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RFID PASSIVE TAGS FOR HARSH INDUSTRIAL ENVIRONMENTS

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Abstract: *The paper aims at developing an application regarding the use of RFID systems to identify objects present in harsh industrial environments. The structure and properties of passive RFID tags for normal environment and the ways of designing and manufacturing the RFID tags resistant to the aggressive environments are described. The research carried out resulted in the design, development, testing and validation of a RFID tag whose features enabled the implementation of the RFID system in the harsh environment of an industrial laundry.*

Key words: *RFID systems, UHF passive tags, contactless, harsh industrial environment, textile items, industrial laundry.*

1. Introduction

Radio frequency wireless technology is one of the technologies which use the property of the electromagnetic field to transfer contactless information and energy [16]. This technology was applied in developing the Radio Frequency IDentification (RFID) systems [6], [8].

Based on their ability to assign an unique identifier to each object, RFID systems are widely used in tracking and monitoring the physical objects. Many RFID applications have been developed, covered different domains, as:

- Healthcare, where along with identification of the disfunctionalities, integrated sensors can collect relevant data, such as vital signs of a patient, temperature and other stresses [9];
- Architecture and constructions, where the RFID labels or tags are attached to building assets throughout their lifecycle, and obtained data are gathered as bases for building Information modeling [13];
- Industrial manufacturing, where, RFID systems can contribute to continuous improvement of human, flexible assembly workplaces [10];
- Tracking and monitoring of shipped perishable goods, and supply chain and security in the agro-food sector [1], [15];
- Electrochemical detection of volatile chemicals [7], or identification and characterization of steel corrosion;

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- Packaging sector, with logistic advantages, specially at the level of pallets [2];
- Security, access control and transportation [5].

But, the most spectacular application of RFID technology is the supply chain management in industrial environments. Through the inventory management and automation, implementation of the RFID systems conducts to the reduction of material and energy consumption, and to the increase of the production efficiency.

With all the successes registered, there are still many challenges in RFID actual researches: RFID tags miniaturization, reduction of energy consumption required for the activation of RFID tags, the integrity of reader-tag communication, possibility to use the tags in harsh environments, mitigation of the susceptibility to electromagnetic disturbances, and others [3], [4], [11], [14].

Regarding the introduction of the RFID systems in textile articles management, new and specific issues should be solved, as: the wash ability and endurance of RFID tags to harsh environmental conditions and repeated washing, the ways of fixing the RFID tag on the textile support, the effective information reading etc.

In this paper, an application regarding the use of RFID communication systems to identify objects in harsh industrial environments is presented. The structure and properties of passive RFID tags for normal environment are analysed comparatively with the RFID tags resistant to the harsh environment. Then, the results in the design, development, testing and validation of a washable RFID tag enabled to implement the RFID systems in the harsh environment of an industrial laundry are described.

2. RFID Principle and Structure

A generic RFID system consists of three main elements:

- an RFID tag, which includes an antenna and an electronic microchip, fixed on the object it identifies,
- an RFID reader, fixed of mobile,
- a software application with a database where information about tagged objects is stored and proceeded.

The working principle is simple: the reader sends a radio signal to the RFID tag, which, after receiving the signal, responds with a signal containing the tag identifier and other data regarding the identified object [6], [16].

A more complex RFID system includes readers (interrogators) linked to a computer and a population of RFID tags, each tag uniquely identifying an entity (person, place, or object) tracked through a software for inventory, monitoring or security. Typically, the software application manages multiple RFID readers/tags.

At present, the retail supply chain has primarily been interested in using passive RFID tags, which are powered by radio waves created by the reader and transmitted via its antennae.

The passive RFID tag is only activated when it is within the interrogation zone of a reader. The power required to activate the tag is supplied contactless through the RF electromagnetic field.

