the P_{RE} of different types of commercial tags (presented in Table I) are measured using the setup presented in Fig.1 [9]. The tags were first classified according to the criteria presented in Section III.

RF measurements devices such as vector signal generator (VSG) and spectrum analyzer are used to perform the reader in transmission and reception mode respectively. A query command, based on EPC class1 Gen2 protocol, is uploaded in the RF generator. The output power delivered from the generator to reader antenna is gradually increased in order to define the minimal power to active the tag under test (TUT).

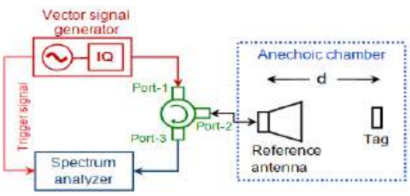


Fig. 1. Experimental test setup.

B. *Experimental Results*

Fig. 2 presents the measured minimal P_{RE} at the frequency of 868 MHz. The characteristics of each family of tag are not clearly remarkable through the evaluation of P_{RE} results. Fig. 3 shows the DP which leads to brighten up the distinction of two different behaviors showing two tag families.

It should be noted that the behavior of HB tags depends more on of antenna dimensions than the type of IC or antenna geometry. The DP of HB tags is also more sensitive with the field decay in function of the distance in NF zone compared to FF tags. For FF tags, the variation of the DP is also similar however it presents a bigger standard deviation between the curves than HB tags. The FF tags have presented a better performance than hybrid tags in all measured distances. They need less power to power up the tag even in NF zone. The influence of loop-matching network can explain the result; the loop couples the fields in NF region.

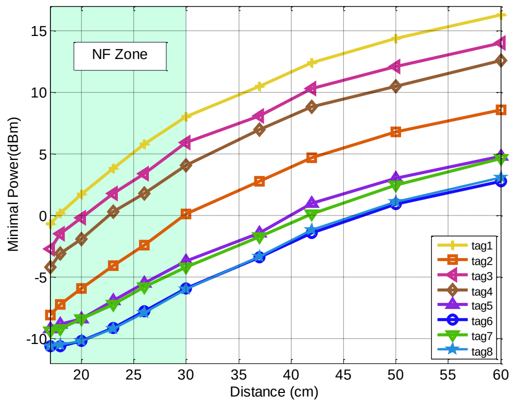


Fig. 2. Measured minimal power P_{RE} to activate the tags in NF and FF zone.

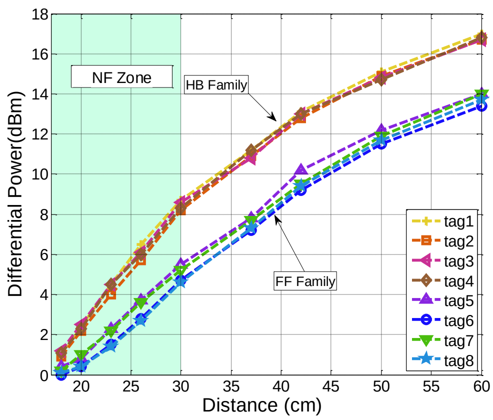


Fig. 3. Differential power of measured tags where it is clearly observed the two distinguished groups.

V. CONCLUSIONS

A method of characterization of UHF RFID passive tags based on the differential activation power was proposed. The measurement results of several HB and FF types of commercial tags showed that the P_{RE} parameter is not enough to discriminate the behavior of a family of tags. According to DP, two distinguished behaviors of power evolution in function of the distance are observed. Among the evaluated parameters of the measured tags, the dimension of antenna is the more influencing parameter in the tag's performance in terms of DP. The form and type of the chip are less sensible to the P_A. The DP represents an interesting parameter to discriminate the family of unknown tags.

REFERENCES

[1] L. Sydanheimo et al., "Characterization of Passive UHF RFID Tag Performance", IEEE Antennas and Propagation Magazine, vol. 50, no. 3, June 2008.

[2] P. V. Nikitin, K.V.S. Rao, "LabVIEW-Based UHF RFID Tag Test and Measurement System", IEEE Transaction on Industrial Electronics, vol. 56, no. 7, July 2009.

[3] A. Pouzin, T.P. Vuong, S. Tedjini, J. Perdereau, L. Dreux, «Measurement of Radar Cross Section for Passive UHF RFID Tags », Proceedings of EuCAP, pp. 1-6, November 2007.

[4] A. Pouzin, T.P. Vuong, S. Tedjini, J. Perdereau, « Automated Bench Test for UHF RFID tags Measurement in Operational Envorinment", International Journal of Microwave and Wireless Technologies, vol. 3, pp. 415-422, May 2011.

[5] Voyantic Tagformance Lite, avaliale at http://www.voyantic.com/tagformance

[6] A. Buffi, P. Nepa, G. Manara, "Analysis of near-field coupling in UHF-RFID systems," IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communication, pp. 931-934, September, 2011.

[7] F. Fuschini, C. Piersanti, L. Sydanheimo, L. Ukkonen, G. Falciasecca "Electromagnetic analyses of near field UHF RFID systems," IEEE Transactions on Antennas and Propagation, vol. 58, no. 5, pp. 1759-1770, May 2010.

[8] Y. S. Chen, S. Y. Chen, H. J. Li, "Analysis of antenna coupling in near-field communication systems," IEEE Transactions on Antenna and Propagation, vol. 58, no. 10, pp. 3327-3335, October 2010.

[9] P. V. Nikitin, K.V.S. Rao, S. Lazar, "An overview of near-field UHF RFID," IEEE International Conference on RFID, pp. 167-174, March 2007.

[10] T. S. Bird, N. Rypkema and K. W. Smart, "Antenna Impedance Matching for Maximum Power Transfer in Wireless Sensor Networks," IEEE Sensors 2009, pp. 916-919, October 2009.

[11] ISO/CEI 18046-3: 2007, Radio frequency identification device performance test methods -- Part 3: Test methods for tag performance.

[12] P. V. Nikitin, K.V.S. Rao, S. Lazar," Antenna design for UHF RFID tags: A review and a practical application", IEEE Trans. Antennas Propag., vol 53, no 12, pp 3870-3876, Dec, 2005.

[13] Alien Technology, available at http://www.alientechnology.com.

[14] UMP Smartrac, available at http://www.upmraflatac.com.

RFID System on Electrical Substation Equipments

Wendy Navarro, Yackeline Ternera, John E. Candelo, Juan Carlos Vélez
Department of Electrical and Electronics Engineering
Universidad del Norte
Barranquilla, Colombia

***Abstract*— Experimental studies in an electrical substation reveal the scopes and limitations of implementing RFID technology on electrical grid equipments. This paper is a summary of experiments about RFID system implementation on an electrical indoor substation in Barranquilla. Results reveal that RFID passive systems are viable to use on metal surfaces and electrical equipments considering some issues.**

***Keywords*— RFID System, UHF, Electrical Substation, Read Rate, Read Range.**

I. Introduction

Radio Frequency Identification (RFID) is one of the fastest growing wireless technologies in this decade. RFID systems are used widely on different industrial and academic applications [1]. However, few studies are related to electrical substation. On the electrical equipments (transformers, sectionalizers, breakers, UPS) the electrical flow generates electromagnetic fields that are sources of electromagnetic interference (EMI). These field can affect the RFID system performance [3].

Monitoring processes and inventory control of electrical equipment are logistical tasks that require to be automated. Many equipments have huge painted numbers on their most visible areas to realize manual inventory processes. Some electrical substations include identification systems based on bar code. These systems reduce time and mistakes in inventory and control processes. However, dust, environmental pollution and wear pieces pose a trouble to receive information of electrical equipment. Thus, RFID systems emerge as a competent proposal over traditional bar codes.

An example of this, is the implementation of a RFID system in The South China Electrical Substation. It allows to automate the monitoring and control processes. RFID tags are used to ensure the accurate data collection. The tags are attached to the metallic surface of equipment and are identified by RFID readers. However, the scopes and limitations of RFID system on electrical substation were not described technically in the brochure of this study case [4].

However, RFID-UHF passive systems present problems on metallic surfaces [5-8]. Performance factors such as read rate and read range are greatly decreased. The metal generates Foucault currents around the tag antenna, when the waves sent by the RFID reader strikes the surface. In this case, the Foucault currents produce a magnetic field opposite to the reader that cancels the reader-tag communication. The metallic surface could even potentialize the tag response signal, reaching unexpected read ranges [3, 9]. The tag antenna parameters such as the input impedance and radiation pattern are affected by the metal [10]. Besides, reflection multiples in a metallic environment cause multipath propagation. Therefore, constructive and destructive interferences may occur [11].

For these reasons, scopes and limitations of implementing RFID technology need to be determinate following three phases: (1) selection of RFID devices, (2) characterization of RFID tags on metal, (3) study of the RFID system performance on electrical substation equipment.

II. Methodology

Ascertaining the scopes and limitations of implementing RFID systems on electrical equipments is our main purpose. For these reason, three important phases have been followed.

A. Selection of the RFID devices

RFID devices are UHF readers, tags and application system, which allow to collect information about electrical equipments. According to requirements and specifications of electrical substations, the reader must be handheld, lightweight and sturdy. ISO/IEC 1800-6 protocol is used by the RFID passive systems in UHF frequency band. The passive RFID tags must be small, adhesive and economic. The application system must be integrated with the reader. Screen of the RFID reader must submit EPC code and read rate. The selected RFID devices were: ATID 870 reader and Shortdipole tags [12-13].

B. Characterization of the RFID tags on metal surfaces

Data were collected through lab tests with the RF system. Read range and read rate parameters were metric performance of the RFID systems on the metal surfaces. These experiments consider two orientation angles (0° and 90°) and the RFID tags were adhered on a metal sheet. All tests allowed to understand the behavior, scopes and limitations of the RFID system on metal. These experiments were conducted in a laboratory room and an indoor substation at the Universidad del Norte.

C. RFID system performance

The RFID tags were placed on transformers, sectionalizers, UPS and power plant. Read range and read rate registered (for different location and orientation angles) allow to determine the best location for the tags on electrical equipments. Finally, an experiment with all the tagged equipment was conducted in an indoor substation. This experiment allow to determinate the average time of identification making an inventory process. Fig. 1 shows the tagged electrical equipments.

III. Experimental Results

According to experimental results, the electromagnetic fields produced in the electrical substation affected the performance of a RFID system. The read range of a passive tag on metal decreased in this environment. However, it remains satisfactory when the passive tag is read within the new read range, 13 readings/s approximately. The maximum range was 1.55m in the electrical substation while in the outdoor environment was 9.2m. During the experiments, the passive tag was attached perpendicularly to the metallic surface with a minimum separation of 2cm to ensure correct identification as in [2]. This value was found experimentally in laboratory tests. Moreover, the measurements showed that the maximum transmission power (30dBm) from RFID reader minimized the probability of read error.

Fig. 1. RFID tags on the electrical equipments.

Different locations of passive tags on electrical equipments were evaluated in order to avoid reading errors during inspection processes. Read rate and read range were measured for each evaluated location (top, side and front) and orientation angle of the passive tag. Fig. 2 shows the maximum read range achieved in each location at 0° and 90°, when the tag is attached on power transformer. Table I shows the best locations found for the different electrical equipments (power transformer, sectionalizer, UPS, electrical plant). These locations ensure a reading probability of 98%. If the passive tag is located in different positions, system performance significantly decrease.

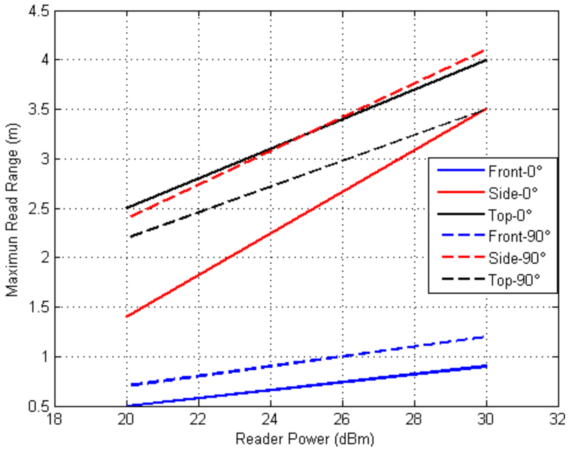


Fig. 2. Maximum read range of an RFID passive tag on a power transformer.

TABLE I. BEST LOCATIONS FOR RFID TAGS ON ELECTRICAL EQUIPMENTS

Electrical Equipment	**Location**	**Orientation Angle**	**Maximum Read Range, (m)**
13200/220V Transformer	Top	0°	4
	Side	90°	4
Sectionalizer	Front	0° and 90°	5
UPS	Front	0° and 90°	2.7
Power Plant	Front	0°	3.2
	Side	90°	3.2

After knowing the best locations of the RFID tag on the electrical equipments, it is proceeded to verify the proper operation of the RFID system. The average time required to identify the electrical devices was measured. A simultaneous reading was performed at a distance of 3m with respect to the tags. The results showed a correct identification in an average time of 1.4 seconds. The inspection times are reduced using RFID systems. This would update the current status of electrical equipments in a few seconds.

IV. CONCLUSION

The results established that read range decreases an electrical substation compared with an outdoor environment. An environmental conditions containing electric equipments negatively affects the RFID system performance. For this reason, the tag attachment technique, transmission power and location tag were proposed.

Passive tags should be attached perpendicularly to a metallic surface of an electrical equipment. Therefore, eddy current problems are avoid if the distance between surface and tag antenna is over 2cm. Reader should transmit to maximum power 30dBm to decrease the error rate. Besides, the results establish the best location for passive tags on every electrical equipments. These locations ensure that the devices can be identified very successfully with a reading probability of 98%.

REFERENCES

[1] D. Dobkin, "The RF in RFID, Passive UHF RFID in Practice". Technical Marketing, WJ Marketing, WJ Communications, San Jose, CA, USA. 2008.

