RFID Equipped Forklift Trucks

Andreas Jungk
Institut für Transport- und Automatisierungstechnik
Leibniz Universität Hannover, Germany
andreas.jungk@ita.uni-hannnover.de

Ludger Overmeyer
Institut für Transport- und Automatisierungstechnik
Leibniz Universität Hannover, Germany
ludger.overmeyer@ita.uni-hannnover.de

***Abstract* - Forklift trucks are a basic element in material handling and will help to control the flow of goods in the future. This paper outlines how forklift trucks with integrated RFID hardware can be deployed in warehouse IT systems. Forklift trucks will be able to communicate with management assistant systems by means of RFID and WLAN. Goods carriers like pallets and pallet cages are equipped with RFID transponders. Information about handling and processing can be locally stored on the goods carriers. A method for the measurement of the stability of communication with components integrated in forklift trucks is presented. Components, which are specifically developed for this new system architecture, are described. Economic advantages are investigated, too.**

I. Introduction

Logistic process steps, e.g. the input of goods issue slips in warehouse management systems, are executed manually today. New integrated wireless systems help to automatise these functions. Data from a forklift control unit is combined with data from RFID tags on pallets. Thus, it is possible to make control decisions where information about the transport process is generated physically.

For optimisation in logistic processes it is necessary to measure control parameters in real-time. This requires a continuous flow of information. Today the goods issue slips are entered manually into a warehouse management system, which produces ware transfer orders. Combined data may be inconsistent because the flow of goods is physically separated from the data.

II. State of the art

Barcode readers are used in warehouse management systems to automatise the input of information from pallets, goods issue slips and storage locations. Drivers have to leave their truck and scan the barcode manually. Barcode labels may get soiled or damaged. It is not possible to edit data on the barcode labels. Information about transport and production process is not stored on goods. It is provided by central IT systems.

Systems for a localisation of forklift trucks are available. These systems use in-ground RFID transponders. To detect various storage areas in this system, localisation data has to be combined with hardware to measure lifting height. Even here information about goods must still be entered manually and is combined with position data. Thus, it is possible to detect and store movements of goods in a warehouse.

Fixed RFID gates allow to store movements between different areas in a warehouse [1]. RFID transponders are placed on the packagaging or on the items. Antennas must be well aligned to read the RFID transponders when they move through the gate. The flow of information is coupled physically to the material flow at gates only.

III. Proposed System Architecture

3.1 Current Research Activities

In co-operation with partners in industrial enterprises and research institutes, the Institute of Transport and Automation Technology develops a system which can automatically document movements of goods [2]. Transport events are provided to the higher level IT-systems. Logistic key data about the ware which has to be transported is stored on RFID transponders [3]. These transponders are integrated in pallets and boxes. An RFID reader integrated in the fork carriage mechanics reads the required information. In addition, it is planned to read transponders on the floor of stock shelfs with this antenna.

In order to realise a high reception range and small antenna setups the UHF frequency (868 MHz in Europe) was chosen. Due to the hazard of collision with goods stored on pallets and adherent mechanical stress, an intelligent design has to be realised to integrate antennas into forklift trucks. Small-sized antenna geometries are necessary.

3.2 Components of the Proposed Architecture

Multiple readers in one area will interfere and performance will decrease. Just 10 channels with a bandwidth of 200 kHz are available in the 868 MHz frequency range due to the ETSI standard [4]. To prevent that different antennas interfere with each other readers must be switched off when reading is not expedient. Otherwise efficient operation of the whole system is impossible. Based on data from the forklift control unit the forklift terminal has to determine when the reader has to be switched on.

For this purpose a new component, termed event box, was developed. This event box consists of a digital signal processor, which is connected to the forklift truck's CAN-BUS. The digital signal processor reads selected CAN messages and converts them to events. The following important events were determined: velocity reduction, pallet on forks, and further more. System structure is shown in figure 1.

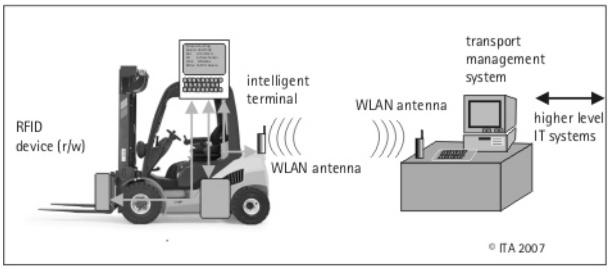

FIGURE 1 - INTEGRATION OF AN RFID EQUIPPED FORKLIFT TRUCK IN IT SYSTEMS

The integrated RFID reader accumulates information about transponders in its receiption range. Event box and RFID reader send their messages to a communication module where they are processed. The communication module is software executed on the forklift truck's terminal. It controls all functions of the RFID reader. If the event box sends an event "pallet picked up" a reading sequence of the RFID reader starts. Different algorithms are implemented to prevent the processing of data based on multiple reading sequences. If more than one pallet transponder is read, reader transmitter power will be reduced.