The stages of the RFID system operation include (Figure 1) the following: the passive

RFID smart tags are attached to objects; the wireless code of the RFID tag is wirelessly read by the RFID reader; data is collected by individual computers / computer networks; the information collected in the database is processed; reports are done on the identification and traceability of the spatial positioning of objects; information is used to perform the feed-back in the automation process.

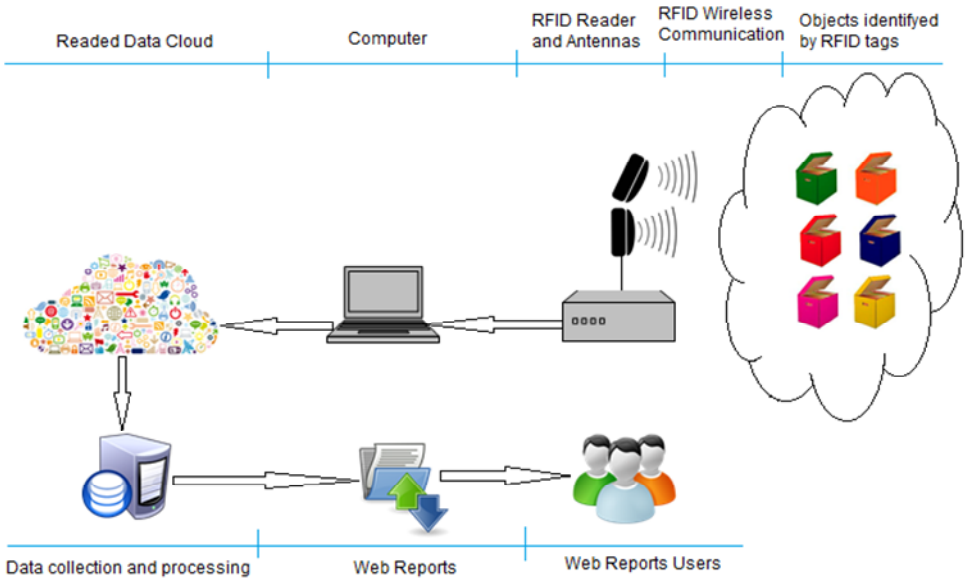


Fig. 1. *Structural scheme of an RFID system for identification and tracking objects*

In operation algorithm, there are also included the anticollision procedures, so that several RFID tags located in the reader's interrogation zone at the same time do not interfere with one another, and can be selectively addressed by the reader.

3. Passive RFID Tags for Use in Normal and Harsh Environments

Passive RFID tags are commonly used in normal environments (dry, normal temperature and low mechanical stress), such as libraries, warehouses, stores etc.

The components of the passive RFID tag are shown in Figure 2. There are specific constructional features for this type of RFID tags. For example, the electrical contacts between the integrated circuit (IC) pins and the UIF antenna are made by direct bonding with conductive adhesive (Figure 2c).

The RFID passive tags for normal environments have many advantages, as: manufacturing process with a high degree of automation, reduced costs. But they also have disadvantages: they are not robust to mechanical stresses, they lack water protection, etc. Nowadays, RFID systems vave been expanded to identify and tracking the objects which operate in harsh environments.

The examples are: the textile objects in industrial laundries, the electronic boards and electronic circuits in the manufacturing process, the medical objects requiring sterilization, and others.

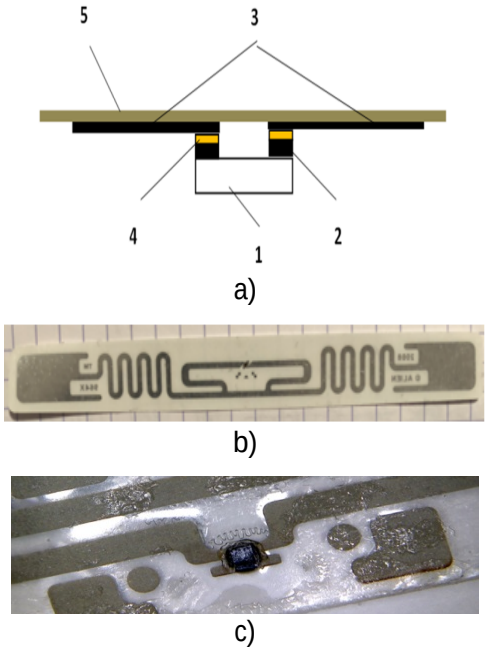


Fig. 2. *RFID passive tag: a) components: 1-integrated circuit (IC), 2-IC pins, 3-UHF antenna, 4-conductive adhesive, 5-tag support; b) view; c) bonding the IC with conductive adhesive*

