Middleware – Software Support in Items Identification by Using the UHF RFID Technology

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Abstract. This article deals with RFID technology, which is a part of automatic identification and data capture. Nowadays, the identification of items in logistic sector is carried through barcodes. In this article we would like to specify, how items can be located in metal container, identified in the transmission process of logistics chain by UHF RFID technology. All results are verified by measurement in our AIDC laboratory, which is located at the University of Žilina. Our research contains of 12 different types of orientation tags and antennas and more than 1000 tests. Our identification performance was close to 100 %. All tested items have been located in metal container. The results of our research bring the new point of view and indicate the ways of using UHF RFID technology in logistic applications. The utilization of the RFID technology in logistics chain is characterized at the end of this article.

Keywords: RFID technology · Logistics chain · Items · Identification · Middleware

1 Introduction

Automatic identification technology currently plays an important role in all areas of the national economy. In terms of optimization of logistic processes, barcode technology is used. However, radio frequency identification technology brings lot of advantages to the table, therefore it is expected that its involvement will significantly expand into all areas of the national economy. The article focuses on research of RFID technology in the process of items - placed in metal containers - identification. It also talks about software support for RFID technology, mainly about creation and configuration of RFID middleware – specialized software tool allowing mutual communication between two or several applications; also known as connector between various application components. The article talks about RFID technology as well as about the completed study of readability of RFID identifiers placed on the items that are put in metal containers. Among the results of the readability, the dependency of tags on the metal parts of the container has been studied. Based on the results of the research, a recommendation for tags positioning on items was published.

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2 Objective and Methodology

Objects of the research are the items transported in metal containers within logistics chain consisting of particular components. These items contained UHD RFID identifier that was read by 2 or 4 antennas of particular scanning device. In order to achieve the relevant results of the research, more than 1.500 measurements have been performed in different testing environments. For testing purposes, we used cubicle metal container that is actually utilized during transport of items. Within the methodology or series of steps, we have chosen a diagram of partial goals that is depicted in detail in Fig. 1.

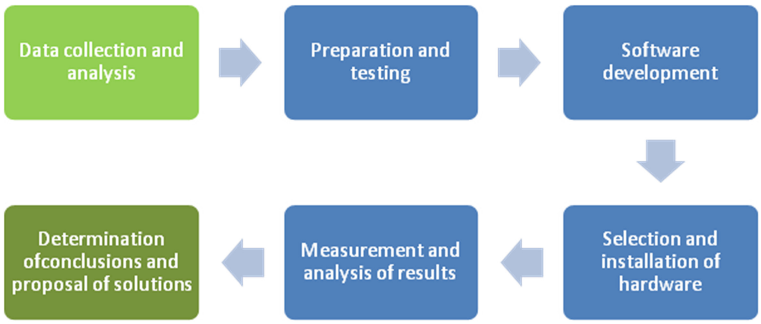

Fig. 1. Diagram of partial goals

3 Theoretically Background

Radio frequency identification is a wireless data collection technology that uses electronic tags which store data and tag readers which remotely retrieve data. It is a method of identifying objects and transferring information about the object's status via radio frequency waves to a host database. An RFID system is a set of components that work together to capture, integrate, and utilize data and information. This section describes some of them [2].

3.1 RFID Tags

An RFID tag is a small device that can be attached to an item, case, container, or pallet, so it can be identified and tracked. It is also called a transponder. The tag is composed of microchip and antenna. These elements are attached to a material called a substrate in order to create an inlay.

Tags are categorized into three types based on the power source for communication and other functionality:

- Active.
- Passive.
- Semi – passive.
- Semi – active.

3.2 RFID Reader

The second component in a basic RFID system is the interrogator or reader. The antenna can be an integral part of the reader, or it can be a separate device. Handheld units are a combination reader/antenna, while larger systems usually separate the antennas from the readers. The reader retrieves the information from the RFID tag. The reader may be self-contained and record the information internally; however, it may also be part of a localized system such as a POS cash register, a large Local Area Network (LAN), or a Wide Area Network (WAN) [1].

