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THE USAGE OF RFID TECHNOLOGY IN WIRING COMPONENT STORAGE SYSTEMS

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Abstract: *In a fast-changing and highly competitive environment like the automotive industry, integrating the latest automation available solutions represents one of the easiest ways to increase productivity. Despite this fact, there are still suppliers in the automotive sector that disregard this possibility and decide to use basic handling equipment, instead of implementing one of the modern technological solutions available for increasing productivity by achieving a higher automation degree. Increasing productivity must be targeted on every level of the production process, from supplying the components and materials needed, to the delivery of the final product. One zone that could benefit from increasing the automation degree by implementing modern technology is represented by the warehouse. Improving warehouse process flow helps increase productivity on all the production phases and reduces costs. There are many modern technological solutions available for warehouse automation, but this paper focuses only on RFID technology. Therefore, the proposed simplified model presents the benefits of RFID technology application inside the components warehouse of a wiring harness producer. The presented RFID system is very flexible and can easily respond to challenges such as a large variety of stored items in different ways of packing, dynamic production supplying needs, replacing obsolete components, replacement of components due to the lack of raw material, or quality issues and so on. This paper aims to be a contribution to the integration of RFID technology in storage systems on a larger scale by pointing out the simplicity of implementing an RFID system to boost productivity.*

Key words: *storage systems, RFID, automotive, wiring harness, components warehouse, theoretical model, modern technology implementation.*

1. INTRODUCTION

Facing a highly competitive environment and having to adjust to new challenges that arise due to climate change, such as governmental laws that impose the reduction of carbon dioxide emissions, the producers in the automotive sector need to find leverage over the others in order to adapt and survive in a fast-changing environment. Integrating the available automation solutions, as well as discovering new ones through continuous innovation as a part of the company's development strategy, represents one of the top directions followed by the companies to become more competitive and increase their market share.

Increasing productivity must be targeted on every level of the production process, from supplying the components and materials needed, to the delivery of the final product. One zone that could benefit from increasing the automation degree by implementing modern technology is represented by the warehouse. The advantages that derive from implementing modern technology in the warehouse process flow are: better control of component flow by real-time data collection, a simplified process by reducing the manual handling operations needed, an important decrease in the possibility of human error, costs reduction, possibility to have real-time material reception and automated pre-established orders if connected with the supplier's systems, and the list could go on.

The modern technologies available for increasing the productivity of the processes carried out inside the warehouses are:

- Warehouse Management System (WMS): having an automated warehousing system is becoming a "must" for every warehouse because it offers a more efficient manner for handling the operations and the data associated, diminish the possibility of having human errors, being more reliable and less expensive than a manual handling system
- Radio Frequency IDentification (RFID): this technology has the potential to be applied in many areas of the production process due to the advantages given by having real-time data about the flow of materials, components, and equipment.

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- Voice picking technology (PbV): the picking process is made by a person that wears a headset connected to a small terminal using audio and voice control to receive and confirm the picking operations. The information is transmitted wirelessly to WMS by the terminal.
- Light picking technology (PbL): this technology uses light signals to determine which products have to be picked. Each storage location has an indicator that lights up if the product to be picked is found there, the pickers confirm picking the quantity displayed on the indicator by pressing a button that turns off the indicator light.
- Automated Storage and Retrieval Systems (AS/RS): has been integrated into warehouses that use automated transportation of loads, it can be adapted to the configuration of each warehouse system and increase its efficiency [1].

S. Škerlič in collaboration with the Automotive Cluster of Slovenia (ACS) [1] developed a survey to discover if the Slovenian suppliers to the international automotive industry are using the modern warehouse technologies. There were 24 companies that agreed to participate in the survey and the questionnaire was mainly completed by warehouse managers. The research model is based on four hypotheses (H1, H2, H3, and H4 as represented in Fig. 1) and takes into consideration the warehouse structure: handling equipment point of view and warehouse systems.

H1 – basic warehouse equipment is not reliable, which is why suppliers in the automotive industry rarely use them.