The harsh industrial environments are characterized by:

- high temperature variations,
- high humidity,
- excessive mechanical stresses,
- exposure to aggressive chemicals.

For example, the characteristics of the environment in industrial laundry for professional textiles are:

- high temperature variations (repeated cycles from + 15 °C to 230 °C),
- high humidity (aqueous medium),
- excessive mechanical stress (mechanical pressure up to $60x10^5$ N/m^2),
- exposure to aggressive chemicals (detergents, chlorides, acids etc.).

Different solutions have been proposed for such environments. The screen printed UHF tags proposed in [17] are wearable but not really washable. The tags realised by gluing tiny IC pins on the massive structure of UHF antenna, were not satisfactory: RFID tags do not resist a sufficiently large number of the operational cycles, often there are breakages, or detach the contacts, which lead to a reduction in overall system RFID system performance [1, 7].

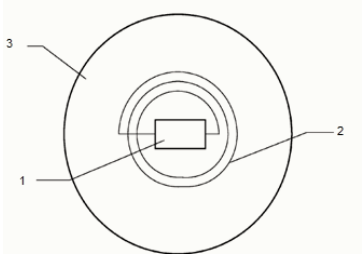
The concrete consequences of repeated stress from harsh environments on RFID tags are shown in [12].

4. Innovative RFID Tag Solution for Harsh Environments

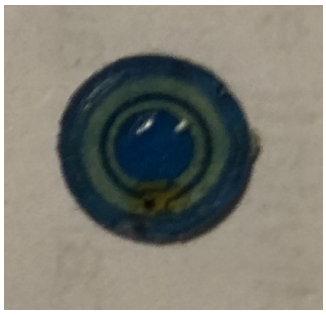
The proposed solution consists in the development of a small transponder (Figure 3) which includes the integrated circuit and a near field antenna, both encapsulated in dielectric material. The transponder is inductively coupled to a UHF antenna (Figure 4).

Parameters and constructive features of the RFID tag are following:

- Communication with the UHF antenna is made in the electromagnetic field by inductive coupling;
- The UHF antenna, designed for the working frequency (860-920 MHz), is made of a conductive textile wire;
- The RFID tag holder is made of mixed fabric (cotton and polyester).



a)



b)

Fig. 3. *Proposed solution for RFID transponder: a) functional scheme: 1 - IC; 2 - field primary antenna; 3 - transponder substrate; b) a transponder view*

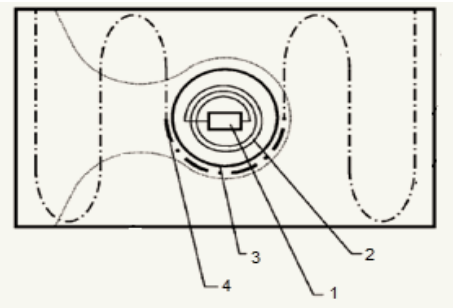


Fig. 4. *View of RFID tag for aggressive environments: 1 - Integrated circuit; 2 - a near-impedance field impedance antenna; 3 - transponder; 4 - antenna UHF*

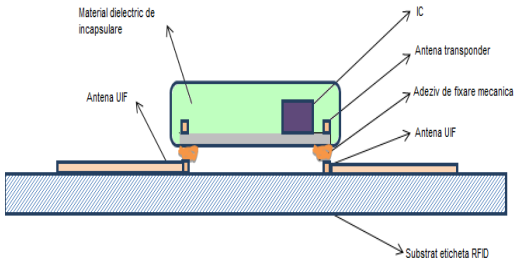


Fig. 5. *Constructive elements of the RFID proposed tag*

The transponder formed by the IC, the near field antenna and its substrate is encapsulated in dielectric material (epoxy resin).