The forklift truck terminal has a wireless interface and communicates with higher-level IT systems. Moreover, it includes the human machine interface for communication with a central localised transport management system. Drivers get their orders and information about origin and destination of the goods to transport. The transport management system gets its orders from higher-level IT systems like WMS, ERP or PPS. These transport orders are stored in this transport management system and afterwards sent to the forklift trucks. Accomplishment of transport orders are controlled by the transport management system by using messages from the forklift trucks.

RFID transponders for goods carriers have to bear extraordinary mechanical strain. Therefore, it is necessary to develop special transponders for the integration in goods carriers. Their mechanical and electrical properties will be compared with common RFID transponders. In figure 2 an RFID transponder with slot antenna is shown. It consists of a metal body and a strap applied on its surface. This RFID slot transponder may be integrated in the bottom of a pallet cage.

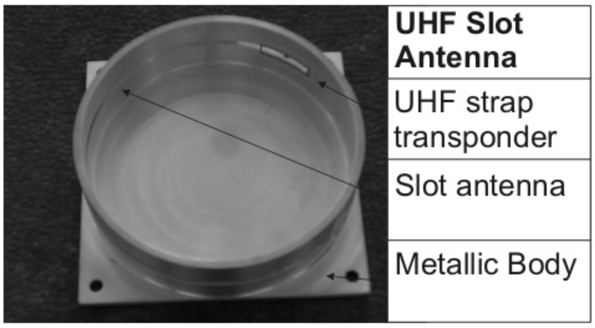

FIGURE 2 - UHF RFID TRANSPONDER WITH SLOT ANTENNA, DEISTER ELECTRONIC

3.3 Advantages of the Proposed System Architecture

RFID gates integrated in forklift trucks allow to couple flow of goods with flow of information physically. Longer stay of transponders in an antenna field will increase reading accuracy. With antennas integrated in the forklift truck, RFID transponders on goods carriers can be read during the whole transport process [5].

RFID transponders integrated in goods carriers contain information about quantity and type of goods that are carried. Information about source and destination, handling, and about storage is available additionally. It is even possible to reduce forklift's velocity when conveying fragile goods or to avoid placing heavy pallets breakable goods. If electrical, mechanical and software interfaces are well defined, users can change system components. This will increase the market acceptance of this system.

IV. MEASUREMENTS

Antenna and goods carriers with RFID transponder are moved together. Therefore, RFID transponders stay longer in the antenna field as if moving them through fixed gates. High reading accuracy can be achieved. It will be tested which places on goods carriers are suitable to integrate a transponder. Extensive test series will help to ensure reading accuracy even under bad conditions. This will help to make the system robust.

Forklift trucks have to read information from RFID transponders integrated in goods carriers before the goods carriers are picked up. Measurements for RFID transponders, like the directional radio characteristic pattern, are well known [6]. However, these measurements do not help to decide if a specific combination consisting of a forklift truck and a goods carrier, both equipped with RFID meets the requirements of process safety.

The Institute of Transport and Automation Technology has developed a new RFID test setup shown in figure 5. Ranges of RFID readers can be checked in cartesian and cylindrical coordinates for different types of goods carriers and reader antennas. Investigations lead to a system where character of goods does not influence the performance. Initially pallet cage and pallet will be tested with different transponders.

It is desirable to communicate with the RFID transponders integrated in goods carriers before the forklift truck picks them up. This is achieved by a high range of reception independent from goods carrier orientation. If later problems occur because more than one transponder is read, antenna power output can be reduced. Even different reader antenna designs are compared. For implementation on a forklift truck a linear reader antenna polarisation will be compared to a circular reader antenna polarisation. An influence to receiption range depending on wether the goods carrier is placed on stone ground or metal ground will be probed.

First results show that the forks do influence the systems performance. Initially, a pallet cage equipped with an RFID transponder was placed on the ground plate. A concrete slap was placed between ground plate and pallet cage to emulate a ground floor comparable to a factory floor. The antenna was moved step by step relatively to the ground plane in horizontal and vertical direction. The pallet cage fixed on the ground plane was moved to vary distance between RFID reader and pallet cage. Measurements started, when the antenna was parallel to the left side of the pallet cage and ended when the right side was reached. All axis were moved consecutively. Between start point and end point every 50 cm a measurement was made. To execute a measurement, the RFID antenna was switched on. After 1 second the antenna was switched off. When a reading sequence occured, this event was stored togehter with the position information. To convert this measurements to a diagram, every successful reading sequence became denoted by a point at the corresponding position. In figure 3, a fork emulation was fixed on the test setup. The same setup was tested without forks (figure 4). Point density is reduced when a fork emulation is mounted below the reader antenna due to a distortion of the antenna's radiation lobe.