3.3 RFID Middleware

Middleware is software that controls the reader and the data coming from the tags and moves them to other database systems. In our cases we have used the Aton AMP middleware. It carries out basic functions, such as filtering, integration and control of the reader. RFID systems work, if the reader antenna transmits radio signals. These signals are captured tag, which corresponds to the corresponding radio signal.

This is a very special software device enabling mutual communication between two and more applications. This device is marked also as a mediator between various application components. The core activity of such devices covers the linking of and switching various different applications or hardware components for exchange, record and data modification purposes. There is a RFID middleware located between reader and server/database or other software device. This can have various functions depending on complexity of the system [5].

We can say that middleware fulfils following functions:

- Masks the communication distribution of many cooperating parts of the system located in various physical places,
- Masks the heterogeneity of various hardware components, their different operational systems and communication protocols,
- Provides unified interface enabling easier system extension and its easier communication with world.

4 Description of Measurements and AMP Model Configuration

In order to achieve relevant outcomes, it was inevitable at first to design functional system enabling realization of single measurements under laboratory conditions. In order to comprehend single measurements, we have to define the principle they operated under and what is being detected by them.

4.1 Description of Measurements

At first, we have to find out the readability of RFID tags of items placed in metal container at the moment of its passing through RFID gate with antennas. At second, we have to realize that we perform several types of measurements. These types differ in RFID tags orientation on items as well as by number of antennas; used for scanning the tags. In order to ensure the credibility of measured results, each type of measurement is repeated 100 times and therefore each single of them is called partial measurement. We do have the type of measurement and 100 partial measurements within, from which we have made statistical results. The relation between type of measurement and partial measurements:

- Type: Placing of identifiers on the top of the item: four antennas:
  - Partial measurement No. 1.
  - Partial measurement No. 2.
  - Partial measurement No. 3.

By accomplishment of single measurements, we obtained required data for deduction of results and recommendations. The accomplishment of measurements according to our requests needed certain preparation indeed. As for the preparation process, it was inevitable to select pasteboard boxes representing the items placed in container. In order to fill up the entire loading capacity, we needed 40 boxes of different size.

As each single item had to contain one RFID tag, we needed 40 passive RFID tags. The identification number (tagID) of each tag was reprogrammed by the use of hand RFID reader in order to get the other activities simplified. The structure of these IDs would be 3008 0000 0000 0000 0000 00xx. As we used 40 items overall, the last two digits would be 00–40, where the first value 00 would be assigned to launching RFID tag placed on container. At the same time, we were detecting the readability quality of particular RFID tags during the process of reprogramming. Thanks to that, we noticed that one tag had much lower level of readability in comparison to other tags. The value 01 of last two digits was assigned to this tag.

Following reprogramming process, we placed the tags to items. In order to prevent any damage of tags and at the same time, to ensure their fully functionality after realization of our measurements, we attached them by an adhesive tape. We put down the last two digits of tags ID during the sticking of tag due to later identification and analyze. All the items were placed into container, whereby the item with lower readable tag (01) was placed on the very bottom of the container. Afterwards, ID's of tags were filed into MySQL database and configurations White lists, by which we set the RFID reader exclusively for scanning of 40 + 1 tags.

The very last step was the involvement of antennas. The upper two antennas were placed onto metal construction and sides' antennas were attached to telescopic stands, by which we ensured RFID gate simulation.

4.1.1 Hardware Part

Hardware part consists of server, connecting cables, RFID gate (reader with antennas) and obviously with RFID tags placed on items and on plastic container. RFID reader Motorola was inevitable component of our hardware set. The reader consisted of – maximally - four active antennas in our configuration.

