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On the Usage of RFID Tags for Tracking and Monitoring of Shipped Perishable Goods

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Abstract

This paper presents idea for solution to several recurring problems in shipping perishable goods, derived from the basic question – howcan one assess the status of the content of a sealed container without opening it. This problem is particularly important for contents than can be spoiled and/or otherwise diminished by opening the container outside a protected environment. The idea is to employ the RFID technology in conjunction with integrated sensors to build the system.Key elements of the system are identified and overall design proposed. The proposed system when fully developed can be useful for numerous situations, from routine customs inspections to robust transfer procedures between a producer and its end customer. Although the paper focuses on liquids used in the food industry, such as fruit concentrates, but the concepts presented here can be applied to a wide range of perishable goods that are to be shipped in strictly-controlled conditions.

*Keywords:*Radio frequency identification (RFID); traceability; perishable goods; sensors

1. Introduction

Traditionally, there are four basic functions of packaging: to protect the product against the deteriorative effects of the external environment, to communicate with the consumer as a marketing tool, to enable easier usage of products, and to contain products of various sizes and shapes [1]. However, recent changes in business requirements, technology development and healthy regulations introduced the need for more advanced (intelligent) functions of

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packaging – a packaging system that is capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems [2]. Under special pressure is food industry. Namely, in the last few decades the regulations and requirements imposed on the food industry with respect to traceability have increased dramatically; it is now an important tool in ensuring the quality of products, for informing and protecting the end users of the product. One of the oldest and still unsolved problems in this field is how to assess the status of the content of a sealed food container, especially perishable goods, without opening it. Within this research we aim to contribute to solving this problem.

The purpose of this article is to identify key elements and design of a system for assessing the status of the content of a sealed food container without opening it. The idea is to employ the RFID technology in conjunction with integrated sensors to build the system. RFID is one of the most promising and widely used technologies that make traceability effective at reasonable costs [3]. It is a technologywhich provides appealing opportunities to improve themanagement of information flow within the supply chain and security in the agri-food sector [4a, 5a, 6a].Another important technological development for food quality is the tremendous advance in integrated sensors, which provides for inexpensive continuous monitoring of a wide range of parameters, from the usual environmental temperature and pressure to the presence/concentration of chemical and biological agents [7]. Ideally, this system should lead to significant savings, improvement of food safety, and supply chain management.

The remainder of the paper is organized as follows. After a general discussion about RFID, the paper presents typical problem setting and examines the key elements and design of a system. The paper ends with some conclusions and propositions for further research. The first author's PhD thesis should develop and extend some of ideas presented here into a more general and detailed way.

2. RFID technology

Technology based on radio frequency identification (RFID) is a very effective tool in the process of monitoring and digital processing in food production. RFID is a system for automated data acquisition based on tagging items. The tags contain transponders that emit messages readable by specialized RFID readers. Most RFID tags store some sort of identification number (e.g. product / customer number), based on which reader can retrieve information about the ID number from a database, and acts upon it accordingly[8] (Fig. 1.). This allows collection and wireless (radio wave) transfer of production- and business-related data.

On the one hand, RFID systems can be based on active or passive tags. Active RFID tags are equipped with self-powered or battery on the tag, while passive tags are read with the help of the electric field generated by the reader (antenna).

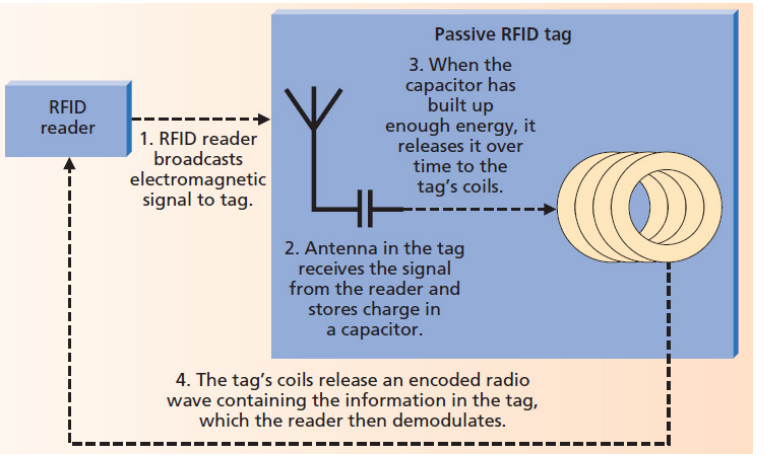

Fig. 1. Simplified view of data transfer in low-frequency passive RFID tags [8].