H2 – modern warehouse systems are reliable, which is why they are often used by suppliers in the automotive industry, due to increased demand for data processing.

H3 – the perception of the safety of the use of warehouse technology in businesses using modern technology is different than in companies that do not use modern technology.

H4 – the management of a company that uses modern technology reacts differently to warehouse errors than the management of a company that does not use modern technologies.

The results of the survey showed that the majority of Slovenian suppliers to the international automotive industry decided to use basic handling equipment, instead of implementing one of the modern technological solutions available for warehouse automation. As shown in Fig. 2, even though technologies like RFID, PtL, PbV have proven reliability, barcode technology is still the preferred technology implemented in this type of warehouse.

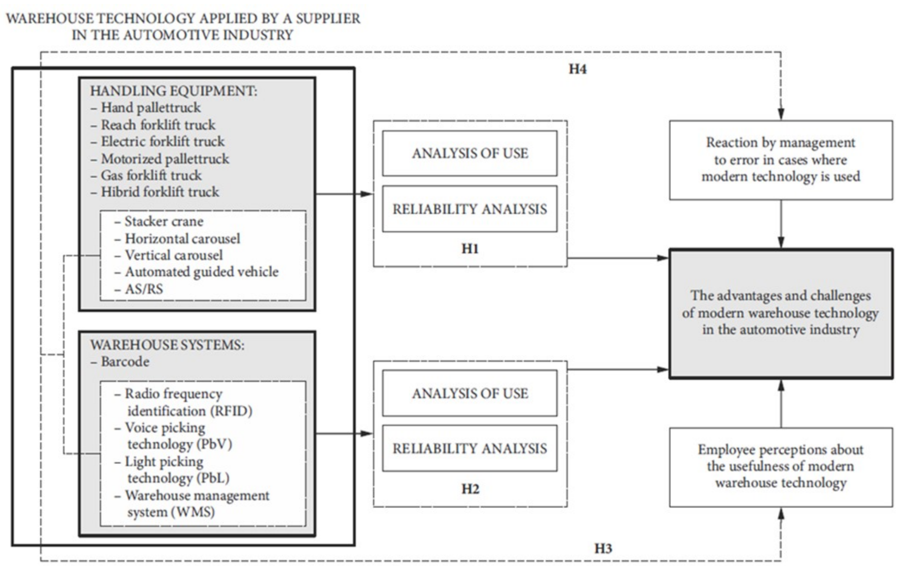

Fig. 1 Research model [1].

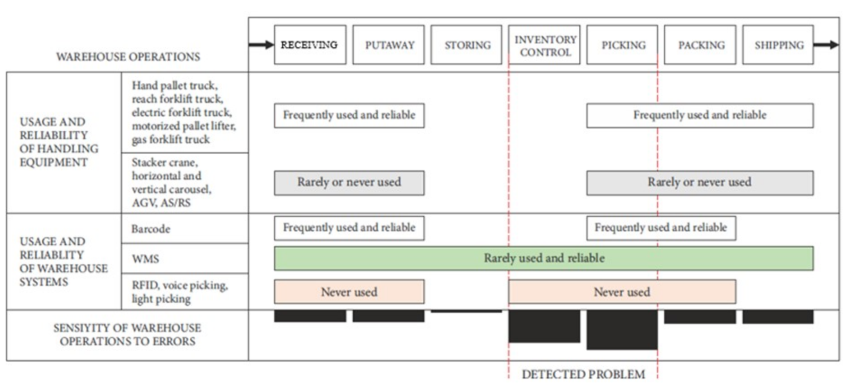

Fig. 2. The usage and reliability of warehouse technology in the Slovenian automotive industry [1].

In conclusion, even though the research results do not apply to all automotive industry because the survey was carried out only on Slovenian suppliers, it provides a certain level of understanding of how the modern technologies are perceived by the suppliers that are part of the automotive industry for quite some time, especially in smaller countries in Central and Eastern Europe, where the supply sector of the automotive industry is becoming more important.

Therefore, this article proposes a simplified model for the application of RFID technology inside the components warehouse of a wiring harness producer.