This RFID reader is characterized by its compact processing, easy installation, high performance and besides, is able to be directly hooked up by use of data network cable (Power over Ethernet). Its use is applicable also in case of limited areas.

Very important part was to choose efficient and affordably priced RFID identifier applicable for such a laboratory tests. Their structure consists of antenna and integrated circuit. These components are vapoured on elastic sticky plastic paper, so the tags can be easily attached directly to the object needed.

Each UHF RFID inlay is basically a dipole, which is located on an underlay substrate of a specified permittivity. Logically, all inlays are designed so they their range is as long as possible. In agreement with the radiolocation equation it is essential that the UHF RFID inlay antenna should be as large as possible and able to intercept the largest possible amount of EM energy and, conversely, be able to transmit energy as great as possible back to the transmitters.

$$l = \sqrt[4]{\frac{Ptx * C * K * A^2}{160\pi^2 * \mathrm{Pr}x * \lambda^2}} \tag{1}$$

I is the distance of the antenna from the target, Ptx is the transmitting power, C is a constant given by the nature of the target (design of the tag), A is the area of the receiving antenna, k – a constant given by the type of the antenna (3–10), Prx is the received power.

As it is clear from the formula, a radical increase of the range can be achieved by a change of the antenna's area or a wave length rather than a change of the transmitting power. Since the wave length and the maximum power in RFID are determined, we can work with only one variable, which is the antenna's area.

Figure 2 illustrates simulation of UHF RFID tag used in measurements.

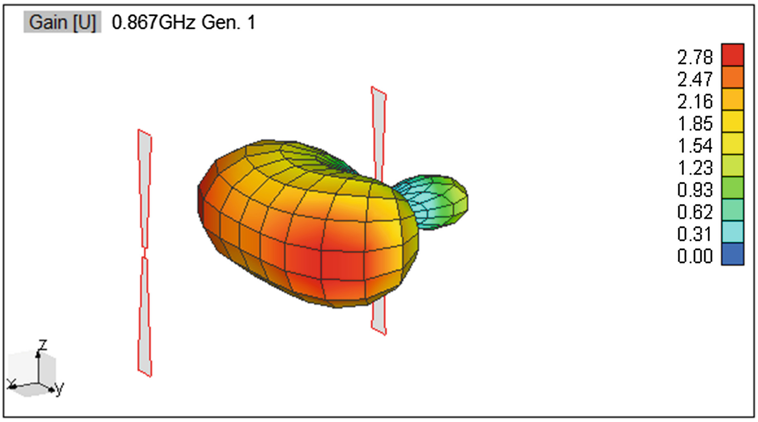

Fig. 2. UHF RFID inlays, apart 15 cm

4.1.2 Software Part

As for the software parts, we used operation system MySQL database, middleware and web application. The mutual relations of particular components (items) are depicted in the most proper way on Fig. 5. What needs to be said is that this is only a very simplified model and not every item can be marked as elementary, because each of them consists of other parts (Fig. 3).

Operation system ensures the flow of overall model, particular software items run under the system. As can be seen, web application does not communicate with middleware directly, but data are exchanged between them through MySQL database. In order to get overall view, we will explain shortly the basic functions of particular items and system operation principle.

Middleware ensures communication between hardware and software part of our model. At the same time, it enables to set up the configuration itself, so by its use we define practically what, how and when should the particular hardware and software components operate. All the data obtained from RFID gate are stored into database as well as all the data sent by user through web application. These data are accumulated