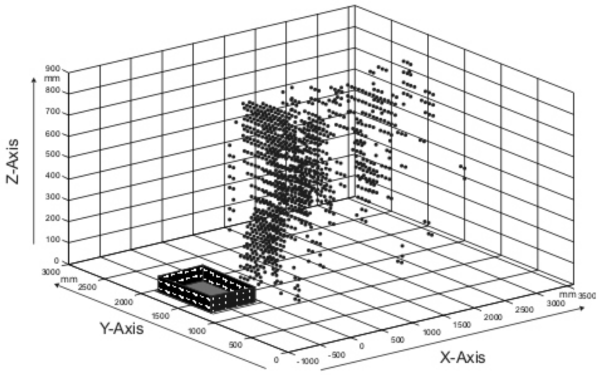

FIGURE 3 - MEASUREMENT ON RANGE TEST SETUP; PALLET CAGE WITH SHORT FORK EMULATION

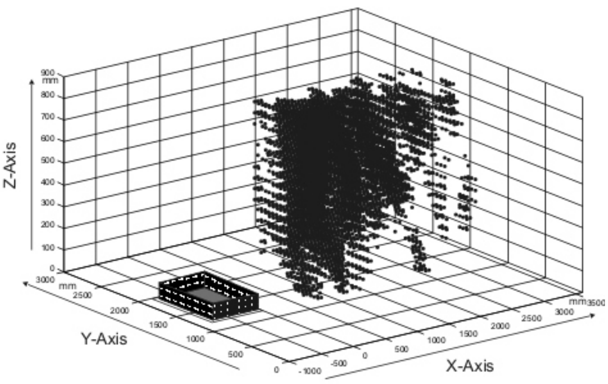

FIGURE 4 - MEASUREMENT ON RANGE TEST SETUP; PALLET CAGE WITHOUT FORK EMULATION

Next step is to equip even special goods carriers with RFID transponders. Special goods carriers are more expensive than pallets or pallet cages. Therefore, transponders price has only little influence on goods carriers price. Moreover, special goods carriers are often used in closed logistic circuits. These circuits simplify implementation of an RFID equipped system in comparison to open logistic circuits.

Furthermore, goods carriers with RFID transponders have to be resistant to mechanical and climatic influences in warehouses. This will be investigated with special mechanical test equipment. Exposition under extreme climate will be tested in a climate chamber.

V. ECONOMIC ASPECTS

A wide acceptance of this system can only be achieved when economic investigations are made, too. For this purpose logistic processes of the German robot manufacturer KUKA Roboter GmbH were analysed. A new process regarding forklift trucks equipped with RFID technology was defined theoretically. With economic key data, like loans and machine-hour rates, savings of costs were computed. Moreover, continuous system supervision and massive parallelisation of processes are vantages, which boost process stability [7].

VI. CONCLUSION

Soon a complete system will be installed at goods receipt by KUKA Roboter GmbH, Augsburg (Germany). An optimised system will be achieved by analysing results of this test installation. After launching this first test, even economic logistic processes will be adapted until they fit to the application.

Later another test in an automobile manufacturer's logistic centre is planned to analyse goods transport between different plants of an enterprise. In future, RFID transponders will have a longer range, better reading accuracy and more user storage, as well as the possibility to pre-process data on

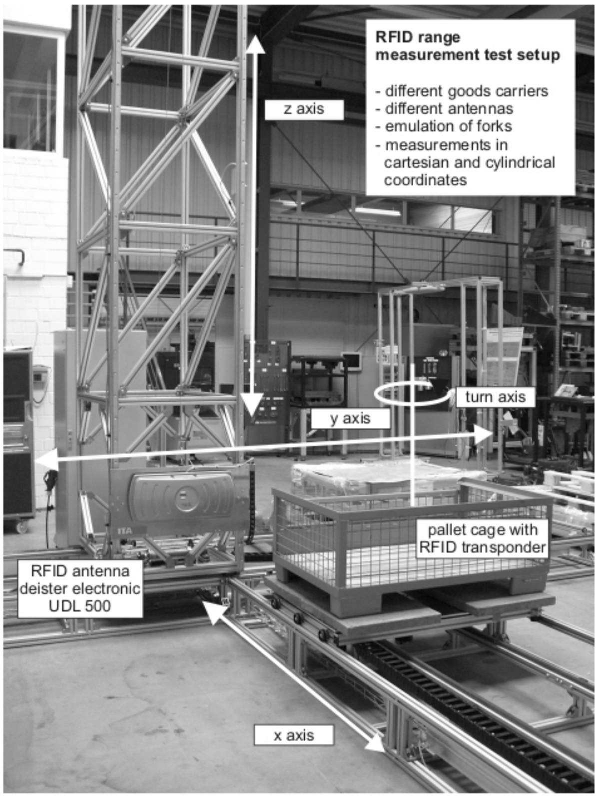

FIGURE 5 - RANGE TEST SETUP AT INSTITUTE OF TRANSPORT AND AUTOMATION TECHNOLOGY

the label. New options for process control, like generation and monitoring of logistic key data, will be established [8] [9] [10] .

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