2. RFID TECHNOLOGY

The most common structure of a RFID system is composed of a reader connected on one side to an antenna, and on the other side to a server on which the information obtained after reading the tags is stored. [2]

The reader is an electronic device that uses radio waves to emit and receive data to and from the RFID tags that are in its range. The reader is equipped with a microprocessor and memory, so it can decode and store the information received from the tags [2].

The reader functions together with one or more antennas that can be either integrated into the reader case, either separated, connected from the outside of the reader.

Most RFID tags contain an integrated circuit for modulating and demodulating radio frequency and an antenna for transmitting and receiving signals. The technical characteristics of the RFID tags ensure a diverse usage by being compatible with many surfaces (they can be attached to boxes, different product labels, pallets, containers, equipment, shelves, or directly to the ceiling).

There are three types of RFID tags: active RFID tags (energy supplied by a battery, readable from a longer distance), passive RFID tags (powered by the electromagnetic waves coming from the reader), and semi-passive RFID tags (uses the same principle as passive tags but have extended communication range due to the included battery). Independent of their type, RFID tags operate on different frequencies, depending on the application field: low-frequency – *LF* (LF < 135 kHz), high-frequency (HF, usually 13.56 MHz), and ultrahigh-frequency (UHF, between 860 and 930 MHz) [3].

The fact that the tags information can be read and stored in a database on a server in real-time, makes the RFID system appliable in many domains such as production management, storage systems, productions cells, equipment inventory, automatic production areas, supply chain cost reduction, etc. [2, 4]

3. THEORETICAL MODEL OF RFID IMPLEMENTATION IN WIRING COMPONENT STORAGE SYSTEMS

As concluded after the ACS survey carried out on Slovenian automotive components suppliers, organizations with low corporate maturity tend to disregard the latest approaches of warehouse automation and use traditional equipment and technology, such as barcode technology which was first implemented forty years ago. This is the reason why this paper presents a model of usage of RFID technology in the components warehouse of one of the most challenged suppliers in the automotive industry, meaning the wiring harness producers.

The necessity of improving the warehouse managing system derives from the complexity of the wiring harness that is composed of a large number of various components, that have different storing requirements, so the warehouse has to meet the conditions in order to store and handle properly all the components. Being so diverse wiring harness components come in different ways of packing (boxes, rolls, bulk), so misplacing them could become a quality issue for the part itself.

To meet the production supplying needs, the delivery order for the components warehouse is made for each assembly line and it depends on the wiring type, versions, and demanded quantity, which is directly linked with the orders received from the car manufacturer. The estimation of the volumes for the requested wiring harnesses is shared with the wiring supplier in an interconnected orders system. The actual order is a very dynamic element in the production flow, being influenced by factors like increase or decrease of the cars demand on the market, the preference for one model/ equipment level over the other that may fluctuate in time, a component crisis that may cause stoppage of the car manufacturer plant [5]. Another aspect that requires a real-time inventory of all parts is that due to the impact of law-imposed regulations or evolution of the parts, some components will become obsoletes that leads to the necessity of knowing their exact location (in all areas) to replace them with the ones that respect the requirements and avoid any mixing error. The storage system must also be very flexible to respond to unforeseen situations like the replacement of components due to the lack of raw material or quality issues that may impose the replacement of a component or adding new ones in order to ensure the robustness of a technical solution.

The warehouse proposed in the theoretical model is structured in four areas meant to ensure the fluidity of the logistic flow specific to wiring harness production (Fig. 3).

The receiving area has four entrances from the outside in order to streamline the reception of goods. [9] After the pallets are unloaded, they are transferred into the storage area by forklift trucks equipped with an RFID system that allows them to read the tags and log the information into the warehouse system [7].

The entrance into the warehouse is made through one of the two RFID portals. When the vehicle passes through the portal, the tags are read again, the information is confirmed and the location on the rack for the transported goods appears on the vehicle's screen, depending on the used system the shortest path may also be shown on the screen [6]. After the goods are placed at the indicated location, the RFID labels mounted on the rack are scanned and the cargo information is checked.