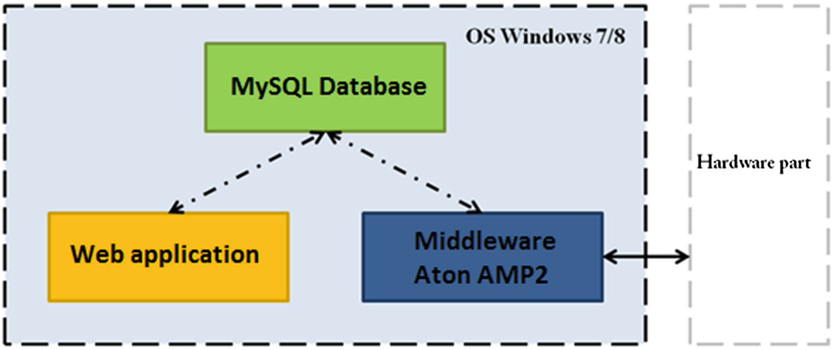

Fig. 3. Software part of measurements

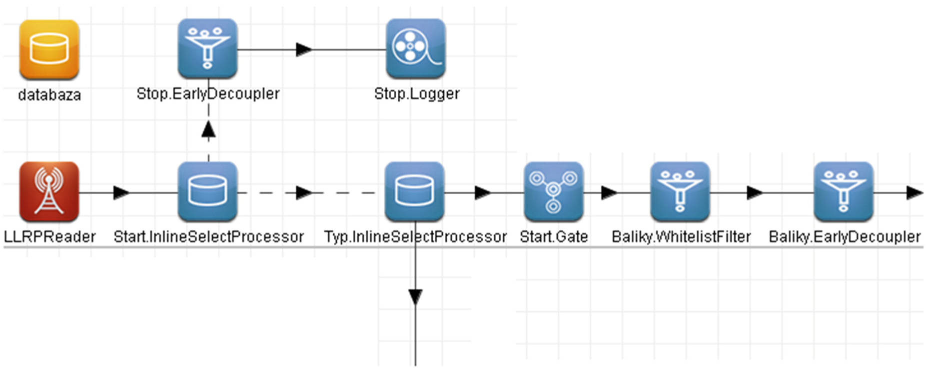

Fig. 4. Launch of measurements

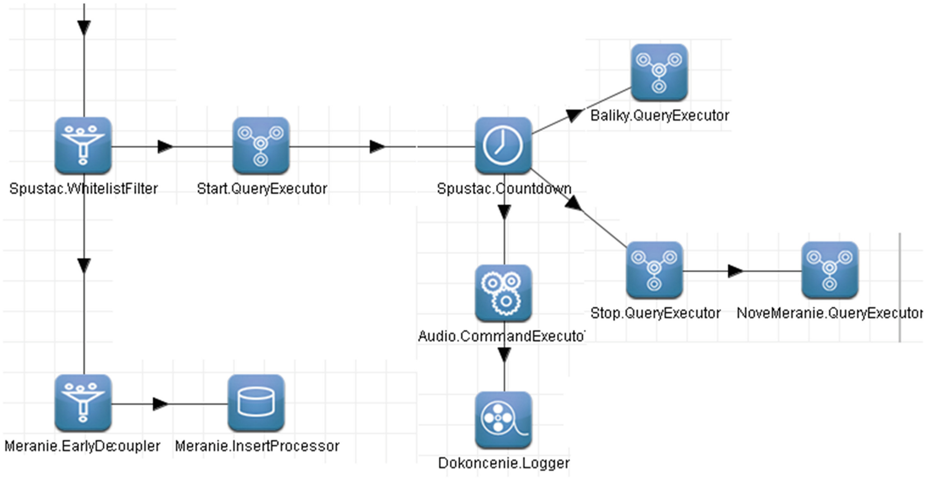

Fig. 5. Capacity control and sound signalization

here and provided by request to web application and to middleware. MySQL database serves as a place for gathering of all the collected data waiting for further demand. Web application serves for presentation of all the data from database and its further processing due to need to accomplish analyze by user.

4.2 AMP Model Configuration

Configuration of the model for readability measurement of items was designed in environment of AMP middleware. It was split into three parts:

1. Launch of measurements,
2. Capacity control and sound signalization,
3. Time formatting and recording into database.

First module serves for initialization of MySQL database, RFID reader as well as for detection, whether some type of measurement had already been launched. According to this finding, we define next procedure and following processes (Fig. 4).