[2] M. Kim, and K. Kim, "Automated RFID-based identification system for steel coils", Progress In Electromagnetics Research, Vol. 131, 1-17, 2012.

[3] P. Chong, and K. Hwan, "RFID Label Tag Design for Metallic Surface Environments", in Sensors Journal, Dongguk University, 2011.

[4] Brochure DTResearch, "WebDT Mobile POS Tablet Conducts Intelligent Inspections at the South China Electrical Substation". Case Study, 2013.

[5] P. Cole, "A Study of Factors Affecting the Design of EPC Antennas & Readers for Supermarket Shelves," Auto-ID Center White Paper, 2002.

[6] R. Orozco, and R. Linares, "Análisis de modelos de propagación e interferencia de la tecnología RFID pasiva de UHF para aplicación en la identificación vehicular", tesis M.S, Instituto Politécnico Nacional, México, D.F Junio 2011.

[7] R. Angeles, "RFID technologies: Supply-chain applications and implementation issues," Information Systems Management, vol. 22, no. 1, pp. 51–65, 2005.

[8] M. Kim, B. Song, D. Ju, E. Choi, and B. Cho, "Development of Metallic Coil Identification System based on RFID", Microwave Conference Proceedings, Vol. 4, 2010.

[9] J. Prothro, G. Durgin, and J. Griffin, "The effects of a metal ground plane on RFID tag antennas," in IEEE Antennas and Propagation Society International Symposium, Albuquerque, New Mexico, 2006.

[10] P. Raumonen, L. Sydänheimo, L. Ukkonen, M. Keskilammi, and M. Kivikoski, "Folded Dipole Antenna Near Metal Plate, IEEE International Symposium in Antenna and Propagation", Columbus, OH, USA, June 2003, Vol. 1, pp. 848-851.

[11] M. Nikkari, T. Björninen, L. Sydänheimo, L. Ukkonen, A. Elsherbeni, F. Yang, and M. Kivikoski, "Performance of a Passive UHF RFID Tag in Reflective Environment", IEEE International Symposium on Antennas and Propagation, July 2008.

[12] CAEN RFID, "User Manual Guide, AT870 Windows CE® .NET Ruggedized PDA".

[13] SMARTRAC, "ShortDipole Datasheet", 2012.

Low Cost RFID Portable Management System

Diego Polaz, Galdenoro Botura Junior, Everson Martins, Marilza A. de Lemos, Márcio A. Marques,
Automation and Control Engineering
Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP
Sorocaba, SP – Brazil
E-mail: galdenoro@sorocaba.unesp.br

Abstract - This article introduces a radio frequency management system that integrates a database, using a mobile processing system employing the ATMEL AVR microprocessor on an Arduino board, RFID reader and a personal microcomputer. Its technical features allow an eventual and portable usage at locals where there is not a management system, besides giving flexibility and viability of use in different applications. The system was tested through the elaboration of an app focused at inventory control of a multinational company, demonstrating the capability to perform tasks with efficient quality.

Keywords—RFID; Microprocessor; Arduino; Database.

I. INTRODUCTION

Nowadays RFID identification is part of our lives, being used in hundreds of applications such as goods and anti-theft alarms for vehicles, entry/exit parking lots, pike roads identification systems, traffic management, books tracking at libraries, health services, residential security and inventory management, among others [2]. This technology was first used in World War II, when countries of the axis and allies used radar to detect approaching aircraft and identifying enemies. The solution provided by the British was an identification system known as IFF (identify friend or foe), consisting in inserting a transmitter on the aircraft, which when identifying a signal from a radar generates another one, allowing its identification as ally [1].

The utilization of processing mobile devices based on microprocessors allowed the flexibility of this technology. A health auto-management system having RFID technology, which enables the user to store his physiological conditions automatically, is described at [3]. The integrated system of an embedded microprocessor inspects the user identification activating the peripheral device to measure its physiological conditions. The measured data are transmitted and stored on the RFID tags database. A radiofrequency identification system using a single chip microprocessor to solve anti collision problems is presented at [4]. An ARM9 microprocessor was used at [5] as controller of a RFID UHF reader system. The implemented system granted identification on IS/IEC18000-6C high-speed tags solving the crosstalk problems existing between the readers at the industrial site through the multicast IP technology based on Linux operational system. Several others RFID applications in combination with microprocessor devices can be found at [6].

This work presents a management and identification information system based on RFID easy displacement, versatile, low cost, that communicates with a database which can be customized for the most different applications.

II. DEVELOPMENT

To match the desirable features, the identification system using RFID was developed with the prototyping platform Arduino Uno Rev. 3; ID-12 tags reader; low frequency passive tags and a personal computer with serial communication.

The prototyping platform Arduino is consisted of 8 bits ATMEL AVR microcontroller, digital and analogs inputs/outputs, serial or USB interface for programming and interacting in real time with a host computer. The use of the ID-12 reader allows the individually reader of tags in a maximum distance of twelve centimeters. The used tags have the following technical features: RFID IC based on ISSO EM4001; 125 KHz Carrier, 2kbps ASK, Manchester Codification, 32 bits single ID, 64 bits data stream [Header + ID + Data + Parity].

For the microprocessor programming, was used the Arduino IDE developed environment which is a multiplatform application written in Java. The Arduino IDE uses the GNU toolkit and the AVR Libc to compile and record the programs on the board. The hardware topology of the system was established connecting the ID-12 RFID reader to the Arduino board, which was connected to the personal computer through a serial communication. The figure 1 shows the connection scheme used. In the system implementation was used the Microsoft Visual Studio software to develop the interfaces with the user through the C# language and the Microsoft Access program to generate the database.

For this system, an app was developed with the purpose of parts inventory management to a multinational company, in a way that the managers could be capable to verify, in real time on the computer screen, the necessary demands. The tag reading of the system allowed the realization of the following procedures: registration, research, movement log and products exclusion. The app screen for the product registration is displayed on figure 2. The figure 3 presents a flow chart of the operations sequence implemented through the tags reading and the computer interface.

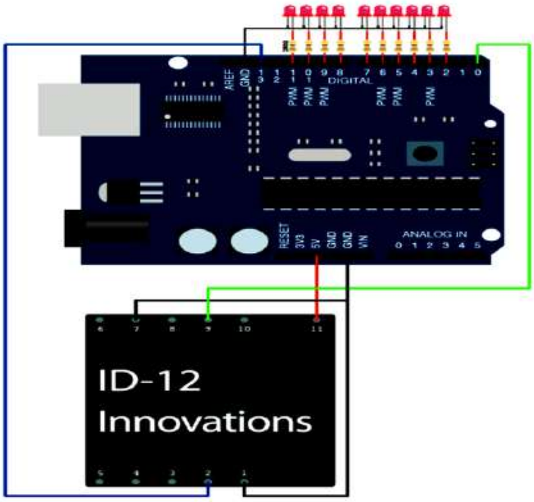


Fig. 1. Wiring diagram between arduino board and RFID reader

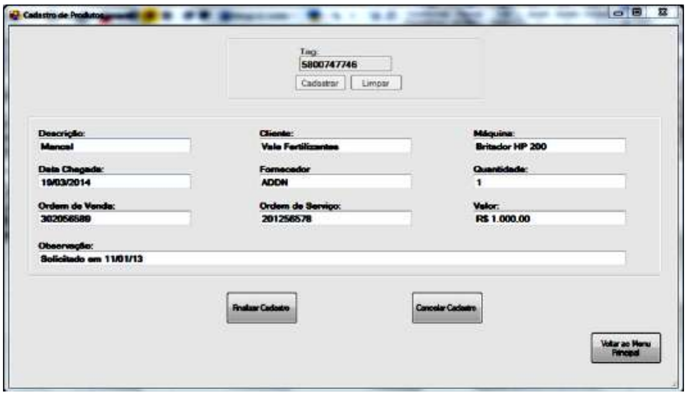


Fig. 2. Registration screen app

The operations were successfully executed with RFID identifications and handling information in real time through the database. The only system restriction is the simultaneous reading of two or more tags. The system identifies only the closest tag.

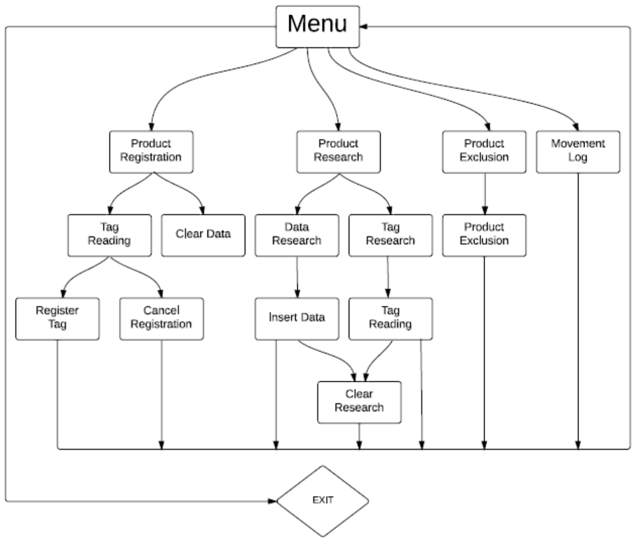


Fig. 3. Implemented operations Flowchart sequence

III. CONCLUSION

The project consists on a low cost RFID identification system, flexible and portable, with possibility to be shifted to different locations, like events that run casually or itinerants, congresses and fairs or even a mobile library, for example. In its conception and implementation were used low cost devices. The developed app allowed the inventory management of a company through a database, showing that the integrated technologies on the project can be a practicable and low cost solution. The deployed hardware allows the use in different kinds of apps, making the system flexible and allowing the customization for different situations, giving a generic nature to them.

REFERENCES

[1] J. Landt, The History of RFID, IEEE Potencial, vol. 24, pp. 8-11, oct-nov, 2005.

[2] B. Violino, The History of RFID, RFID Journal at http://www.rfidjournal.com/articles/view?1338 Acessed im 04/08/14.

[3] S. Shih, C. Shiu, C. Hsu; C.Chao, Self healthcare management system based on RFID technology, 7th International Conference on. Networked Computing and Advanced Information Management, pp. 252-255, 2011.

[4] W. Chen, A Feasible and Easy-to-Implement Anticollision Algorithm for the EPCglobal UHF Class-1 Generation-2 RFID IEEE Transactions on Protocol Automation Science and Engineering, vol. 11, pp. 485-491, maio, 2013.

[5] H. Xia, J. Wu, B. Xiao, X. Zan, G. Wang, Design of UHF RFID reader and the solution of crosstalk problems,. International Conference on Computational Problem-Solving (ICCP), pp. 212-217, 2012

[6] http://ieeexplore.ieee.org/search/searchresult.jsp?newsearch=true&queryText=rfid+microprocessor.

NFC-enabled decentralized checkout system

Orlando Volpato Filho
Mobile Computing Department
SAMSUNG Research Institute Brazil
Campinas/SP, Brazil
Email: orlando.f@samsung.com

Fabio Piva
Mobile Computing Department
SAMSUNG Research Institute Brazil
Campinas/SP, Brazil
Email: fabio.piva@samsung.com

***Abstract*—In this work, we propose a new model for mobile commerce (m-commerce), which allows users to purchase products on physical stores in a fully decentralized, unassisted fashion. We introduce a new type of electronic article surveillance (EAS) tag, embedded with near field communication (NFC) capabilities, which can be disabled by the user's own mobile device – provided that online payment has been completed[1].**

***Keywords*—M-commerce, NFC, EAS, decentralized checkout.**

I. Introduction

Alice has just bought tickets for the movies. Since the session is scheduled to begin in no less than thirty minutes, she decides to visit her favorite book store in order to kill some time. There, while browsing through the available products, Alice finds the newest release of her favorite video game franchise. She happily grabs a copy and heads directly towards the cashier – only to find a seemingly-endless line of people already waiting to pay; she decides to wait for a few minutes, but the line advances slowly, which prompts Alice with a tough choice: Should she give up her long-sought video game, in order to make it in time for the movie, or should she wait? Without much time left to think, Alice regretfully puts the product back where she found it and leaves.

Current solutions in retail environments rely on the premise of centralized checkout counters, where customers line up to validate their purchases and complete payment transactions. In the common event of more customers wanting to complete their purchases than checkout counters are able to process, lines are formed – which often leads to customer dissatisfaction [1] and, ultimately, to the loss of potential buyers to the competition [2].

However, previous work has shown that it is not the effective time spent in lines that annoys customers, but instead the sense of lost, unproductive time wasted on absolute idleness [3], [4]. This is the reason behind some airports' decision to place the baggage claim area far from arrival gates [1], [5], thus causing travelers to spend more time walking than actually waiting for the luggage arrival; despite the fact that this approach can, on occasion, effectively increase the total time needed to get to ones luggage, it is also known to reduce dissatisfaction towards the service as a whole.

In this work we review the need for checkout counters (both controlled by a human cashier and automatic) in retail stores. Our goal is provide a low-cost, alternative sales model, designed to eliminate any user-terminal interaction, in order to effectively extinguish lines in checkout counter operations. We believe this feature can greatly improve end-use experience by allowing physical retailers to emulate the advantages of e-commerce shopping.

[1]Patent pending.

The remainder of this document is organized as follows: In Section II we describe our alternative sales model, which enables buyers to perform decentralized (i.e., cashier-free) purchases by using their own mobile devices. Section III contains details about the proposed tag itself, as well as relevant considerations on security and logistics. We conclude in Section IV.

II. Sales model description

In this section, we provide a high level description of the proposed purchase process. We assume a potential buyer $Alice$ enters retailer's $Shop$'s establishment and starts browsing through its available products. We also assume that $Alice$ is a returning customer, and as such has already gone through the required set up steps, which include connecting to $Shop$'s WiFi network, downloading $Shop$'s purchase application (app), creating a user account and setting up her preferred payment methods.