Information has been associated with the shelves to complete the warehousing process, to achieve the synchronization of checking location.

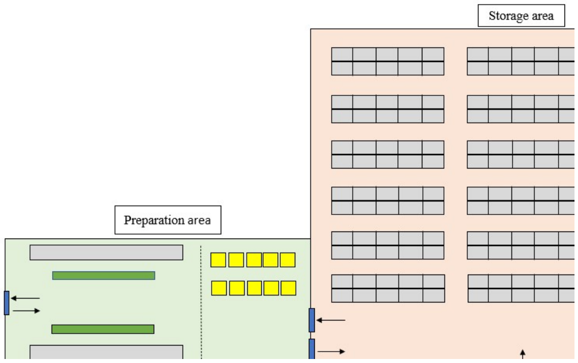

Fig. 3. Wiring components warehouse layout.

To ensure the assembly flow with the necessary components, a delivery order is registered in the system. According to the order, the information regarding the location of the desired components is sent to the forklift truck. After the parts are removed from the shelf, the staff scans the electronic labels on the shelves to unbind the parts with the shelves.

The parts are leaving the storage area through a gate equipped with an RFID portal that reads and registers the exact quantity of goods that passes through the gate. In order to ensure the transport fluidity, the communication between the storage area and the preparation area is made by two RFID portals, one for bringing the pallets into the preparation area and the other one to retrieve the pallets into the storage area. The pallets with modified quantities are scanned when passing by the RFID portal, the new information regarding the quantity is transmitted into the system and the storage location is sent to the forklift truck. Afterwards the association procedure between the part references, quantity, and shelf location is retaken. Empty pallets are taken into a storage area dedicated especially for this purpose.

In the preparation area, the components are sorted depending on the required quantity and temporarily stored on the racks. The storing is made following the same principle as in the main storage area, the tags for each package are read and associated with the shelf. Afterwards, when the delivery is made the package is unbound from the self and loaded onto the transport vehicle. All the tags are scanned and read automatically when passing through the RFID portal, mounted at the exit from the preparation area.

The diagram below presents the main logistical operations in correlation with the implemented RFID technology

The diagram presented in Fig. 4, highlights the way that the RFID technology is integrated into every step of the storage process. Having real-time data transfer for every handling operation reduces significantly human error possibility, leading to a higher quality level of the process. It also simplifies the sorting process making it easier to respond to the assembly line supplying needs.

The proposed RFID system provides real-time inventory of all parts combined with a track and trace functionality ensured by the RFID portals and the forklift trucks RFID equipped, connected with the wiring producer applications through RFID Middleware software. All the RFID equipment is connected to the middleware, which manages all the data coming from the RFID tags and ensures the communication between devices and the enterprise software (as represented in Fig. 5). It also filters and translates the data into different formats, to make them usable by different applications [8].