Second module provides the entering of records of new partial measurement into respective type of database. This section also defines when this partial measurement is finished, when the capacity of gate is closed again and what is being accomplished besides sound signalization.

Third module formats at first the date and time of scanning of each item and mainly ensures the entry of data into MySQL database (Fig. 6).

5 Results from the Measurements

Prior to launching of measurements themselves, we had performed a line of several testing measurements in order to detect the functionality of overall system. At the same

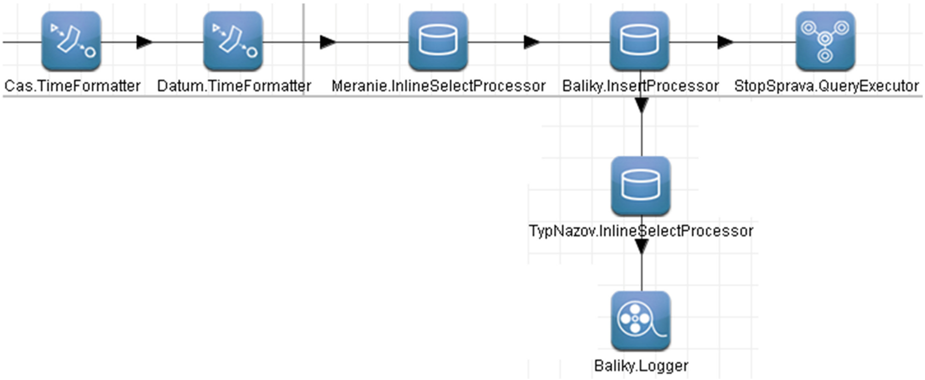

Fig. 6. Time formatting and recording into database

time, we found out by use of these tests that intensity of reader's scanning set in configuration has a minimal effect on scanning of particular tags in container. Therefore we set this intensity at each measurement for 100 % level.

Concerning the readability research of items placed in container, we performed the measurement for dependency of RFID identifiers placement on items as well as their orientation in regard to position of reading antennas. We performed following types of measurements:

1. Tags placed on the top side of items,
2. Tags placed on the bottom side of items with regard to bottom of the container,
3. Tags placed with edges towards all antennas,
4. Tags placed at the walls of container.

5.1 Tags Placed on the Top Side of Items

The choice of the first type was the one with RFID tags placed on the top side of items. We assumed that the results should be theoretically the best of all the types as the position of antennas was most favorable, considering radio frequency waviness and its impact to RFID tags (Fig. 7).

As we can see, the results of this type of measurement are indeed very positive. We measured the readability efficiency of 99.25 % by scanning the container with all four antennas. The only tag with weaker level readability was the one with tagID 01. This was successfully read only 76 times out of 100. Signal was not strong enough so that the antennas could successfully detect at each measurement the item with weaker readable tag placed on the very bottom of the container. If we ignored this one particular tag, we would have achieved overall average readability attacking level of almost straight 100 %.

5.2 Tags Placed on the Bottom Side of Items with Regard to Bottom of the Container

At this case, we assumed moderate fall of readability. This assumption was not much fulfilled at the very end (Fig. 8).