Figure 1 summarizes Alice's purchase transaction. Upon choosing a product she might desire, $Alice$ takes her NFC-enabled mobile device (a smart phone or a tablet, for instance) and places it next to the product; this action activates the previously-installed app, which automatically reads the NFC tag's unique identifier t_{id} and prompts the user to read the product's bar code, from which the product's ID p_{id} is retrieved (1); the app then connects to $Shop$'s server, and retrieves product information p_{info} (which may include price, item description, etc.) from the store's database; t_{id} and p_{id} are also compared in order to mitigate fraud attempts (2).

After checking the retrieved p_{info} on the app's interface, $Alice$ is prompted with a *"Buy it"* button. By clicking it, she allows the app to connect to any previously-configured third party payment services, and to transfer funds to $Shop$'s seller account. Upon a successful transaction, the electronic receipt is forwarded by the app to $Shop$'s server, which only then retrieves a secret kill password t_{key} associated with t_{id} from the store's database and sends it back to the mobile device (3). Finally, the app sends t_{key} to the NFC tag, which compares it to a secret kill password locally stored in an unreadable region in the tag's memory module. If this value matches the received t_{key}, the tag's anti-theft EAS feature is disabled and a "Purchase Completed" message is sent back to the app, as well as an electronic receipt of purchase (4). $Alice$ can now safely leave the store without triggering the EAS portals's alarm.

Since $Shop$'s database system associates every tag to a particular product, inventory information is kept up-to-date and conflicts in the local store records can be trivially avoided. As for security requirements, one relevant aspect of the proposed tag – with logistical impacts in deployment – is that fraud resiliency is mostly kept "out of the tag" by design. This means that most of its security features are intentionally designed

Fig. 1. NFC-enabled model for decentralized purchases.

at software level, on the retailer's server side, by employing appropriate cryptographic protocols for the transmission of sensitive data between the retailer's servers and $Alice$'s mobile device.

Nevertheless, the critical EAS feature deactivation step is designed as a challenge-response-based mechanism, in which the challenge is a randomly-chosen number, pre-programmed on the tag by its manufacturer and shared only with $Shop$'s manager; the correct response is only retrievable by $Alice$'s device upon a successful payment, and only from $Shop$'s server – as opposed to being retrievable from the tag itself.

III. NFC-enabled EAS tag design

In this section, we detail the design aspects of the NFC tag required for our solution. The tag comprises an antenna, which is common both to its NFC and EAS functions. This can be accomplished with a diversity circuit, which enables the tag to work with near field (i.e., 13.56 MHz) signals defined by the NFC standard, as well as the far field frequency employed by current anti-theft portals. Figure 2 illustrates the tag's simplified design.

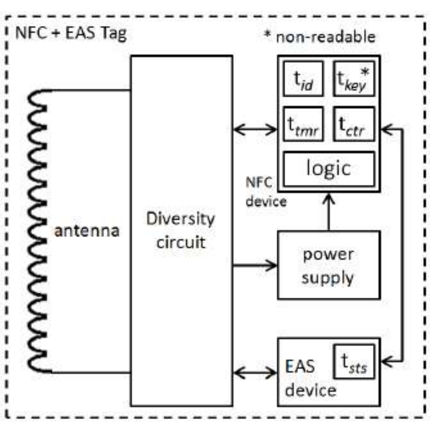


Fig. 2. NFC-enabled EAS tag.

The NFC tag is a passive device that, in order to operate, harvests energy from the electromagnetic field generated by the reader – which is either the user's mobile device or the EAS portals. This energy harvesting is performed by the power supply module. As for its logic part, it comprises a simple state machine implementing a sub-set of the SNEP [6] protocol.

All tag-protagonized protocols are simplified in order to allow substantial simplification of the associated electronic components (relatively to, e.g., a standard NFC tag) and hence reduction of production costs. On the client side, communication with the tag uses only electronic hardware already available, by using the NFC Forum's Simple NDEF Exchange Protocol (SNEP) [6] – a stateless request/response protocol implemented in many smart phones and typically used to push contacts information or web page URLs to other devices.

In order to increase robustness against side channel attacks, the tag's electronic circuit can be implemented as to require identical current consumption and processing times – despite dealing with correct or incorrect t_{key}s. As for brute force attacks, we envision a lockout timer t_{tmr} and a counter t_{ctr}, which renders malicious successive attempts to guess the correct t_{key} too slow to be effective. Finally, since t_{key} is not computable by the client from any available information, no known cryptographic vulnerability can be exploited.

IV. Conclusion

We presented an NFC-enabled EAS tag and associated sales model which, we believe, has the potential of increasing positive customer experience by decentralizing product checkout and thus eliminating buyer's need to enter a line in order to complete their purchase. Our proposed model relies on standard protocols and state-of-the-art e-commerce features, in an attempt to simplify the proposed tag's design and thus reduce both implementation costs and risk of fraud.

The described model does not require significant modifications in currently-available retail infrastructure, and relies on already-deployed multiple purpose devices on the client side – thus being effectively low cost. As for security, we discussed traditional malicious approaches and how both system and tag are able to mitigate them with low cost, logistically friendly design approaches.

In summary, the proposed system is able to provide fraud-resilience with no more than a standard NFC tag enhanced with EAS resonance mechanism, and minimum storage capabilities. This not only simplifies tag implementation, but also allows tag production costs to be kept close to current EAS tags. We also note that, other than the tag itself, standard equipment (such as detection portals and servers, for instance) currently employed by retailers adopting traditional EAS models is compatible with the proposed solution, thus essentially reducing migration costs to software implementation and personal training.

References

[1] A. Stone, *Why waiting is torture*. New York Times, August 18th, 2012. *Online: Last accessed in August 8th, 2014.*

[2] N. Janakiraman, R.J. Meyer and S.J. Hoch, *The Psychology of Decisions to Abandon Waits for Service*. Journal of Marketing Research, 48(6):970–984. 2011.

[3] D.H. Maister, *The psychology of waiting lines*. Harvard Business School, pp. 71–78. 1984.

[4] K.L. Katz, B. Larson and R.C. Larson, *Prescription for the waiting in line blues: Entertain, enlighten and engage*. Sloan Management Review, 32:44–53. 1991.

[5] A. Pruyn and A. Smidts, *Effects of waiting on satisfaction with the service: Beyond objective time measurements*. International Journal of Research in Marketing, 15:321–334. 1998.

[6] *Simple NDEF Exchange Protocol*. NFC Forum, technical specification (aug, 31). 2011.

LNA Practical Design Method for RFID Readers

Andreia Ap. de C. Alves, Leonardo L. Bravo-Roger, Member, IEEE
Telecommunication Division School of Technology-UNICAMP
Limeira, Brazil
a116142@dac.unicamp.br, leobravo@ft.unicamp.br

Hugo E. Hernández-Figueroa, *Senior Member, IEEE*
Departament of Microwaves and Optics (DMO)
13083-970, Campinas-SP, Brazil
hugo@dmo.fee.unicamp.br

***Abstract*— A step by step of method is presented for the design of an Low Noise Amplifier (LNA), used in a RFID reader receiving stage operating in the S-band**

Keywords—RFID; Reader; HFSS; Designer; LNA.

I. INTRODUCTION

For most of the RFID reader, requirements for minimize noise are extremely severe since it can cause errors in the signals processing. For this reason the signal amplification should be in the linear regime and incorporating the lowest noise power as possible. Achieve this objective involves the design of linear Low Noise Amplifier (LNA) [1] - [2].

The linearity and the operation with lowest Noise Figure (NF) can contribute to the RFID reader Signal Noise Ratio (SNR) optimization [3], but these parameters are not the only requirements that must fulfill the LNAs when operating in RFID reader. Low return losses at the entrance of the device (S11 parameter as small as possible), high gain, stability (Mu parameter greater than unity), and usually large bandwidth to operate in the microwave range are also required.

These requirements are not easy to achieve, if we take into account that the majority of transistors available has a frequency behavior such that the optimal conditions for impedance matching (given by ΓMS parameter) are very different from the optimal conditions for low noise operation (parameter ΓOPT). If we represent both parameters, ΓMS and ΓOPT, in a Smith Chart, the points corresponding to these parameters are quite distant from each other. For this reason, usually when we prioritize noise performance, we reach a poor impedance matching input and consequently undertakes the amplifier power gain. Commonly the LNAs are project with minimum noise figure, low gain and mismatched at the entrance [4]. In this article we show a practical and effective method for LNAs design, adequately satisfying the noise requirements without sacrificing the amplifier impedance matching, and this is our main contribution.

II. MATERIALS AND METHODS

The methodology for LNA's project is divided into two phases: the project approaching the RF Circuit Theory and design with electromagnetic approach.

A. *LNA design using RF Circuit Theory*

Transistor choosing and datasheet analysis

The phase using Radio-frequency Circuit Theory begins with the transistor choosing that can meet the requirements originally imposed. Properly operating in the desired frequency range, with the greatest gain and the lowest noise figure possible. Excellent simulation software for RF circuits such as ADS, ANSYS Designer, PUFF, among many others, can be used at this stage. The following requirements for the amplifier were used: Stability at all frequencies from 0 GHz to 20 GHz (Mu ≥ 1), Noise Figure (NF) less than 1 dB, impedance matching with 50 Ω lines with S11 <-10 dB and Transducer Power Gain (GT) greater than 25 dB. To meet these requirements it is necessary to make a study on the chosen transistor datasheet.

- Stability Test

For such, a model in ANSYS Designer software, where the transistor is represented by its S-parameters and the Mu parameter behavior is simulated on and out of the LNA operation band.

If Mu <1 in some frequency range, it is concluded that the transistor is potentially unstable [3]. Commonly transistors are potentially unstable in some frequency range. In RFID reader applications is unacceptable working with a potentially unstable device. There are several stabilization techniques [4]. In this project, the applied stabilization technique use a resistor in series with the transistor [2]. To prevent that the device total gain can be compromised, is necessary to ensure stability with a resistor whose value is minimum as possible.

- LNA design strategy

The strategy proposed for the LNA designing, satisfying all requirements imposed is shown in Fig. 1. The idea is to design the amplifier initial stage making use of a balanced structure, commonly used in power amplifiers [2] and then put another output stage to achieve the required gain. In Fig.1, A is a 3 dB hybrid; B is the Gate bias network and impedance matching for minimum noise figure; C is the stabilized transistor, D is the network impedance matching on output of the first stage; E is the bias network of Drain; F is the hybrid isolated port load and L is the impedance matching network at second stage output.

A hybrid input acts as power divider. The input signal with power P is applied to port 1 and exits with power P / 2 by the doors 2 and 3. The B and C blocks are designed to ensure minimum noise figure, this strategy does not always coincide with maximum power transfer conditions, required for high gain values. In practical terms this means that the LNAs are commonly mismatched amplifiers at the input.

This article demonstrates that placing a input hybrid is possible to solve this problem. The reflections produced by the impedance mismatch from the blocks B and C of Fig.1 enter in the hybrid ports 2 and 3 in the opposite direction. Both the reflected signals are added with opposite phases in the hybrid isolated port (block F). On port 1 the reflected signal comes through the port 2 add in phase with the input signal. Thus, the amplifier input port (hybrid port 1) does not suffer the reflections adverse effect, which means that in practice the amplifier input is matched and therefore this return loss will be minimized.

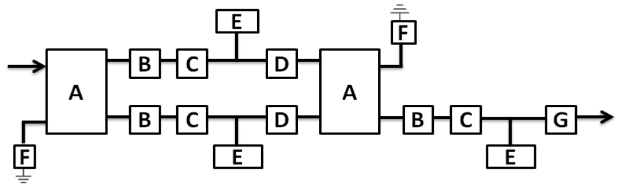


Fig. 1. LNA circuit project strategy.

With the strategy proposed project on the previous-or fully based on Circuit Theory RF section, one can obtain preliminary results for the performance of the LNA which are theoretical targets to be achieved in electromagnetic design. The behavior of the LNA main parameters respect to the frequency, meaning, stability (Mu), noise figure (NF), gain and matching (S11), are shown in the Fig. 2.

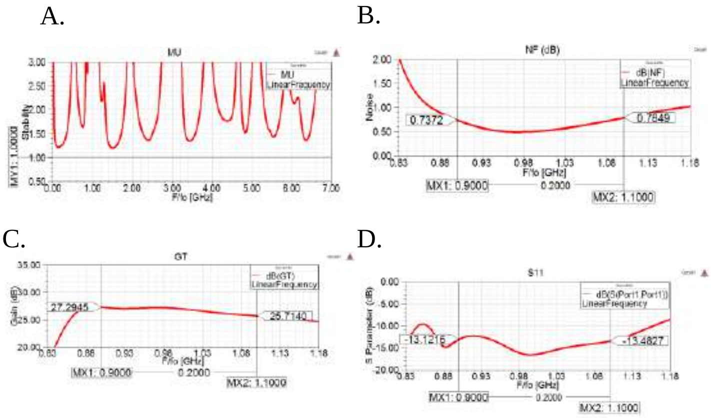


Fig. 2. Response of the LNA main parameters respect to the frequency in circuite analisys: (A) stability, (B) noise figure, (C) power gain and (D) impedance matching.

B. Design LNA with electromagnetic approach

The final stage of the LNA design is the electromagnetic analysis of their behavior. This phase gives preliminary assembly of the prototype and extremely important to define the amplifier layout showed in Fig. 3. The repercussions on the performance of the LNA caused by the spatial arrangement of the pieces, bends of the trails, holes in the plate, height PCB, solders, metal walls of the chassis, effects of the device box and others details can be provided and adjusted at this stage.