On the other, RFID systems are designed to operate on different frequencies depending on what we want to read and in what condition reading will be done.On this basis it was made the division of the RFID system [9]:

- Low frequency (Low Frequency) 125 KHz,
- High frequency (High frequency) 13,56 MHz,
- Ultra high frequency (Ultra High Frequency) 860-960 MHz, and
- Microwave (Microwave) 2.45 GHz

Each of these systems provides benefits to certain requirements of the distance at which it is possible to perform sensing sampling rate and the size of the tag. When it comes to tracking individual product best characteristics are shown in the ultra-high frequency (UHF) systems because the tag can be read from a distance of 3 to 10 meters, offering the possibility of cheap installation in processes such as monitoring product on pallets [10]. An important feature of this system is the ability to read multiple RFID tags simultaneously.

RFID technology is an innovative but still under- utilized technology that offers a wide range of possibilities. It allows real-time identification, during delivery, storage, or any other process taking place within an enterprise. Using RFID technology, it is possible to track products and equipment, with minimum human intervention. This can potentially cut back operating costs and increase real-time visibility during complete product life cycle [11].

Monitoring the production process with the help of this technology enables all the collected data being automatically imported into the database without the mediation of communication, avoiding the human factor in these processes. Besides the obvious benefits of using RFID technology, which are reflected in the competitive advantage of companies which have undergone such a process of monitoring production, increasingly, the producers put conditions on the detailed monitoring of origin and production process, with a goal of providing safe food and placing products on the market .

Benefits of using RFID technology include [8]: the reduction of labor costs, the simplification of business processes and the reduction of inventory inaccuracies. RFID promises to replace the old barcode and contributes to the real time visibility of the goods, regardless of the location of the supply chain.

3. The problem

The age-old problem is to assess the status of the content of a sealed food container without opening it. Here we will describe two situations often encountered nowadays in order to explain problem in more practical way. First, the import/export of perishable goods, such as the fruit juice concentrate. Although the producer has to fulfill very strict requirements when packaging and shipping the concentrate, custom regulations demand that the goods are subject to laboratory tests. The fruit juice concentrate is usually shipped in septic bags in order to preserve the quality of the content; for customs inspection samples are taken by opening some of these septic bags, rendering their content un-proper for use; this leads to significant losses, as the raw material for the production of fruit juices is packed in containers of up to 50kg. A second situation involves the refusal of shipped goods on arrival at the receiving food plant/customer: usually this happens after the receiver opens the container, takes samples and processes them; thus, the sender has no reliable information as to the root cause of the refusal: was it due to the poor quality of the product, or improper transport conditions or improper handling by the receiver.

4. The idea for solution

The main elements of the proposed idea are illustrated at Fig. 2. The key elements are:

- To equip each container with an integrated circuit (IC) comprising the usual elements of an RFID tag and transmitter, along with a set of sensors for monitoring general and specific parameters. For example, a fairly simple temperature sensor can indicate whether the temperature of the IC (thus of the container) was maintained within a set range; a pressure sensor can flag the apparition of gas-generating biological process such as

fermentation; more complex sensor can monitor the apparition/concentration of chemical and biological agents. These data will be recorded by the RF tag and be available for inspection through the integrated radio transceiver.

- The IC should be placed within the lid/cap/plug of the container, with a mechanical implement that disables the chip once the container is opened.
- Other security measures should be considered for preventing the improper use of the tag: for example, the electronic signature of the sender can be stored within the RF tag, to prevent misrepresentation. The IC can also produce an encrypted report that only the sender is able to read.

Fig. 2. Possible solution of integration of RFID and sensors.

The producer of perishable goods such as fruit concentrates will buy a blank RFID tag equipped with the suitable set of sensors, will record the origin-related data for traceability and its own (public) electronic signature; the producer will also set a password, that will be used by the system to generate the encrypted report, readable only by the producer. The IC will be then incorporated in the cap/lid that seals the container. The transport company will read the RFID data when taking responsibility of the container, and verify that the sensors indicate no issues with the content. The status of the content can be assessed on arrival to its destination without un-sealing the container; if problems are detected the receiver will inform the sender by forwarding it the encrypted report read from the RFID tag. Routine customs inspections can also be done by simply reading the RFID tag – possibly provided with specific security features.

5. Conclusion and further research

This paper presents the doctoral research topic of the first author. It puts forward for discussion several ideas for employing the RFID in conjunction with integrated sensors for solving the age-old problem of assessing the status of the content of a sealed food container without opening it. Discussed problem especially impacts shipping of perishable goods, contents than can be spoiled and/or otherwise diminished by opening the container outside a protected environment. We identified key elements and proposed overall design of a solution. The research mainly focused on liquids used in the food industry, such as fruit concentrates, but the concepts presented here can be applied to a wide range of perishable goods that are to be shipped in strictly-controlled conditions. When fully developed, the solution can be useful for numerous situations, from routine customs inspections to robust transfer procedures between a producer and its end customer, and thus bring significant savings, improvements in food safety, and supply chain management. Further research will be oriented towards realization of system and testing in different real-life settings.

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