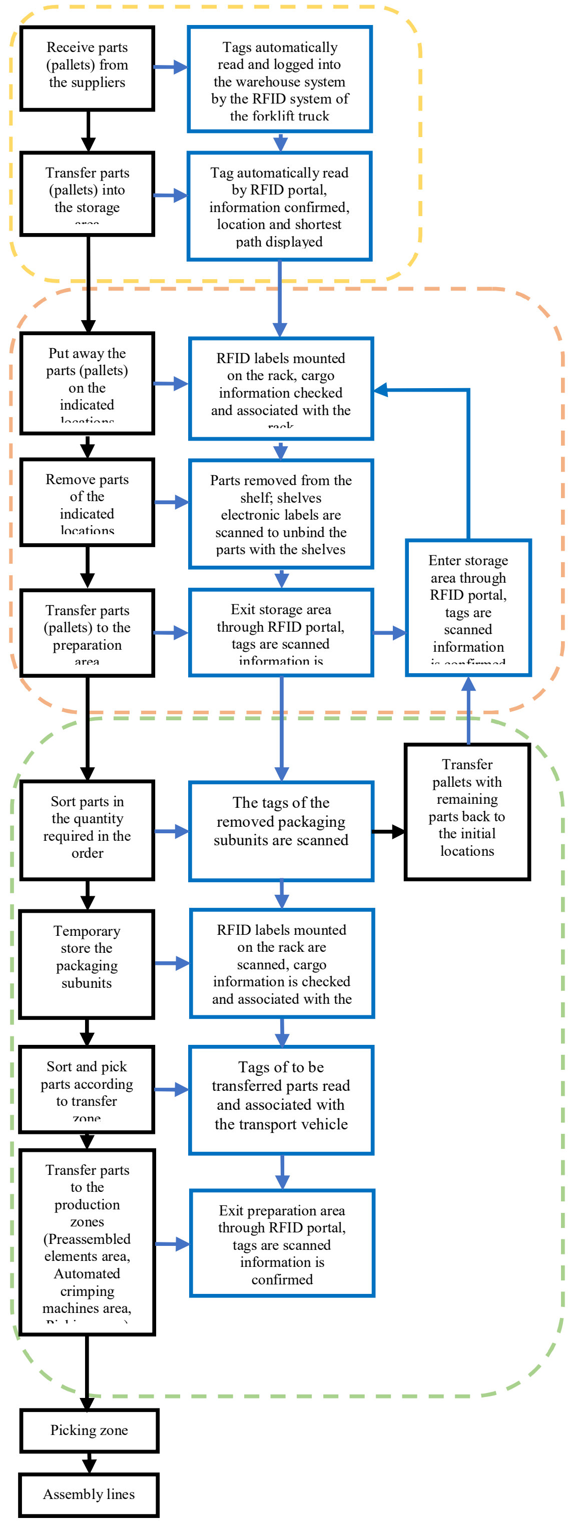

Fig. 4. The diagram of logistics operations correlated with RFID implementation.

Figure 6 shows a schematic representation of the RFID network implemented in the warehouse:

The RFID portal allows the automatic identification of all the tagged items that are passing through [6].

The RFID portal installed in this theoretical model is composed of:

- The master column, equipped with:
  - Mini-PC;
  - Screen TFT 12" colour HD tactile [13];
  - RFID UHF reader [11],
  - Two antennas [12],
  - Ethernet switch,
  - RFID Module [14],
  - Passage detector,
  - LED Signal Tower (green, yellow and red) [15],
  - 24 V power supply common to the various equipment.
- The slave column, equipped with:
  - RFID reader [11],
  - Two antennas [12],
  - 24 V power supply common to the various equipment [6].

The slave column is connected to the master column by an Ethernet cable (as represented in Fig. 7).

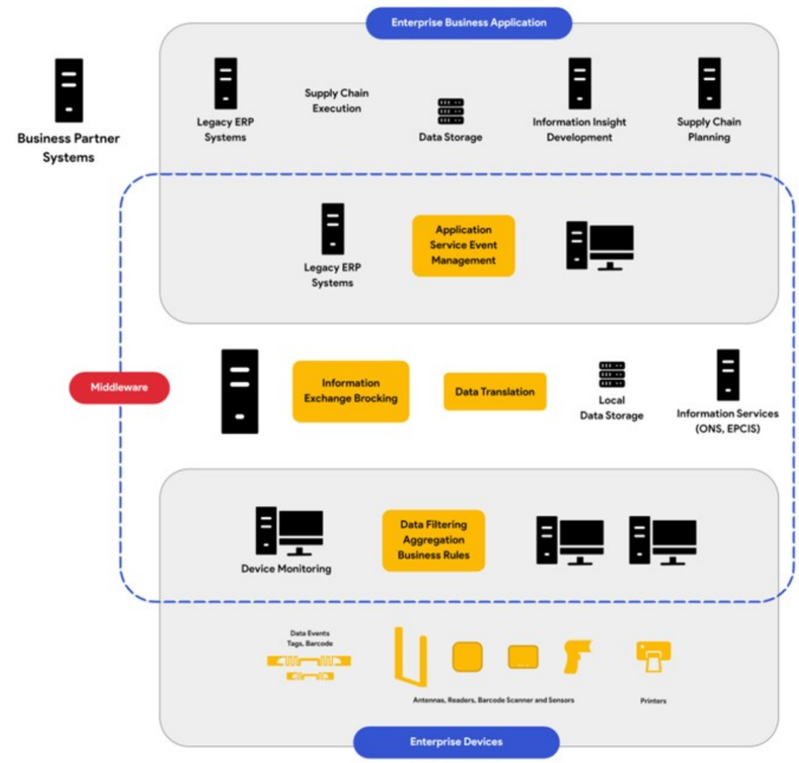

Fig. 5. The intertwinement of RFID middleware functions within the organisation software [8].