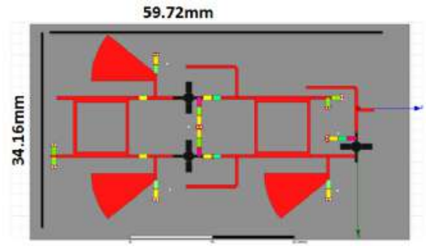


Figura 3. Layout of LNA

There are extremely accurate and reliable electromagnetic simulators to perform this task, among the best known are HFSS, CST Microwave Studio, FEKO, XFdtd, Empro, QuickField, etc. Fig. 3 provides electromagnetic results simulations of the LNA.

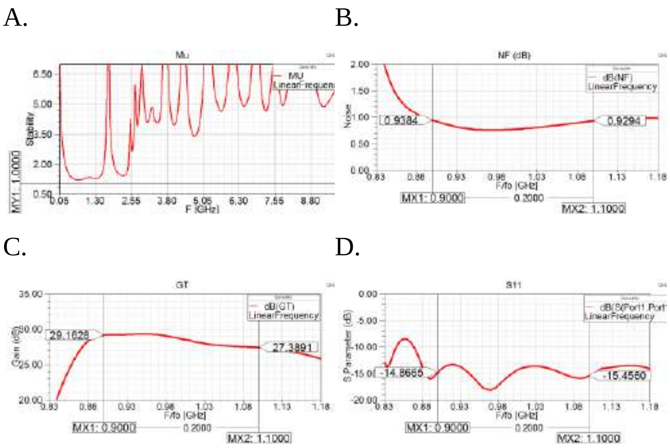


Fig. 3. Response of the LNA main parameters respect to the frequency in eletromagnetics analisys: (A) stability, (B) noise figure, (C) power gain and (D) impedance matching.

VII. CONCLUSIONS

A method for the design of LNA amplifiers in S band was offered. First was realized the design and simulation using the Theory of RF circuits. This phase establish goals for the parameters of the LNA. The simulation results are used as theoretical reference to be achieved in practice. The second stage is to assay of the LNA layout using electromagnetic simulator where is possible to make the final adjustments of the device manufacturing. The electromagnetic simulations showed that all requirements initially proposed used obtained with this methodology.

References

[1] E. da Silva (2001) High Frequency and Microwave Engineering, Butterworth–Heinemann, London.

[2] Guillermo Gonzalez (1997) Microvave transistor amplifier: analysis and design,Prentice Hall, New Jersey.

[3] Application Note, Agilent Technologies, Inc. (2011) at http://cp.literature.agilent.com/litweb/pdf/5990-7527EN.pdf.

[4] Rowan Gilmore , Les Besser (2003) Practical RF circuit design for modern wireless systems,2: 32-33, Artech House, Norwood, MA.

Integrated environment for testing IoT and RFID technologies applied on Intelligent Transportation System in Brazilian scenarios

Leal, Adriano Galindo, leal@ipt.br, Member, IEEE
Santiago, Alessandro, alesan@ipt.br
Miyake, Mario Y, mymiyake@ipt.br
Noda, Mauro K., mknoda@ipt.br
Pereira, Matheus J., mjacon@ipt.br
Avanço, Leandro, lavanco@ipt.br
IPT - Institute for Technological Research, Brazil

***Abstract*—Brazil is approving a series of new regulations, standards for RFID and IoT components applied in transportation scenarios. At this stage, there is already a need for interoperability and Brazilian regulators require that interoperability should satisfy recognized standards such as NTCIP, SINIAV, and ISO/IEC 18000-6. Although there have been published studies for the higher evolutionary level of IoT, much more are needed on the standardization of interfaces and communication protocols. The infrastructure created at IPT will grow to allow testing of products, environments, services, and innovative RFID solutions with applications in the context of the Internet of Things. This laboratory infrastructure is designed for teaching and research purposes, and the next stage involves the connection with experimental networks of Future Internet, enabling researchers, teachers, and students to conduct experimental research using innovative technologies offered by these networks. In this way, we can form a critical mass of knowledge and skills needed to identify and seize new business opportunities, mainly in V2I and V2V environment.**

Keywords—IoT; Smart Cities; ITS; RFID, V2I, V2V, Testbed.

I. Introduction

According to [1], an IoT device is defined as the system entity having as its main task to interface the physical world. Interfacing the physical world means that the device can have the capability to monitor and control physical world properties, and to provide identity information about an entity. The device hence represents a fundamental building block of an IoT-oriented system.

The evolution of ubiquitous computing technology is summarized on [2], where we can describe the following evolutionary steps:

- Intranet of Things – The Thing provides reactive and proactive data. Most of the communication occurs between Things, where the human is a consumer and the Thing is a provider of data;
- Internet of Things – On this level, as before, things provide reactive and proactive data, however, humans offer reactive data like the current location by sensing or tagging. Most of the communication is human-to-human and thing-to-thing, were the later has the ability of sensing local/global environment by collaboration with other things, using local/global information. In this context, things are both consumer and producer of data. Humans are mostly consumer of data;
- Social Internet of Things – On this level, both humans and things are consumers and providers of reactive and proactive data. Hence, all types of duplex communication are possible: Human-to-Human, Thing-to-Thing, and Human-to-Thing. This scenario generates highly useful information by collaborating with other things and analyzing needs of humans, using the information they provide, e.g., needs, interests, locations, demographic properties, relationship characteristics, etc.. It emerges from union of IoT and Social Networks features and a framework to combine users, devices and services to govern.

In [3], the Internet of Things Architecture project (IoT-A) aims at creating an architectural reference model and key building blocks for the Internet of Things in order to bring together disjoint intranets of things into the IoT. In addition to encompassing the scope of existing intranet of things solutions, the IoT-A reference model also aims to address the issues of future scalability and privacy and security. The IoT paradigm aims at connecting anything, at anytime, from anywhere [2].

Nowadays, most of the commercially available solutions are on the first level, Intranet of Things [4]. All the devices and the data are inside your local network, hidden behind a firewall and locally controlled and for remote access, there is a single channel, not one per device. In addition, there are solutions where every device creates a connection to a cloud service, which enables the Things to be controllable through an app from anywhere in the world. All those things and services could be meshed inside an architecture that enables new services for citizens of Smart Cities offering a new approach for optimizing services, reducing costs, and simplifying the management [5].

RFID technology is one of the enabling technologies of IoT, and no longer limits itself to do only product identification. The new RFID applications in the context of Internet of Things involve technologies, in the experimental stages of development even in developed countries, mainly in the transport sector. As an example, in [6] is proposed a new vehicle emission inspection and notification system to help daily monitoring of engine emissions through RFID devices.

In transportation scenarios, RFID has been deployed inside Intelligent Transport Systems (ITS) applications to provide better mobility experience. These systems involve vehicles, drivers, passengers, road operators and regulators, besides covering the interactions between these components and the environment, linking them to core infrastructures [7]. Brazil is passing a new moment of definition, regulations and standardization, like ISO/IEC 18000-6 technologies for vehicle/cargo identification, NTCIP for interoperability of ITS equipment etc. These open opportunities to innovative solutions, however need exhaustive operational and conformance tests to deploy RFID or IoT technologies in applications for V2I (vehicle-to-infrastructure) and V2V (vehicle-to-vehicle) communication.

II. Creation of Testbed for ITS Solutions

Due to all present and future evolutions, IPT created a laboratory to perform conformance of RFID technologies in ITS scenarios. At present, we perform conformance tests for tags and readers, for example, in accordance with ISO/IEC 18000-6 and ISO/IEC 18000-63; ISO/IEC 14443 Type A and B contactless smart card standard. In addition, this Lab also allows the running of experiments with components moving at speed up to 40 Km/h, in real measurement, or up to 120 Km/h in simulated mode (Figure 1).

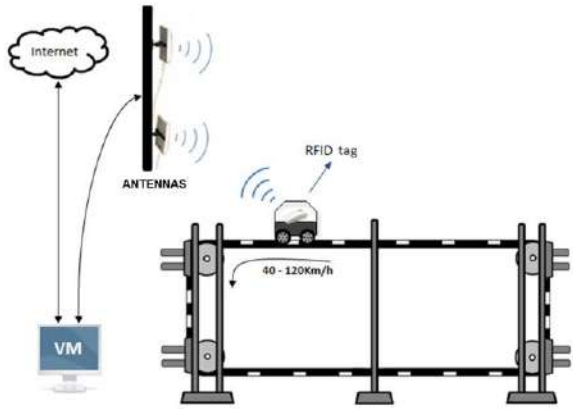


Figure 1 - Software and hardware infrastructure

Furthermore, intends to create a multidisciplinary research environment, by allowing remote users for experimental test and validation of highly innovative ideas for high-level V2I, V2V and RFID solutions. Thus, remote users will access infrastructure to demonstrate the behavior of solutions especially designed to satisfy Brazilian national standardsfor vehicular identification (SINIAV) and DSRC technology for V2V/V2I (Figure 2).

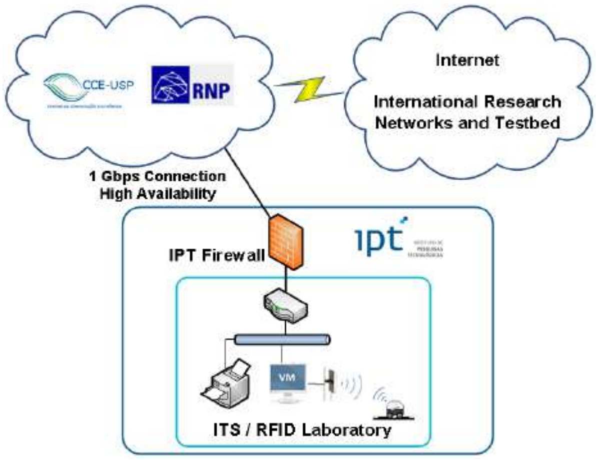


Figure 2 – Connection with Research Networks

III. Conclusions and Future Works

In the next steps of the Project, IPT plans to devise a set of operational procedures to offer remote integration with Future Internet testbeds. This extended testing infrastructure will allow the running of experimental research to explore and develop innovative RFID solutions inside IoT and ITS applications. our policy is to share our facilities not only with our partners, but also to attract technology and solution providers who want to perform tests and pilots of ITS applications.

References

[1] T. I. o. T. Initiative, "First Reference Model White Paper," [Online]. Available: http://www.iot-i.eu/public/public-deliverables/D1.2/at_download/file. [Accessed 28 07 2014].

[2] A. Ortiz, D. Hussein, S. Park, S. Han and N. Crespi, "The Cluster Between Internet of Things and Social Networks: Review and Research Challenges," *Internet of Things Journal, IEEE,* vol. 1, no. 3, pp. 206-215, June 2014.

[3] J. (. Walewski, "Initial Architectural Reference Model for IoT," 2011. [Online]. Available: http://www.iot-a.eu/public/public-documents/d1.2. [Accessed 28 07 2014].

[4] M. Zorzi, A. Gluhak, S. Lange and A. Bassi, "From today's INTRAnet of things to a future INTERnet of things: a wireless-and mobility-related view," *Wireless Communications, IEEE,* vol. 17, no. 6, pp. 44-51, December 2010.

[5] M. Fazio, M. Paone, A. Puliafito and M. Villari, "Heterogeneous Sensors Become Homogeneous Things in Smart Cities," in *Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on* , Palermo, Italy, 2012.

[6] C.-M. Vong, P.-K. Wong, K.-I. Wong and Z. Ma, "Inspection and control of vehicle emissions through Internet of Things and traffic lights," in *Connected Vehicles and Expo (ICCVE), 2013 International Conference on*, Las Vegas - Nevada - USA, Dec. 2013.

[7] B. Williams, Intelligent Transport Systems Standards, 1ª ed., vol. 1, Norwood, MA: ARTECH HOUSE, INC., 2008, p. 839.

Experimental Radiation Pattern Analysis of a Text Antenna for RFID IC Transponders

E. Bolzan, H. X Araujo, I. R. S. Casella, A. J. Sguarezi Filho, and C. E. Capovilla

***Abstract*—In this work, an experimental radiation pattern analysis of a text antenna based on meander-shape dipole structure is presented. The use of text antennas can bring interesting technological advantages in terms of advertising, marketing and logistics. The planar antenna operates at UHF band and its shape is designed to represent the name of the Universidade Federal do ABC (i.e. Federal do ABC - UFABC). The radiation pattern performance of the antenna is evaluated by measurements in a tested built prototype inside at UFABC anechoic chamber.**

***Index Terms*—Planar antennas, dipole antennas, meander lines, RFID integrated circuit.**

I. Introduction

The wireless remote sensor applications have become a great source of knowledge and technological innovations. The Radio Frequency IDentification (RFID) has been used on a large scale, and now, has become an important tool applied in logistics operations. The RFID antennas, operating in the Ultra High Frequency (UHF) band, can assume different shapes, depending on its application [1], [2]. One interesting class of antennas that can be used for RFID applications is the meander line antennas [3], [4]. They were proposed in [5] as an attempt to reduce the physical size of the antenna by folding the antenna in sections, so that, its resonant frequency is reduced when compared with a similar one of the same physical length [6]. In this context, we present an experimental radiation pattern analysis of a text antenna, operating in the range of 900 MHz to 940MHz (UHF band), based on a meander line structure that represents the name of the Universidade Federal do ABC.

II. Text antenna at UFABC anechoic chamber

Among several options of antennas available for RFID applications, the use of text format antennas is quite unique [7] since they are based on non-uniform meander lines. Brand names or logos can be used to make the radiating element for RFID tags, which gives an additional value to their tags as a high-tech advertising [8]. The analyzed antenna, presented in Figure 1, was designed on a FR-4 substrate (ε_r=4,4, δ=0,018 and $h = 1,6$mm). It was chosen due to its easy acquisition and low cost prototyping [9].