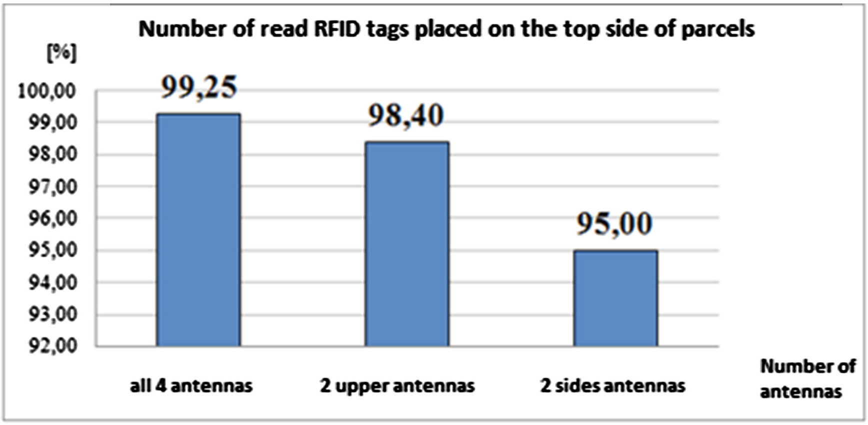

Fig. 7. Results of measurements 1

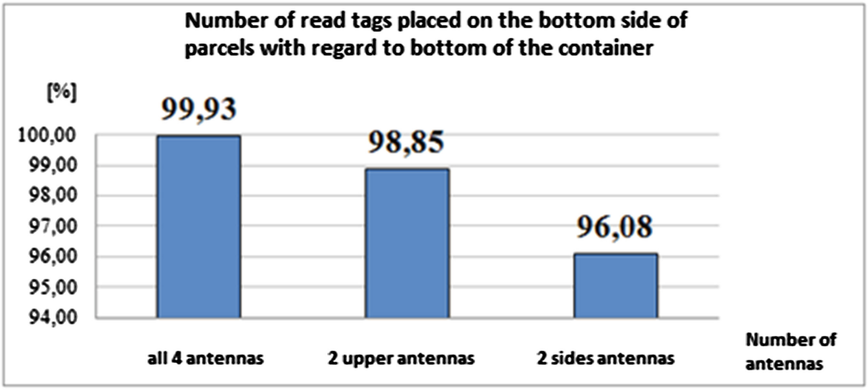

Fig. 8. Results of measurements 2

We can see that the readability was not only reduced but even increased by scanning with all the antennas up to level 99.93 %. The most relevant influence on this outcome has indeed the problematic tag 01 that was placed again at the very bottom of the container, but this time the tag was directly touching the bottom of container. The presence of the tag closer to floor and reflection of signals either from metal construction of container or from the ground very likely caused its 100 % readability by scanning with all four antennas.

5.3 Tags Placed with Edges Towards All Antennas

At this variant, we made our decision to make the reading of the tags more difficult with their placement - vertically to all the antennas. The tags were replaced on sides of items relating to back side of the container. Besides, the previous type of measurements proved that the activation of side antennas had only a moderate influence on

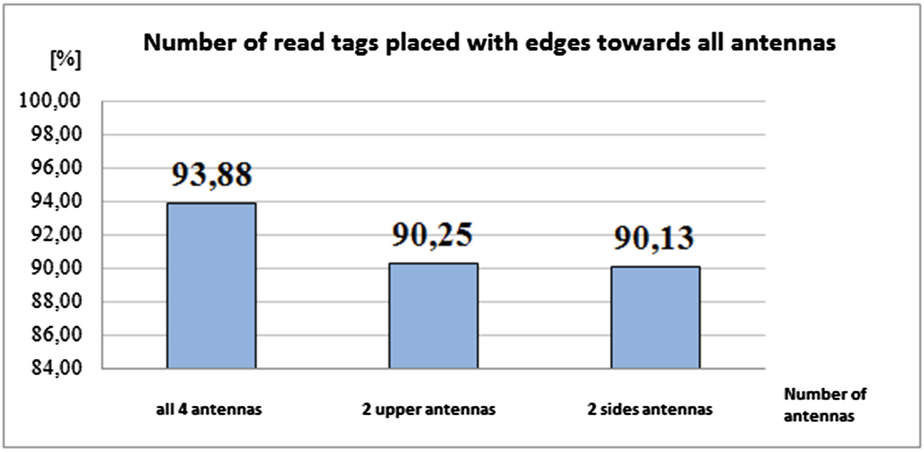

Fig. 9. Results of measurements 3

readability, unrelated to tag orientation. Therefore we placed the tags also into horizontal position (Fig. 9).