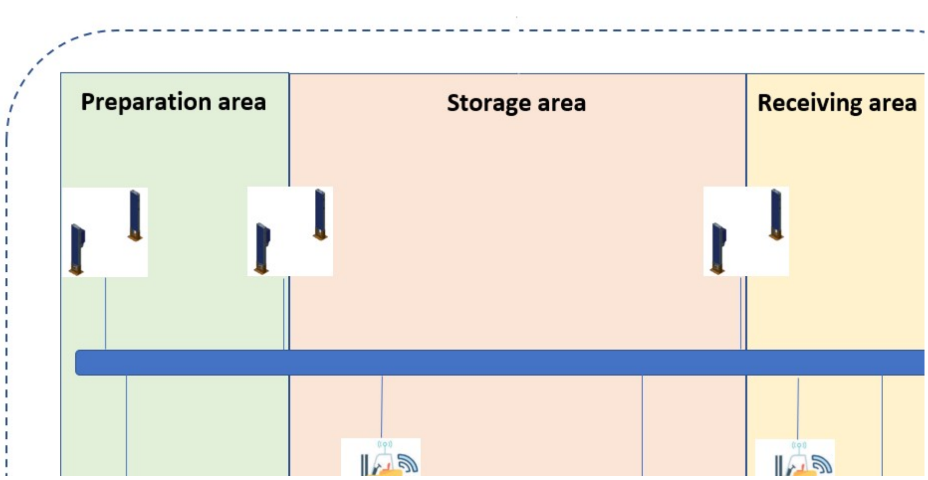

Fig. 6. RFID network representation.

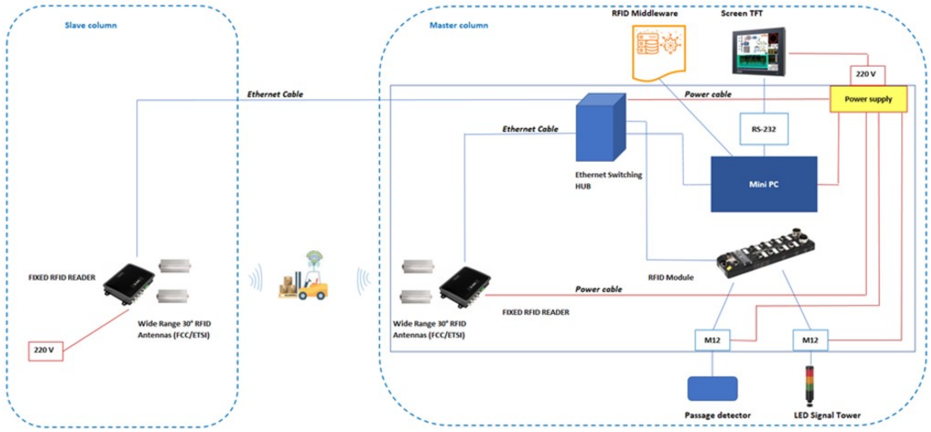

Fig. 7. RFID portal equipment representation.

Fig. 8. RFID equipment for forklift [7].