The simulations were performed using the Method of Moments (MoM), taking into account all the required boundary conditions (lack of ground plane, substrate with finite dimensions, and differential input signal). In order to optimize the prototype, an iterative process was used. The letters spacing, line thickness, and axial length were optimized for the desired frequency range between 900 and 940 MHz. The optimized axial length is 98 mm, a reduction of 24% in comparison with the half-wave dipole. This size reduction is due to the meander shape that the letters have applied to the antenna structure.

Figure 1: Photography of the built antenna (98 x 6.5 mm).

The connection between the antenna and the network analyzer was performed by a balun (balanced-unbalanced), which was designed with RG316 coaxial cable. In general, the nominal permittivity value of the substrate is not accurate enough for the design of planar antennas. However, it can be noted in Figure 2 that the simulated and measured results are in complete agreement with the resonance frequency of 920MHz, showing that, for this prototype, ε_r is tending to the typical value. The simulated bandwidth is around 7.5% (888 MHz to 957 MHz), while the measured one is 4% (900MHz to 937MHz) for a $S_{11} \leq$ -10dB criterion. This reduction of the measured bandwidth is caused by the intrinsic characteristics of the employed balun (50Ω coaxial cable). To prove this hypothesis, it is shown also in Figure 2 a new simulation result considering the effect of the balun. We can see perfectly the reduction in the bandwidth caused by the balun and the similarity of the simulated and measured results.

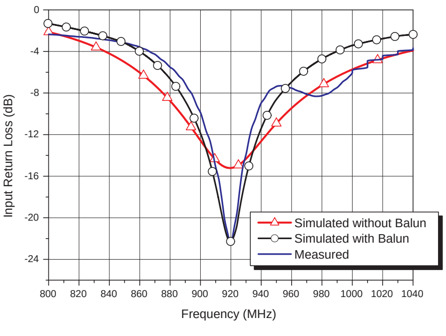
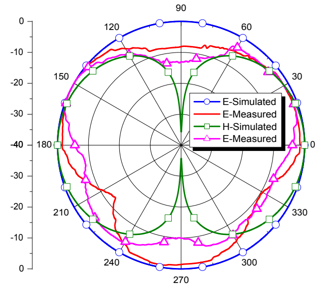


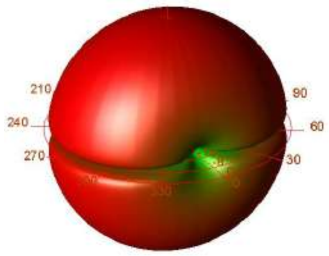
Figure 2: Simulated and measured results of antenna input return loss.

E. Bolzan, I. R. S. Casella, A. J. Sguarezi Filho, and C. E. Capovilla are with the Universidade Federal do ABC - UFABC, Brazil. E-mails: evandro.bolzan@aluno.ufabc.edu.br, ivan.casella@ufabc.edu.br, and carlos.capovilla@ufabc.edu.br H. X Araujo is with the Universidade Federal de Sao Joao del Rei - UFSJ, Brazil. E-mail: hxaraujo@ufsj.edu.br

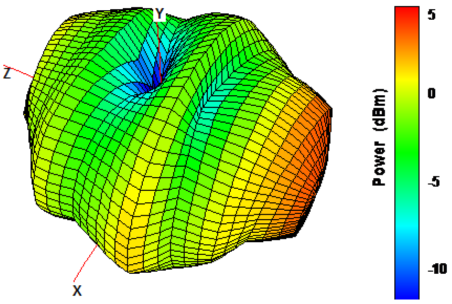
In Figure 3(a) is presented the simulation and measurement results of the E-Plane and H-Plane radiation patterns, for the antenna at 920 MHz (normalized). Through the analysis of the radiation pattern, it can be observed that the antenna is linearly polarized, with the E plane (E-CoPol) predominant at the substrate, and the H plane (H-CoPol) normal to the substrate. The simulated radiation pattern results are in agreement with the measured ones, showing the efficacy and ensuring the functionality of the prototype. The cross polarization fields (E-Xpol and H-Xpol) are at least 25 dB below, ensuring a good purity for the linear polarization of the antenna. Figure 3(b) presents another radiation pattern view, where a 3D simulation of the antenna pattern is shown.



(a) 2D



(b) 3D - Simulated



(c) 3D - Measured

Figure 3: Simulated and measured antenna results of radiation pattern at 920MHz.

Completing the radiation pattern analysis, it is presented in Figure 3(c) the measured 3D antenna pattern. The resulting pattern looks kind of like a nonhomogeneous bagel radiating energy outward. The strongest energy is radiated outward, perpendicular to the antenna in the x-y plane.

This nonhomogeneous behavior is due to the letters of the dipole as a text line meander. Notice that the patterns in any orthogonal plane (any plane, actually) are directional, and so, this antenna meets an omnidirectional behavior. Besides, it can be seen that the antenna has quasi-omnidirectional behavior, which evidences and ensures its good behavior as a radiator element for RFID transponders. These results demonstrate that the antenna keeps the good characteristics of a traditional dipole, even on the meander shape.

As illustrated in Figure 4, the 3D radiation pattern measurements were performed in the anechoic chamber (7.6m x 3.1m x 3.1m) installed inside the Laboratory of Information and Communication (LIC) at UFABC. This chamber was fabricated by ETS-Lindgren (Spacesaver H26 Model - up to 18 GHz) with Rodhe & Schwarz equipments. Both, the transmitting horn antenna (EQ3117 Model) and the prototype, were positioned inside the quiet zone, defined as an imaginary sphere where the antennas must be placed inside to guarantee that the level of the reflected signal is less than 30dB [10]. Also, in this chamber, the electromagnetic field uniformity is less than 6 dB and the normalized site attenuation is less than +/- 4 dB in the range from 1 GHz to 18 GHz.

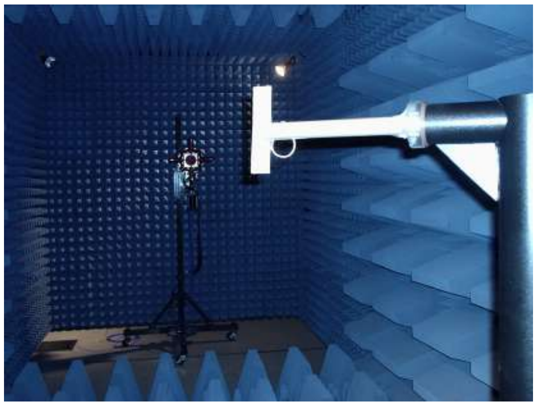


Figure 4: Text antenna at UFABC anechoic chamber.

III. Conclusion

The analyzed text antenna presents at 920MHz a bandwidth around 40MHz. Regarding to the radiation pattern, its behavior is quasi-omnidirectional, like a normal dipole, for both E and H planes. The radiation pattern results are satisfactory for both planes as well. In this context, the analyzed text antenna is fully operational for low cost RFID applications and is suitable for transponders with needs or desires a marketing appeal in UHF band.

References

[1] G. Marrocco, “The art of UHF RFID antenna design: impedance-matching and size-reduction techniques,” *IEEE Antennas and Propagation Magazine*, vol. 50, no. 01, pp. 66–79, 2008.
[2] E. Perret, S. Tedjini, and R. S. Nair, “Design of antennas for UHF RFID tags,” *Proceedings of the IEEE*, vol. 100, no. 07, pp. 2330–2340, 2012.
[3] C. Calabrese and G. Marrocco, “Meandered-slot antennas for sensor-RFID tags,” *IEEE Antenas and Wireless Propagation Letters*, vol. 07, pp. 05–09, 2008.
[4] O. O. Olaode, W. D. Palmer, and W. T. Joines, “Effects of meandering on dipole antenna resonant frequency,” *IEEE Antenas and Wireless Propagation Letters*, vol. 11, pp. 122–125, 2012.
[5] J. Rashed and C.-T. Tai, “A new class of resonant antennas,” *IEEE Transactions on Antennas and Propagation*, vol. 39, pp. 1428–1430, September 1991.
[6] Y. Sato and T. Fukusako, “Low-profile and electrically small meander-line antenna using a capacitive feed structure,” *IEEE Antenas and Wireless Propagation Letters*, vol. 11, pp. 1281–1284, 2012.
[7] M. Keskilammi and M. Kivikoski, “Using text as a meander line for RFID transponder antennas,” *IEEE Antenas and Wireless Propagation Letters*, vol. 03, pp. 372–374, 2004.
[8] A. M. A. Salama, *Antennas of RFID Tags*. In-Tech, 2010.
[9] L. C. Kretly and C. E. Capovilla, “A novel antenna array based on quasi-yagi element for adaptive wireless system applications,” *IEEE International Microwave and Optoelectronics Conference*, vol. 01, pp. 307–312, September 2003.
[10] H. Arai, *Measurement of a Mobile Antenna Systems*. Artech House, 2001.

Applications of RFID and WSNs Technologies to Internet of Things

Leonardo B. Campos
Escola Politécnica
University of São Paulo, USP
Instituto Federal de Educação, Ciência e Tecnologia da Bahia, IFBA
Vitória da Conquista, Brazil
leonardobcampos@ifba.edu.br

Carlos E. Cugnasca
Escola Politécnica
University of São Paulo, USP
São Paulo, Brazil
carlos.cugnasca@poli.usp.br

***Abstract*—Abstract— Internet of Things is identified as one of the main pillars to next-generation Internet. Two technologies supporting this technological advancement are Radio Frequency Identification and Wireless Sensor Networks. They are used to automatically identify people, objects, and animals, as well as monitoring environmental parameters, and area monitoring. Thus, this article presents five areas of applications of these technologies in the Internet of Things context. Internet of Things is verified to go beyond the ubiquitous availability of computing infrastructure.**

Keywords—Internet of things, RFID, WSNs, pervasive computing.

I. INTRODUCTION

The interconnection between objects through the Internet has attracted much attention from researchers and companies across the world [1][2]. In this context, the term "Internet of Things" (IoT) is broadly used to refer to the presence of things or objects around people that, through a single addressing scheme, are able to interact with each other and to cooperate with their neighbors to achieve common goals [3]. In the Hype Cycle for Emerging Technologies report released in 2014 by Gartner's, the IoT is the most over-hyped technology in development today [4]. According to [5] the International Data Corporation (IDC), the number of things connected to the Internet exceeded the number of people on earth in 2008, see Figure 1.

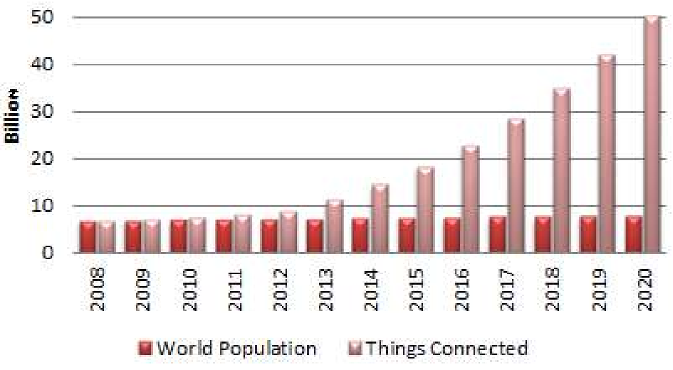


Fig.1. Growth of 'things' connected to the Internet and world population.

In this scenario, two technologies have enabled the advancement of IoT : Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSNs). RFID technology allows identifying objects and capturing data without the need of a visual field between reader and identifier (tag). In addition, the Electronic Product Code (EPC number) provides a unique identity to every physical object [6]. WSNs allows monitoring environment parameters, such as temperature, relative humidity, soil water potential, light, atmospheric pressure, etc. [7]. Thus, an increasing number of applications have emerged based on the IoT paradigm.

After an extensive literature review, by examining relevant articles from five major academic databases (IEEE Xplore, ISI Web of Knowledge, ACM digital library, INSPEC, and ScienceDirect), the applications of RFID and WSNs technologies for IoT were grouped into five categories, as follows: healthcare, agriculture, logistics, smart cities, and smart home.

II. RFID AND WSNS APPLICATIONS IN THE IOT CONTEXT

This Section shows the main applications described in academic articles according to relevance, based on number of citations, frequency of applications in the same area, and recent year of publication.

A. Healthcare

Most applications focus on Body Area Network (BAN), also referred to as Body Sensor Network (BSN) or a Wireless Body Area Network (WBAN). Sensors are used to monitor parameters, such as blood pressure, body temperature, breathing activity. To that end, sensors may be entirely within, on, and in the immediate proximity of a human body in pockets, by hand, etc. Through gateway devices, it is possible for medical professionals to access patient data online. Therefore, there are applications that involve patient surveillance, fall detection, and medical fridges [8].

B. Agriculture

Applications in the field of agriculture that use RFID, sensors, actuators and their network are now at advanced stages [9][10]. This contributed to an increase in varieties of terminologies currently in use, such as Precision Agriculture (PA), Smart Agriculture, Variable Rate Technology (VRT), Precision Farming, Global Position System Agriculture, Farming by Inch, Information-Intensive Agriculture, Site Specific Crop Management, etc. [11]. In this context, the following application areas are taken into consideration:

irrigation [12], food traceability [13], animal identification and tracking [14][15], and viticulture [16].

C. Logistic

The use of RFID and WSNs technologies supports logistics in a very positive direction [17]. Combining logistics and IoT enable real-time optimization and distribution systems. Nearly every fact in a company, from identifiers and ubiquitous sensors, is available instantaneously. Current applications include, among others, storage incompatibility detection [18], Real-Time Location System (RTLS) [19], and quality of shipment and tracking conditions [20].

D. Smart Cities

The adoption of the IoT paradigm on a wider scale finds applications in many different domains and contexts of a City, [21]. In a recent paper [22], published in 2014, nine IoT applications in smart cities are presented, as follows: structural health of buildings, waste management, air quality, noise monitoring, traffic congestion, city energy consumption, smart parking, smart lighting, and automation and salubrity of public buildings.