5.4 Tags Placed at the Walls of Container

We detected from previous types of measurements, that the barred metal wall of container from which the signal was reflecting has had the major influence on scanning of items. Therefore we decided that in the last variant, the majority of RFID tags on items would be placed on the walls of container. We assumed that this setting of items would have the most significant influence with regard to readability. The readability of tags did not drop significantly by scanning with all four antennas; it just dropped to still very satisfying level of 93.35 %. Despite a quite good average outcome of readability, we have to state that the tags placed at metal parts behave unpredictable from readability point of view.

5.5 Proposed Placing of Tags on Items and Lay-Out of Antennas of RFID Gate

Based on results of previous measurements, we could perform a measurement dealing with most convenient placement of RFID tags on items in container along with a placement on antennas. Tags were placed upon top side of items. As the results of measurements were not deformed by any weaker readable tag (01), we made a decision upon recommended configuration to change this tag for the other one. At first, we scanned exclusively by use of two top antennas only. After 100 repetitions, we recorded average detection of items at level 99.8 %. Then, we placed another two antennas upon second end of top construction of RFID gate, by which we ensured vertical scanning by all four antennas at once. Two antennas were placed as input and two as output of RFID gate, by which we achieved approximately the same long scanning interval of each tag in container. We performed the measurements 100 times. We achieved such configuration that the average level of readability was equal to 100 %. The very same results were achieved also in case, when the tags were turned - they were placed on the bottom side of items – in direction to bottom of the container (Fig. 10).

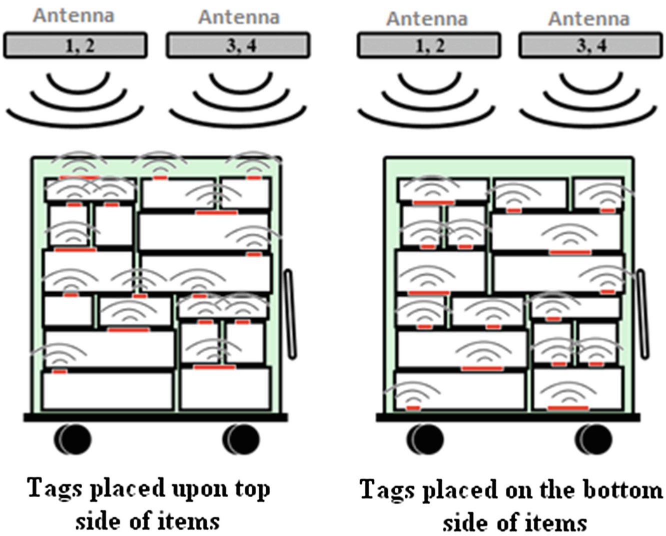

Fig. 10. Proposed placing of tags on items

6 Conclusion

We can state that introduction of passive radio frequency identification of items in logistic operation is technically feasible as a very high level of readability was achieved by scanning of particular items under laboratory conditions, reaching equal to 100 %. The results are very depending on specific placement of RFID tags on items in container and at the same time on placement of antennas of RFID reader. Another significant gained knowledge is that optimal solution is with utilization of four RFID antennas placed on top side of RFID gate enabling scanning of tags in vertical direction. Two antennas were placed at input and two at output of RFID gate. Thereby we ensured equally long scanning interval of each item in container resulting in a very high overall level of readability. Such solution would not be technically demanding under real conditions in operation. Besides, we found out that metal parts of container construction represent the prime problem of items' scanning in container. Significant signal means the potential scanning /not scanning of items would be very tough to predict. On the contrary, the highest percentage efficiency of scanning was recorded in case of RFID tags placed on top and bottom side of items. Under these conditions, the signal is not interfered by metal parts of container construction and the items are scanned without any serious problems even in case of only two top antennas utilization.

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