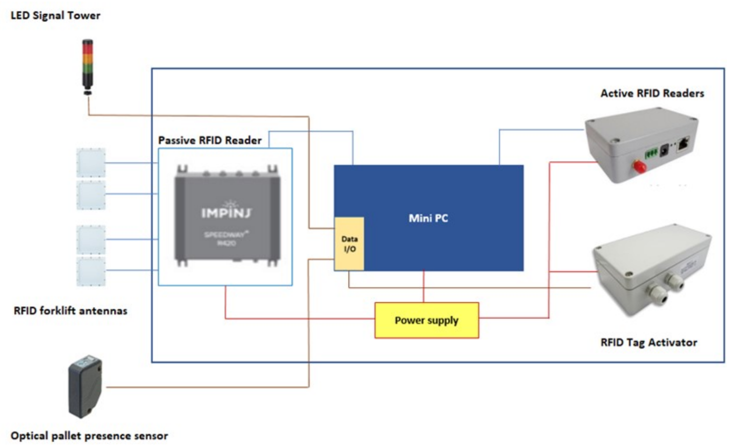

Fig. 9. RFID forklift system representation .

The second equipment implemented in the warehouse is the forklift truck with an RFID system (Figs. 8 and 9) [7]. The RFID system mounted on the forklift is composed of:

- Mini-PC,
- Passive RFID reader [17],
- Active RFID reader [19],
- Tag activator [20],
- Common power supply,
- LED Signal Tower (green/yellow/red) [15],
- Four antennas [16],
- Optical pallet presence sensor [18].

The housing is powered by the 12 V forklift taken from the accessory socket [7].

To complete the "Track and Trace" functionality, RFID pug dots have been implemented inside all the areas of the warehouse. The pug dots will transmit accurate data regarding the location of the forklift truck. The operating principle has the following steps:

- Pallets are detected by the optical presence sensor;
- Passive RFID reader is activated;
- The pallet is loaded onto the forks of the truck;
- The RFID passive tags are associated with the location of the forklift truck.

Puck Dot is an active RFID tag that operates on two frequencies 125 kHz for reception and 433 MHz for emission (Figs. 10 and 11). Low-frequency reception enables extremely accurate distance measurement, compatible even with highly metallic environments. UHF emission offers a greater detection distance, reaching over 100 meters. Puck Dot has long battery life and a robust waterproof casing. When a forklift truck passes in the proximity of a puck dot, it is activated and transmits its data to the active RFID reader. Every puck dot identified by the active reader is registered in a log file transmitted to the RFID middleware [10].

The maximum LF reception range of the RFID puck dots varies from 5 to 15 m depending on the installation environment and the RFID antennas mounted on the forklift trucks. In the proposed model, the puck dots were mounted at approximatively 12 m distance by each other according to the characteristics of the warehouse and the selected equipment. A data filtering system was put in place to keep only the relevant data to determine the accurate position of the loaded forklift trucks. For this purpose, a reference reading was performed, considered to be representative for reading all the tags corresponding to the load transferred on the forklift. All readings taken near an activated puck dot are compared with the reference reading. The path of the loaded forklift trucks is established according to the readings that pass after being compared with the reference and only if it contains at least two log files from two different pug dots. Figure 12 shows the placement of the puck dots inside the warehouse areas and the intertwinement of their reception ranges.

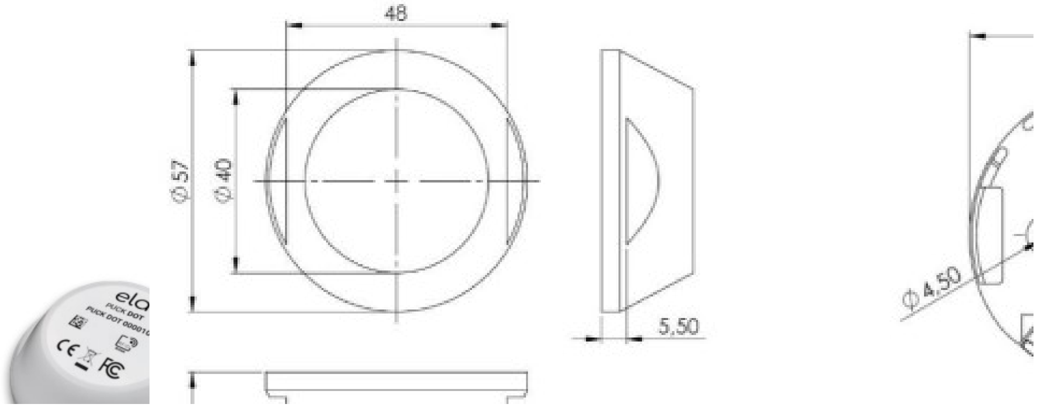

Fig. 10. RFID puck dot representation [10].