E. Smart Homes

Wireless home automation networks (WHANs) enable monitoring and control applications for home user comfort and efficient home management. WHANs enable a variety of use cases, as presented in [23], with a non-exhaustive list of examples: light control, remote control, remote care, besides security and safety.

III. Conclusions And Final Remarks

The peak of inflated expectations around the Internet of Things has stimulated the search for more and more applications. This paper showed a large number of solutions and contexts in which RFID and WSNs technologies are used. However, implementing IoT involves a multitude of challenges, such as huge volumes of data, privacy, interoperability, and standards.

Acknowledgment

The authors acknowledge the financial support and motivation provided by IFBA (Instituto Federal de Educação, Ciência e Tecnologia da Bahia), Brazil, and by CNPq (National Council of Scientific and Technological Development) to a research fellowship (142160/2013-0) and support to research project (485847/2013-2).

References

[1] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, “Internet of Things (IoT): A vision, architectural elements, and future directions,” Future Generation Computer Systems, 2013.

[2] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Computer Networks, vol. 54, pp. 2787-2805, 2010.

[3] D. Giusto, A. Iera, G. Morabito, and L. Atzori, The Internet of Things: 20th Tyrrhenian Workshop on Digital Communications: Springer Heidelberg, 2010.

[4] Gartner’s hype cycle special report for 2014, Gartner Inc., 2014. http://www.gartner.com/technology/research/hype-cycles/

[5] International Data Corporation (IDC). Worldwide smart connected device shipments, March 2012. Available from: http://www.idc.com/getdoc.jsp?containerId=prUS23398412 [01 August 2012].

[6] X. Jia, Q. Feng, T. Fan, and Q. Lei, "RFID technology and its applications in Internet of Things (IoT)," in Consumer Electronics, Communications and Networks (CECNet), 2012 2nd International Conference on, 2012, pp. 1282-1285.

[7] L. Mainetti, L. Patrono, and A. Vilei, "Evolution of wireless sensor networks towards the internet of things: A survey," in Software, Telecommunications and Computer Networks (SoftCOM), 2011 19th International Conference on, 2011, pp. 1-6.

[8] Z. Pang, J. Tian, and Q. Chen, "Intelligent packaging and intelligent medicine box for medication management towards the Internet-of-Things," in *Advanced Communication Technology (ICACT), 2014 16th International Conference on*, 2014, pp. 352-360.

[9] L. Ruiz-Garcia and L. Lunadei, "The role of RFID in agriculture: Applications, limitations and challenges," Computers and Electronics in Agriculture, vol. 79, pp. 42-50, 10// 2011.

[10] A. Z. Abbasi, N. Islam, and Z. A. Shaikh, "A review of wireless sensors and networks' applications in agriculture," Computer Standards & Interfaces, vol. 36, pp. 263-270, 2014.

[11] A. Srinivasan, Handbook of precision agriculture: principles and applications: Food Products Press Binghamton^ eNY NY, 2006.

[12] Y. Kim, R. G. Evans, and W. M. Iversen, "Remote sensing and control of an irrigation system using a distributed wireless sensor network," Instrumentation and Measurement, IEEE Transactions on, vol. 57, pp. 1379-1387, 2008.

[13] K. Sugahara, "Traceability system for agricultural productsbased on RFID and mobile technology," in Computer and Computing Technologies in Agriculture II, Volume 3, ed: Springer, 2009, pp. 2293-2301.

[14] D. Yan-e, "Design of Intelligent Agriculture Management information system based on IoT," in Intelligent Computation Technology and Automation (ICICTA), 2011 International Conference on, 2011, pp. 1045-1049.

[15] A. S. Voulodimos, C. Z. Patrikakis, A. B. Sideridis, V. A. Ntafis, and E. M. Xylouri, "A complete farm management system based on animal identification using RFID technology," Computers and Electronics in Agriculture, vol. 70, pp. 380-388, 2010.

[16] G. Anastasi, O. Farruggia, G. Lo Re, and M. Ortolani, "Monitoring high-quality wine production using wireless sensor networks," in System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on, 2009, pp. 1-7.

[17] Y. Cheung, K. Choy, C. Lau, and Y. Leung, "The impact of RFID technology on the formulation of logistics strategy," in Management of Engineering & Technology, 2008. PICMET 2008. Portland International Conference on, 2008, pp. 1673-1680.

[18] A. Atali, H. L. Lee, and Ö. Özer, "If the inventory manager knew: Value of visibility and RFID under imperfect inventory information," Available at SSRN 1351606, 2009.

[19] M. N. K. Boulos and G. Berry, "Real-time locating systems (RTLS) in healthcare: a condensed primer," International journal of health geographics, vol. 11, p. 25, 2012.

[20] S. Mahlknecht and S. A. Madani, "On architecture of low power wireless sensor networks for container tracking and monitoring applications," in Industrial Informatics, 2007 5th IEEE International Conference on, 2007, pp. 353-358.

[21] H. Schaffers, N. Komninos, M. Pallot, B. Trousse, M. Nilsson, and A. Oliveira, Smart cities and the future internet: Towards cooperation frameworks for open innovation: Springer, 2011.

[22] A. Zanella, N. Bui, A. P. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for smart cities," IEEE Internet of Things Journal, 2014.

[23] C. Gomez and J. Paradells, "Wireless home automation networks: A survey of architectures and technologies," IEEE Communications Magazine, vol. 48, pp. 92-101, 2010.

Location Guide DV

Mori Junior, C., da Silva, F. J., Bertolino, P. V. and L. F., Delboni,
claudiomorijr@gmail.com, francislei@pucpcaldas.br, delboni@pucpcalda.br, bertolino.paulo@gmail.com
Department of Electrical Engineering PUC Minas
Avenida Padre Francis Cletus Cox, 1661
Poços de Caldas – Minas Gerais, Brasil

Abstract – The guidance system, which was named DV Location Guid. It was created to help people with blindness or low level of visual acuity to locate places and distinguish objects. The Location Guide DV uses a RFID system that provides the current location information to the user using audio waves. The system has a database of places that can be updated by a USB connection plugged in computers.

Keywords—RFID; visually impaired; orientation system;

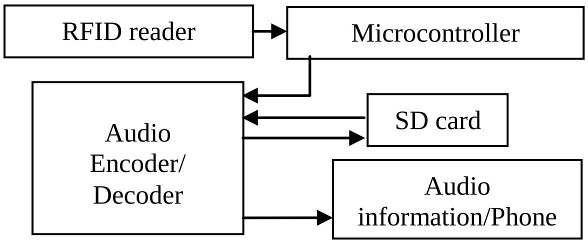
I. Introduction

The association of the RFID with technology systems nowadays is increasing qualitatively and quantitatively with the big possibilities of applications created by electronic and programmable microelectronics. Many buildings, hotels and residences have replaced traditional keys by RFID access cards because of security and easiness that the own system provides. It creates the own controlled hierarchical systems with access levels, then the access to specific sites is restricted to persons in accordance with the RFID chip personal card. The microcontroller systems in the drive allow the ability to store and report on access to local (GLOVER, Bill; BHATT) [1]. More recently, the RFID system has been used in locating products in market and industry, and livestock by the possibility of identification of animals (GOMES, Hugo Miguel Cravo) [2]. The *Location Guide DV* was designed through a partnership Association of Support for the Visually Impaired (AADV) of Poços de Caldas, Minas Gerais, who participated actively with suggestions and features to be incorporated in the prototype tests. AADV believe this product will be incorporated into the current forms of guidance used by the visually impaired, such as walking stick and guide dog.

II. Composition of Prototype

The *Location Guide DV* was designed on a ARDUINO UNO's® platform with ATMEGA's® 328P-PU microcontroller. The system of identification consists in a RFID's reader of 125 kHz model ID-12 of INNOVATIONS® produced on a board of communication of SPARKFUN's company, one MP3 VLSI® 1053 encoder/decoder of audio, which is responsible for the access to the SD's memory card, in which are stored audio files from local or identified products. The system is fed with 6V battery. The programming was done in C/C++ language and was structured in the flowchart shown in Figure 1.

Figure 1 – Flowchart of system *Location Guide DV*.



The places are identified with passive cards with a unique code, which are linked through the *Location Guide DV* system to specific audio files form SD cards location.

Figure 2 – First version of *Location Guide DV*.

The system also has external switches (buttons) that gives the user the control of the audio's intensity (with a resolution of 0.11 dB) that is connected to a headset, the battery level (low, medium and high), choice to play audio from last location set and the system's on/off. The system is set in the user's arm through adjustable elastic due the location of the reading cards that were set at heights ranging from 1.0 m to 1.5 m (Figure 2).

III. METHOD OF USE (PROTOTYPE)

For testing the *Location Guide DV*, thirteen locations and multiple access points at the corridors were identified with a RFID card in the main building of PUC Minas in Poços de Caldas. The route was defined from the main entrance, in which there was a multiple access ID card, to a course room, particularly the Physics Laboratory, in which there was a location card.

The ID cards were previously registered in a database and the location and multiple access point audio was connected to the ID of each card by software based on the same system using the RFID reader connected to the computer. The new databased, with these thirteen locations and multiple access points and the corresponding audios, was transferred to the SD card of the *Location Guide DV*.

For the first test, one of the authors had the system fixed at one arm and start to follow the previously defined route of thirteen locations and the multiple access points. It was possible to read each ID card by the RFID reader of the *Location Guide DV* when the distance between them was around 10-15 cm (Figure 3). Then the software of the system searches the corresponding audio location or the multiple access point. So the program directs the audio playback on the handset of the system to the Audio Encoder/Decoder. The user then listens to the audio which identify the corresponding location or the point in the route. The user could identify all the locations and points of the route.

Figure 3 – Tests with Location Guide DV.

A second test of the *Location Guide DV* was performed at the instalation of AADV in Poços de Caldas. The route was defined from the main entrance to the lunchroom, in which thirteen location and multiple access point ID cards were fixed. As before, a visually imparied user succesfully get the final location, identifiyng locations and multiple access points of the route.

IV. RESULTS

The *Location Guide DV* was built in a very robust platform and easily handled by the user. The database can by easy updated by a simple USB connection to a computer. The database from different installations could be accessed by the web, when the systems get in the market. Due to the operation mode, mainly in standby, the *Location Guide DV* has very low battery energy consume. This new approach for location and orientation system to visually impaired people has an advantage when compared to the usual braille identification boards.

The main difficult observed in this prototype was the very short distance between the ID card and the RFID reade, about 10 cm, needed to be identified. To visually imparied people, this distance can be a enormous problem maily in building with large spaces.

V. CONCLUSION

In this article a new location and orientation system was developd based in the RFID techmology. The *Location Guide DV* was able to provide to visually impaired person a guidance through a stabilished route, identified by ID cards along the locations and multiple access points. The system still needs improvement mainly in the distance between the user and the ID cards. In our system this distance is around 10 cm, but disntance of about a meter could provide a better accessibility in a large number of spaces. This improviment could be obtained by using active ID cards, that will be considered in our new version.

Acknowledgment

Along the development of the prototype the researchers created a bond of great importance to the people who contributed in some way, but the Location Guide DV wouldn't be developed in a satisfactory way if the members of AADV of Poços de Caldas didn't have contributed with several suggestions. This project also had the support of the Physics Laboratory at PUC Minas in Pocos de Caldas, lending the physical space, equipment and consumables, and scholarship for undergraduates Claudio Mori Junior and Paulo Vinicius Bertolino granted by PROBIC / FAPEMIG program 2013 /n 8076-15.

References

[1] GLOVER, Bill; BHATT, Himanshu. Basics of RFID. Rio de Janeiro: Altas Books, 2007.

[2] GOMES, Hugo Miguel Cravo. Construct an RFID system with delocalization special purpose. Aveiro: 2007. 90f. Dissertation (Master's degree in Electronic Engineering and Telecommunications). Universidade de Aveiro, Department of Electronic Engineering, Telecommunications and Informatics, 2007.

[3] HEIMERS, W. Como I educate my blind son? A guide to the education of children who are blind and vision impaired. São Paulo: s.n., 1970.

[4] AMIRALIAN, M. L. T. M. Compreendendo o cego: uma visão psicanalítica da cegueira por meio de desenhos-estórias. São Paulo: Casa do Psicólogo,1997.

[5] N. Bourbakis, D. Kavraki, An intelligent assistant for navigation of visually impaired people Bioinformatics and Bioengineering Conference, in: Proceedings of the IEEE 2nd International Symposium on 4–6 November, 2001, 2001pp. 200–230.

[6] K. Yelamarthi, D. Hass, D. Nielsen, S. Mothersell, RFID and GPS integrated navigation system for the visually impaired, in: IEEE Engineering and Technology, 2010, pp. 1149-1152.9.

Metamaterial-Based Antenna for RFID Applications

H. X. Araujo[1], E. Bolzan[2], I. R. S. Casella[2], C. E. Capovilla[2], and L. C. Kretly[3]

[1]Universidade Federal do Tocantins – UFT, Brazil.
[2]Universidade Federal do ABC – UFABC, Brazil.
[3]Universidade Estadual de Campinas – UNICAMP, Brazil.

Abstract— **In this work, a metamaterial-based antenna is designed to operate at 2.5 GHz for RFID applications. The proposed device is composed by a circular antenna surrounded by fractal metamaterial structures placed at strategic positions, improving bandwidth and enhancing the antenna tunability at a desired frequency. The obtained results show that the use of the proposed antenna in RFID systems is very promising.**

***Index Terms* — RFID, metamaterial, fractal.**

I. Introduction

Based on RF signals for identification of objects, the RFID (Radio Frequency Identification) technology experienced considerable progress during the last decade. In this context, many applications such as logistics, transportation and manufacturing process are nowadays demanding the RFID technology [1] for better performance.

RFID systems are composed by a transponder (tag) and a reader, and are classified according to parameters such as operational frequency, range and communication between the tag and the reader. Normally, the reader has one antenna or an array of antennas, and the tag consists of an IC RFID connected to the tag antenna.