Resistance to harsh environments is ensured by encapsulation of the transponder, the use of suitable adhesives for fixing the transponder on the substrate of the UHF antenna and the conductive textile material for the UHF antenna (Figure 5).

5. Designing, Manufacturing and Testing the RFID Tag

The assessment of strength to harsh stresses for a proposed new passive UHF RFID tag has been done (Figure 6). During the textile washing cycles, aspect and functionality of RFID tag has not been affected.

The electromagnetic performances of the new passive UHF RFID tag were measured using a laboratory UHF RFID Reader, the Nordic Sampo S1, situated at 6.3 m distance from the tested tag. The Reader's software shows good measurement results. In Figure 8, there are shown the RFID tag ID, the RSSI (Received Signal Strength Indicator) dBm value, the antenna used by the Reader, and read tags number, one item here.

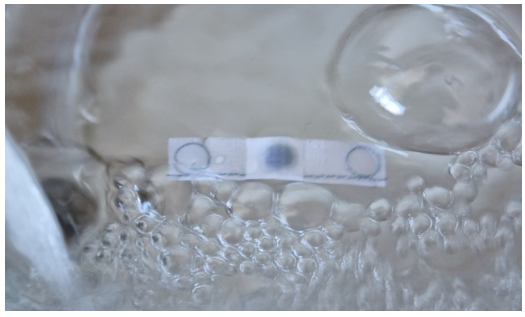


Fig. 6. *Testing the RFID tag in the aggressive environment (water with detergent)*

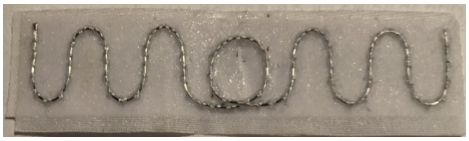


Fig. 7. *UHF antenna pattern sewn with conductive textile yarn*

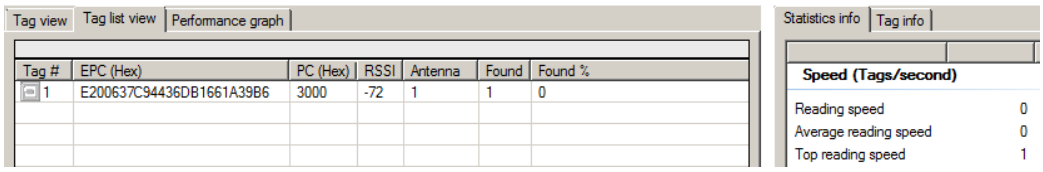


Fig. 8. *Measurement result*

In Table 1 the results of measurement of RFID developed tags parameters are shown.

Results of tests for RFID developed tags Table1

Characteristics	**Result of the tests**
Resonance frequency	(860-960) MHz
Reader Power	500) mW
Power of the reflected signal	-70 dB
Maximum response distance between tag and interrogator antenna	6 m
Maximum operating temperature	230 ^{o}C
Mechanical endurance test	Resistant to over 10,000 bending cycles
Chemical stability test	Resistant to acids, oxidants, alkaline concentrate substances
Water immersion test	Resistant to over 500 cycles

6. Conclusions

Due to their advantages, RFID systems with UHF passive tags are appropriated for inventory management and automation in industrial environment, assuring high performances in accurate and easy multiple reading the tags, with low error rates.

The proposed solution of RFID tag for harsh environment consists in design and construction of a small transponder, which includes the integrated circuit and a near field antenna, which is inductively coupled to a UHF antenna.

This new type of UHF passive tag with textile support has been certified to withstand to washable environment of the high-throughput laundries.

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