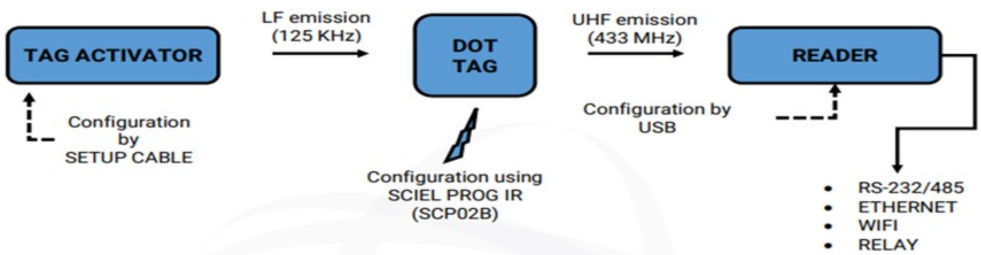

Fig. 11. RFID puck dot (tag dot) operating principle [10].

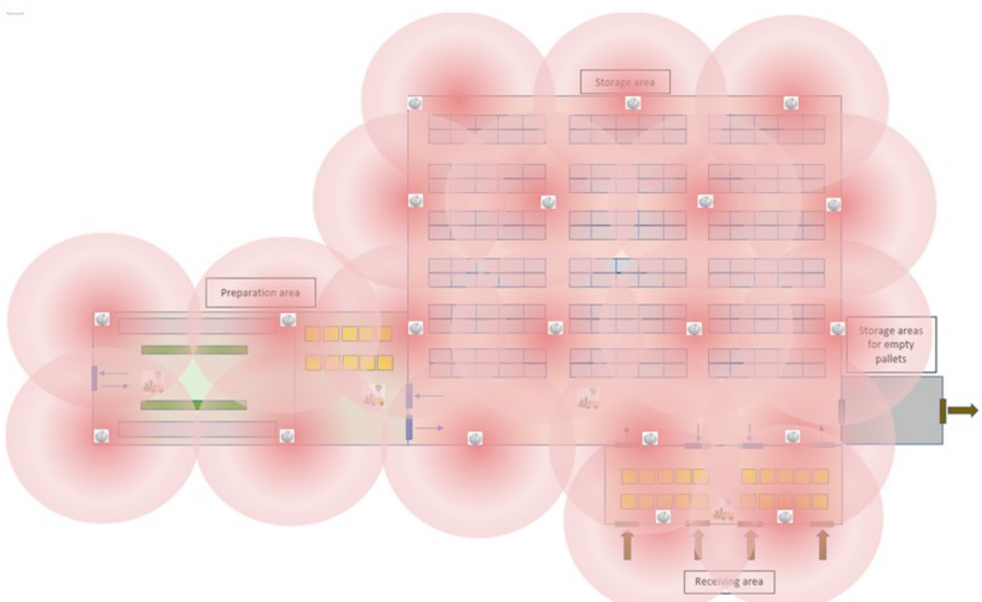

Fig. 12. RFID puck dot implementation.

4. CONCLUSIONS

The theoretical model proposed in this paper is intended to be a contribution to the integration of RFID technology in storage systems on a larger scale. The presented RFID system is very flexible and can easily respond to challenges such as a large variety of stored items in different ways of packing, dynamic production supplying needs, replacing obsolete components, replacement of components due to the lack of raw material, or quality issues and so on.

The implementation of the system is simple and can be carried out without major modifications to the existing equipment and software, leading also to low investment costs. Wiring producers as well as other suppliers in the automotive industry could really benefit from implementing RFID technology and having better control over their stocks. Therefore, the perception of the company management over modern technology must be improved by increasing the level of information on the available automation solutions in order to align the practice with the technological possibilities (future work).

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