Previously, RFID tags were developed in such a way that battery was required to supply the necessary power to the integrated circuits. However, the present great challenge is to develop tags as small as possible having only the room for mounting a passive (without battery) RFID circuit. Therefore, based on backscattering [2,3], all the energy required by the passive tag to operate, comes from the carrier signal transmitted by the reader.

The RFID is one of several applications of circular antennas. The circular antenna shows good response over its bandwidth that can be even better when associated with metamaterial structures. The basic metamaterial cells pattern employed here consists of a periodical arrangement of pairs of cooper structures located at strategic positions. Owing to its unit cell symmetry, an isotropic response is provided to any linearly polarized incident wave.

In this paper, a metamaterial-based antenna is proposed for RFID applications, due its characteristics as high gain, bandwidth, frequency resonance, its ease of construction and compact dimensions.

This work is part of an exploratory project to investigate the influence of periodic structures as the one presented here on the performance of antennas and other planar structures.

II. Proposed Antenna with Metamaterials

Patch antennas are typically narrow band, with a bandwidth around 2% [4]. Even though the efforts and researches, the maximum improve is achieved with multilayer substrates [5].

The circular antenna is present in several applications as radars, military systems, commercial and medical, and also in mobile devices. Its main characteristic is a high transmission data, requiring a high bandwidth which is a limitation of printer antennas. Therefore, a good way to solve this problem is to introduce metamaterials on the structure of the antenna.

The proposed antenna was designed over the substrate Rogers RO 4003, with $\varepsilon_r = 3.55$ and thickness of 0.81 mm. In Fig. 1 is shown the proposed antenna.

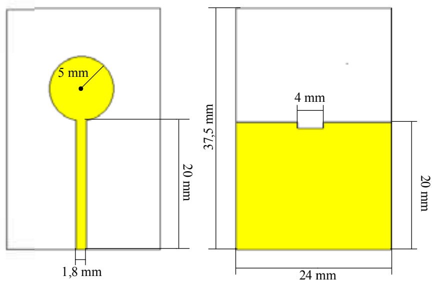
Several works in the literature deal with the effect of RFID tag in the presence of a ground plane [6]. According to [7] the gain penalty for placing RFID tags near the ground plane is reasonable, but on the other hand, the antennas become more directive. One of the advantages of this kind of antenna referrers exactly to the ground plane at the unbalanced input, in its simplicity for impedance matching with the IC, which is more convenient and practical to solve matching problems.

The concept of artificial material, i.e metamaterial, was synthesized in the late 90. However, in the past 20 years, the interest on metamaterial technology had strong increased, with researches on superlens and telecommunication environment, including transmission lines and antennas applications [8].

Actually, metamaterial is a macroscopic composite of periodic or non-periodic structure, whose function is due to both the cellular architecture and the chemical composition.

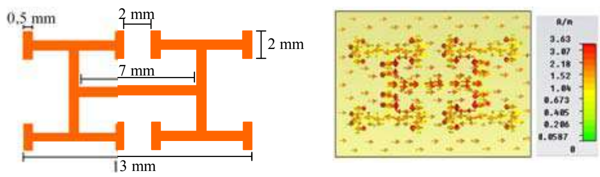
The construction of photonic metamaterial patterns to incorporate on the antenna was done through 4-level fractal structures, which are sometimes called a space-filling curve. The fractal pattern is generated by a master line, or the first level of the structure. The multiband functionality and subwavelength effect are the two most important features of this H-shaped fractal. The subwavelength property allows the total size of the system be much smaller than the wavelength along all directions at resonance, which indicates that the structures can act as very compact reflectors. Fig. 2 shows the fractal unitary metamaterial cell and its current distribution, where it can be observed a concentration of its flux on the major axis of the structure.

The proposed antenna, circular patch associated with fractal H-cells, showed a good resonance on the desire frequency, despite the original ones do not work in such frequency. The S_{11} parameter for the proposed antenna and the original circular patch is shown in Fig. 3.



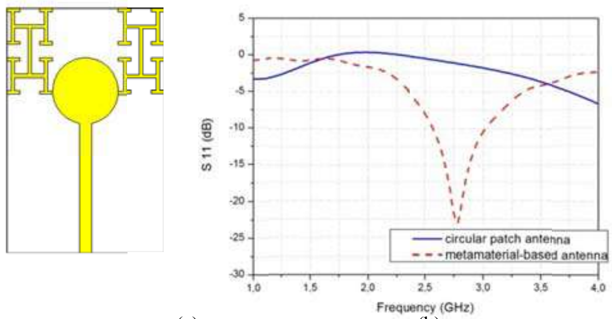
(a) (b)

Fig. 1. Original circular patch antenna: (a) top; (b) bottom.



(a) (b)

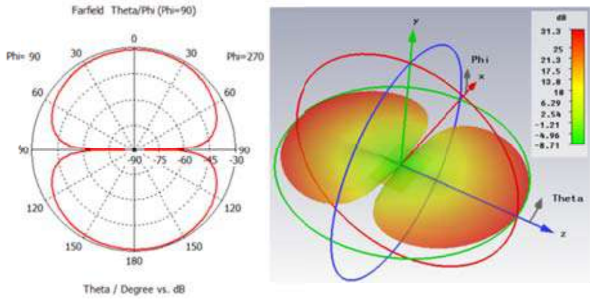
Fig. 2. (a) Unitary fractal metamaterial cell; (b) current distribution on the unitary fractal cell surface.



(a) (b)

Fig. 3. (a) Proposed metamaterial-based antenna for RFID applications; (b) S_{11} comparison between the metamaterial-based antenna and the original circular patch antenna.

The simulated radiation pattern for the antenna at 2.5 GHz is shown in Fig 4, where it can be observed the main lobe magnitude below 30 dB.



(a) (b)

Fig. 4. Simulated antenna results E radiation pattern: (a) polar view at 2.5 GHz, main lobe magnitude at -31.1 dB; (b) 3D radiation pattern at 2.5 GHz.

III. Conclusions

A UHF RFID tag for the 2.5 GHz microwave band has been proposed in this paper. In this way, a circular patch antenna was associated with metamaterial fractal cells.

Based on the obtained results, the device steadied appears as a good option for the design of RFID tags. Additional flexibility is granted to the designer for improving the RFID antenna and tag performance.

References

[1] K. Finkenzeller, RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification. New York: Wiley, 2003.

[2] B. Strassner and K. Chang, "Integrated Antenna System for Wireless RFID Tag in Monitoring Oil Drill Pipe," IEEE International Symposium on Antennas and Propagation, vol.1, pp. 208-211, June 2003.

[3] S. Basat, M. M. Tentzeris and J. Laskar, "Design and Development of a Miniaturized Embedded UHF RFID Tag for Automotive Tire Applications", *IEEE Antennas and Propagation Conference*, 2006.

[4] C. A. Balanis, Antenna Theory Analysis and Design. 2nd Edition, 1997.

[5] D. M. Pozar and B. Kaufman, "Increasing the Bandwidth of a Microstrip Antenna by Proximity Coupling", Electronics Letters, 1987.

[6] D. M. Dobkin and S. M. Weigand, "Enviroment Effects on RFID Tag Antennas", *IEEE International Microwave Symposium*, June 2005.

[7] J. T. Prothro, G. D. Durgin and J. D. Griffin, "The Effects of a Metal Ground Plane on RFID Tag Antennas", IEEE Antennas and Propagation Symposium 2006, Albuquerque, New Mexico, July 2006.

[8] T. J. Cui, "Electromagnetic Metamaterials: Recent advances on the theory, experiments, and applications," *IEEE Antennas Propag. Mag.*, 2008.

Miniaturization of a Microstrip Antenna with Magneto-Dielectrics Substrates for a Passive Tag RFID Operating at 915 MHz on a Metallic Surface

Javier A.Luna Bonilla, Gaby E. Zemanate Rengifo, Luciano Prado de Oliveira and Hugo E. Hernández Figueroa.
*Department of Communications, School of Electrical and Computer Engineering,University of Campinas,
Campinas, SP 13083-852, Brazil, (javier09, gzemanat, luciano, hugo)@dmo.fee.unicamp.br

***Abstract*— This article presents the miniaturization of experimental mode using the electromagnetic simulation tool CST MicroWave Studio® of the design of a rectangular patch antenna to operate at 915 MHz using a substrate magneto-dielectric so as to not impair the performance of the RFID tag antenna which has been designed to be used on metal surfaces. The design carried out considers the factor of miniaturization in function of the intrinsic properties of the substrate used, in addition to the impedance matching between the antenna and the chip Impinj Monza 4E with impedance Zchip= 11+j143 Ω, obtaining a simple design tuned to the desired frequency with impedance matching.**

I. INTRODUCTION

The systems of Radio Frequency Identification (RFID) that have been used for the automatic identification of products, people, animals and all kinds of object that is required [1]. The system RFID is composed for a reader end a tag. The tag is composed by an antenna and a chip, which has been store the information. Basically, the radio frequency waves are sent by the reader toward the tag in a frequency band, in this way, when the tag receives the signal in the frequency that has been specifically designed to operate, there is an adaptation of the impedance between the antenna and the chip, producing the coupling by backscatter while absorbing the energy of the signal to activate the chip and it can transmit the information contained in its memory through the adaptation and mismatch of its impedance, generating a effect of transmission and reflection of energy respectively, transmitted a signal that will be picked up by the reader [3]. This work presents a study on the design of an antenna type patch for use on metal surfaces operating on 915MHz using a substrate magneto-dielectric for its construction.

II. PATCH ANTENNA DESIGN

The rectangular patch type antennas are the most commonly used due to their low weight, ease of manufacture and therefore low cost. This composed basically of three parts; a ground plane, above a dielectric substrate and its surface a radiating element. The substrate has two important features. In the first place, is its thickness. An increase in the thickness leads to an increase in the efficiency of radiation of the antenna, but also an increase in the losses in the dielectric, as well as an increase of surface waves. Secondly, is its dielectric constant. The length of the rectangular patch is directly related to the operating frequency of the antenna. However, due to the effects of strip, electrically the patch microstrip antenna seems to be higher than its physical dimensions, so it is necessary to take into account a ΔL extension in its physical dimensions which are a function of the effective dielectric constant and the relationship of the width of the patch and the height of the substrate, therefore the length of the patch is given by [4]

$$L = \left[\frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}}\right] - 2\Delta L \tag{1}$$

Where ϵ_{reff} and ΔL are given by and .

$$\epsilon_{reff} = \left[\frac{\epsilon_r+1}{2}\right] + [\frac{\epsilon_r-1}{2}][1+12\frac{h}{w}]^{\frac{-1}{2}} \tag{2}$$

$$\Delta L = [0.412h]\,(\epsilon_{reff}+0.3)[\frac{w}{h}+0.264] \tag{3}$$

To consider an adequate efficiency of radiation can be calculate the width of the patch as [5].

$$W = \left[\frac{1}{2f_r\sqrt{\epsilon_0\mu_0}}\right]\sqrt{\frac{2}{\epsilon_r+1}} = \left[\frac{c}{2f_r}\right]\sqrt{\frac{2}{\epsilon_r+1}} \tag{4}$$

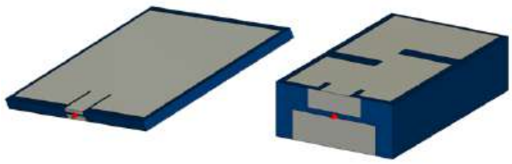
Where c is the speed of light in a vacuum.From previous relationships and taking into account that you want to design an antenna with resonance frequency at 915 MHz for an RFID tag with a chip Monza 4E [6] of impedance Zchip= 11+j143 Ω, using a dielectric substrate $\epsilon_r > 1$ and $\mu_r = \mu_0 = 1$ with $\epsilon_r = 10$ and height $h = 0.3$ cm, it is estimated that the structure should have dimensions $L = 5.16$ cm and $W = 6.99$ cm. The designed antenna is shown in Figure 1a where was used the tool of electromagnetic simulation CST Microwave Studio®.

The return loss and the input impedance to a discrete port of 50Ω are shown in figures 1b and 1c in red color respectively.

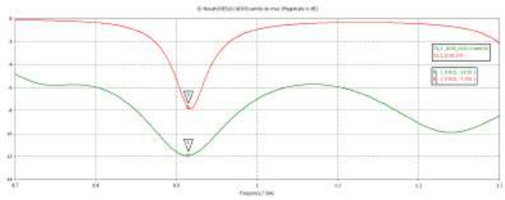
The input impedance to the antenna as shown in Figure (in red color) 1c is $Z_{chip} = (27.87 - j92.53)\Omega$, therefore, in spite of that the antenna is tuned, not operate for the RFID tag due to the impedance mismatch with the chip. Could increase the value of the dielectric permittivity for minimize antenna, however, this considerably affect the efficiency of the antenna and reduce the bandwidth, so that it is not recommended [7], it is for this reason, it is necessary to use a substrate whose intrinsic characteristics can be used to design an antenna whose input impedance is inductive type for that being able to perform the adaptation with the chip, furthermore to overcoming the limitations of efficiency and bandwidth. According to [8], the materials magneto-dielectric provide these features by which use a substrate with permeability larger than the permittivity ($\mu_r > \epsilon_r$), will allow you to significantly reduce the size of the patch and achieve a higher bandwidth and efficiency of the antenna that would be achieved using a substrate dielectric type only.

III. MINIATURIZATION OF A MICROSTRIP ANTENNA

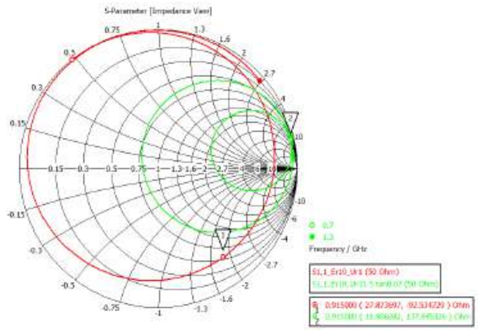
The profile of the proposed antenna shown in figure. 1a the right side, is designed on an 3 mm thick magneto-dielectric substrate whose relative permittivity is 18 and relative permeability is 31.5. Due to higher permitivitty and permeability the tangent loss was 0.02. Compare to conventional less expensive widely used dielectric substrate, magneto-dielectric material substrate reduces the width



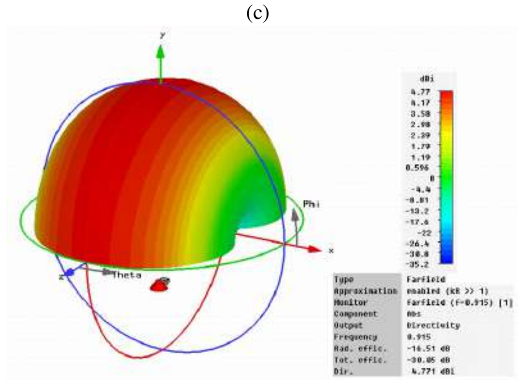
(a)



(b)



(c)



(d)

Fig. 1: Modification of a Microstrip Antenna with $\epsilon_r = 18,\ \mu_r = 31.5\ and\ tan\delta = 0.02$ Operating in 915 MHz, (1a) Original and Modified Design, (1b) Return Loss off two Antennas, (1c) Smith Chart of two antennas and (1d) Radiation Parner Modified Antenna

and length (W, L) antenna by a factor of $0.0213\lambda_0 * 0.037\lambda_0$. Additional to the variation of the values of permittivity and permeability of the substrate, incorporated two additional slots on the length of the patch, in order to have greater control in the tuned in resonance frequency of the antenna. Concerning of the modification of the said microstrip power supply of the patch is possible can be adjusted the values of input impedance, the imaginary and real impedance. Comparing the two grafics of the figures 1b note that the use of a substrate magneto-dieltrico did not decrease the bandwidth of operation of the antenna in the frequency of interest. Figure 1c shows the change in the value of impedance at the antenna input, reaching a value very close to the complex conjugate of the characteristic impedance of the Monza chip 4, thus allowing ensure the matching of impedances of these two elements and the best condition of operation of the tag.

IV. RESULTS

However for the case in question has to be treated by a substrate of magneto-dielectric considered have loss tangents ($tan\delta_\epsilon = tan\delta_\mu = 0.02$). Them, the patch resonant length directly obtained from simulations and rigorously given by (5) is compared to the approximated resonant length given by (6)

$$L = \left[\frac{\lambda_0}{2\sqrt{\epsilon_{re}\mu_{re}}}\right] = rigorous\ resonant\ length \quad (5)$$

$$L \cong \left[\frac{\lambda_0}{2\sqrt{\epsilon_r\mu_r}}\right] = approximated\ resonant\ length \quad (6)$$

As can be seen, the main difference between expressions (5) and (6) only concerns the substrate parameters (ϵ, μ). To our knowledge, there is no available formula for calculating the effective permeability (μ_{re}) of the substrate even if accurate formulas already exist for calculating the effective permittivity (ϵ_{re}) [4], [9].

In this formulation, the relative parameters (ϵ_r, μ_r) have been considered instead of the effective ones (ϵ_{re}, μ_{re}) for that reason.

Important to note that both the permittivity and the permeability alters the value of input impedance of the antenna, still less when ϵ_r decreases and increasing once μ_r makes it.

V. CONCLUSION

In this article was discussed the design of a rectangular patch antenna to an RFID tag operating at 915 MHz from the theory of design of microstrip antennas on an experimental basis by electromagnetic simulation. It was demonstrated that the use of a substrate magneto-dielectric allows miniaturize the patch in function of the square root of the product between the dielectric permittivity and magnetic permeability of the material while preserving the relationship of $\mu_r > \epsilon_r$. Moreover, the use of a substrate with the characteristics mentioned allowed to design a simple model of patch whose impedance has an inductive behavior to which impedance matching is achieved with the chip yielding low loss and thus return an optimal coupling between the antenna and designed chip.

VI. REFERENCES

[1] Bendavid Ygal, Linda Castro, Louis A Lefebvre, and Elisabeth Lefebvre. Explorando los impactos de la rfid en los procesos de negocios de una cadena de suministro. 2006.

[2] Steve Lewis. A basic introduction to rfid technology and its use in the supply chain. *Laran RFID, White paper*, 2004.

[3] Pavel V Nikitin and KV Seshagiri Rao. Theory and measurement of backscattering from rfid tags. *Antennas and Propagation Magazine, IEEE*, 48(6):212–218, 2006.

[4] Constantine A Balanis. *Antenna theory: analysis and design*. John Wiley & Sons, 2012.

[5] JR Mentzer. The use of dielectric lenses in reflection measurements. *Proceedings of the IRE*, 41(2):252–256, 1953.

[6] Impinj. Monza 4 tag chip datasheet. *Seattle, US*, 2014.

[7] RK Mongia, A Ittibipoon, and M Cuhaci. Low profile dielectric resonator antennas using a very high permittivity material. *Electronics letters*, 30(17):1362–1363, 1994.

[8] Pekka MT Ikonen, Konstantin N Rozanov, Alexey V Osipov, Pekka Alitalo, and Sergei A Tretyakov. Magnetodielectric substrates in antenna miniaturization: Potential and limitations. *Antennas and Propagation, IEEE Transactions on*, 54(11):3391–3399, 2006.

[9] Ramesh Garg. Microstrip antenna design handbook. 2001, pp 41-43.

[10] José Luis Jiménez Martín, José María Rodríguez Martín, and Vicente González Posada. Procedimiento de diseño y realización de antenas de parche en tecnología microstrip. *IAC*, (1), 2011.

RFID in Cashew Nut Industry

Edmilson Carneiro Moreira
Votu RFID Solutions
Fortaleza, Ceará, Brazil
Email: edmilson@voturfid.com.br

Romeu Freitas Jr.
Companhia Industrial
de Óleos do Nordeste
Fortaleza, Ceará, Brazil
Email: romeu@cione.com.br

Alexei Morais
RCN&BS Tecnologia
Fortaleza, Ceará, Brazil
Email: alexei@rcnbs.com.br

Antônio Sergio Sombra
Departamento de Física
Universidade Federal do Ceará
Fortaleza, Ceará, Brazil
Email: sombra@ufc.br

***Abstract*—This paper focus in adoption RFID in the cashew nut industry to improve traceability and supply chain management and efficiency traceability management. The challenges in this project are discussed and methodology is concisely described. At end, the results obtained are showed and next steps are proposed.**

I. Introduction

The cashew nut manufacturing industry plays a major role in the economics of the Brazilian State of Ceará . According to [1], this industry sector represents 13,6% of the total exported by this State, accounting for $160,1 millions dollars in 2012. In this market, the possession of the ISO 22000 certificate is a *de facto* requirement due the fact that it ensures the quality of food safety and traceability management systems as stated in [2]. Even though, according to [3], the cashew nut manufacturing industry presents several problems, including very poorly articulated supply chain.

In order to facilitate the achievement of the quality of food safety and traceability management demanded by ISO 22000 certificate and to increase supply chain integration and efficiency, CIONE, Companhia Industrial de Óleos do Nordeste(Northeast Oils Industrial Company), started the adoption of RFID in its internal logistic process. This Auto Identification and Data Capture system carries information around through the use of radio frequency waves. This technology is able to radically improve supply chain management and efficiency, being increasingly adopted in various industry sectors. RFID has the ability to identify each item individually, being this matter a key aspect in the traceability management needed by ISO 22000 standard.

This paper shows the efforts in the adoption of ISO 18000-6C RFID system as the main AIDC in the internal logistic process of CIONE, having the physical layer specified in [4] as it focus. With it, this process will present a new level in traceability and in supply chain management of cashew nuts boxes, allowing CIONE to achieve the requirements of quality demanded by ISO 22000 standard. This RFID adoption project has three stages: analysis and design, implementation and evaluation.

II. The Logistic Process

Nowadays, the CIONE logistic process begins with the reception of raw almond sent by the producers. Then, several manufacturing activities transforms the cashew nuts *in natura* in the product that will be commercialized. The almonds are selected and receive a two stage packing. First, they are packed into bags for biological and chemical protection and then placed into carton boxes to avoid mechanical hazards. When the packing process is finish, each package with a net weight of 50 pounds or 2270 grams receive a label with a barcode and other miscellanea information. Pallets with a maximum of 60 boxes are then arranged. The tasks of selection, packaging, labeling and palletizing are performed in the packaging sector. Once the pallet is properly formed, it is moved to the shipping sector. In that sector, the pallets are stored until their shipment.

In this RFID adoption project, were establish that all boxes must receive a RFID tag encoded in the packaging sector, and a portal must be developed to read all items in a pallet during the shipping process.

III. Analysis & Design

The phase of analysis and design has four activities, being the study of the item to be tracked the first one. The importance of this task is understand how the items can interfere in the radio waves used by a RFID system. In this project's scenario, the discussion is simplified because the bags used in the packaging are conductive electrically, causing an electromagnetically isolation of the cashew nuts inside them. After the study of item to be tracked, the ISO 18000-6C RFID hardware must be select. This selection is made considering the project requirements, references about hardware performance and previous experiences. The reader, printer and the tags for this project were selected from off-the-shelf items. The antenna used in this project is a competitive differential provided by Votu Rfid Solutions. It presents a high gain, more than 9dbi, and is made recycling plastics and reusing metals. The third activity in analysis and design is the investigation of the electromagnetic activity of the environment were the RFID system will operate. The purpose of this task is identify and eliminate potential sources of interference in the ISO-18000-6C RFID frequency band. The shipping sector of CIONE have no significant source of noise regarding the RFID system in question. At last, the preliminary researches are performed. This activity consists in series of proof of concept to investigate several key aspects in a RFID adoption project and design solutions regarding those matters. In CIONE's RFID adoption project, the portal layout, the placement of the tags in cashew nuts boxes, the reading of undesired tags and the printing and codification of tags are the investigated aspects in preliminary researches.

In the portal layout definition, a pallet dimensions analysis is the first thing done. Regarding those dimensions, an initial portal infrastructure that can be easily reconfigurated is mounted, allowing a deep investigation of the portal layout. That structure allows to different types of portal layout: one with 4 antennas placed on the upper part of the structure and other with 2 antennas on each side of this initial portal. The performed researches indicates that the layout with 4 antennas on top presents an interrogation zone that does not cover entirely the region where the pallet pass by, but it promotes a smaller quantity of undesired tags reading. On the other hand, the layout with 2 antennas on each side covers well the region where the pallet transits, although it performs easier unwanted tag reading. Once the most important thing in portal layout design is the reading of all item tags that are in the pallet and undesired tag reading can be solved trough shielding, the layout with 4 antennas on top is discarded. Now, the portal layout with 2 antennas on each side must have the position of those electromagnetic devices fine tuned. This task is made measuring the power distribution in the pallet and with the identification of miss read tags.

After the investigation and design of portal layout, the tag placement is researched preliminary. The carton boxes already has a defined spot for tag attachment. Thus, this tag placement process analyzes witch orientation has better tag detection. The orientations studied are Vertical, when the tag is placed perpendicularly to ground line, and Horizontal, when the tag is placed in a parallel position regarding the ground line. The Vertical orientation presented better results, being thus selected for implementation and showed in Fig.1a.

As stated earlier, the designed portal read several unwanted tag items. Thus, the range of those undesired tag items reading must be understand in order to design the proper shielding of the place where the shipping portal is placed. This preliminary research was made tagging items in the pallets adjacent to the portal. Tags of items in those pallets could be read as far as 15 meters from the portal. Regarding those results, a metallic grid was designed to shield the shipping portal area.

To finish the preliminary researches, the printing and codification of tags are observed. The process is simple and execute with no relevant technical challenges.

IV. Implementation

After the analysis and design phase, the definitive infrastructure is then implemented and it's performance validated according with the results obtained in the previous activity. The tags are encoded and placed in the items using the Vertical orientation as illustrated in Fig.1a. Then, the metallic grid for electromagnetic shielding is mounted in the shipping sector, as presented in Fig.1b.

(a) Tagged item (b) Shielding grid

Fig. 1: Tagged item and Shielding grid

The RFID shipping portal is than manufactured and the whole system is validated according with the proposed in the analysis and design phase, concluding the implementation process. In the Fig. 2 is possible to see the whole system mounted, reading a pallet of items.

Fig. 2: RFID shipping portal in the shielded area.

V. Evaluation and Conclusion

The evaluation of the portal consists on the simulation of 100 shipping process using RFID portal on each of 11 products categories that CIONE has. The final result presents a 99.894% of reading accuracy, attesting the success of this RFID adoption project. As next steps, this physical layer implemented must be integrated with TI layer in order to put the entire system actually in use.

Acknowledgment

The authors would like to thank FUNCAP (Brazilian agency).

References

[1] Sindicaju.org.br. (March, 2013). *FIEC, Sindicaju e bancada cearense se movimentam em prol da Castanha cearense*. [Online]. Available: http://sindicaju.org.br/2012/05/ceara-recebe-1%C2%BA-navio-de-castanha-da-africa/.

[2] C. Kozlowski, (January, 2012). *Food Safety and Traceability*. **Crisis Control Newsletter.** [Online]. Available: http://www.catlin.com/

[3] L. Oliveira, *Integração da Cadeia Produtiva do Agronegócio do Caju ao Desenvolvimento Sustentável*, M.S. thesis, UECE, Fortaleza, Ceará, 2009.

[4] P. Sanghera, *RFID+ Study Guide and Practice Exam*, Rockland, MA: Syngress Publishing, Inc., 2007.