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RFID TECHNOLOGY AS A PROMISING SUPPORT IN LOGISTIC INFORMATION SYSTEMS

Abstract: The article concentrates on information technologies supporting logistics. In the information society, in which knowledge possessing is the main source of wealth, companies in order to meet client needs have to adapt to constantly improving IT solutions. Logistic information systems allow the cooperation among producers, deliverers, distribution centers and clients. This cooperation needs each participant of the supply chain to communicate. Automatic identification of data improves this communication. One of the most promising solutions within logistic information systems of automatic identification is RFID technology. Its functioning and advantages surpassing bar codes are characterized in the article.

1. Introduction

There might be identified three sectors of the economy, which construct three ages in the history of human being. The primary stage of economy growth was agriculture and the extraction of raw materials from the earth. This era lasted about 10 thousand years, until mid-17th century, when J. Watt invented steam machine in 1769. This event gave the beginning of industry period. In the agriculture society possessing some land meant being rich, whereas in the industry era capital and raw materials turned into finished products were indicators of wealth. Then, the third era, the era of information began, in which knowledge possessing is connected with riches, as it is the main assets. The information is treated equally with other resources.

One of the variety of information society faces are complex processes of virtualization of human life. Nowadays these processes occur in almost every branch of social and economical activity. Money are replaced by various paying cards and e-transactions. Traditional paper books, maps, articles have their electronic substitutes. Wide range of appliances of every day usage (e.g. camera) are altered into digital forms. Music used to be registered on discs or tape recorders, now compact discs are commonly implemented. The same situation is with VHS films replaced by DVD [*Generowanie*… 2004].

The process of constant information flow improvement is essential in our developing, fast changing world. Organizations need optimizing methods of managing. Modern IT technologies implemented in order to improve collecting, storing and processing information, which make the organization work more efficiently are connected strongly with development of logistics. Logistics is managing the processes and potential in order to coordinate realization of goods flow [*Słownik*… 2006].

The aim of this article is to present the importance of information systems in logistics. The main body of the paper concentrates on implementations of automatic identification systems especially the RFID technology.

2. The examples of implementing information systems in logistics

Information system in logistics can be defined as the structure of interdependent people, equipment and procedures, which provides the chief manager of logistics appropriate information needed to plan, realize and control logistic activities [Coyleet al. 2002, p. 524]. Modern logistic information system goes beyond singe organization, it has multi-organizational character. This system lets the information flow among each links cooperating in the supply chain. Supply Chain Management (SCM), is the information system which helps monitoring of distribution network. It involves a range of solutions enabling the companies strategic planning and using tasks connected with processes of purchasing, production, storing, selling and servicing within the supply chain. SCM integrates the clue business processes of each links in the logistic chain, that is distributors, producers and receivers in order to achieve maximal benefits [www.logistyka.net.pl].

A number of information tools operating at certain stages and facets of logistic chain can be identified within SCM systems which are responsible for managing the processes of supply chain. These are programs made to identify goods and sending data (e.g. EAN-UCC system), to interchange data electronically (EDI), to transfer funds electronically (EFT, ECR). These IT solutions allow flowing the stream of materials and improving the level of customer care. Among SCM systems there are also systems operating storing processes, such as Synaptic Stock, which improves managing stock keeping. There are also complex logistic and transporting systems (ILS/ITLS) or intelligent transport systems (ITS).[1]

Logistic information systems are often implemented within technologies connected with Automatic Identification (AI) of data. It is the way of identifying an object through an appliance with automatically introduced data into a computer and using data base about this object [Baraniecka 2004]. Automatic Identification systems are useful to follow the flow of goods in whole supply chain and to collect and process the data connected with this process into useful information.

[1] Within SCM systems not only tools but various times of strategies that coordinate cooperation between business and IT tools are distinguished (e.g. strategies of quick customer care, such as QR (quick response), or ECR (efficient customer response), after: www.ispsa.pl; www.logistyka.net.pl. See also: [Leszczyńska, Łopaciński 2007, pp. 208-216.

One of the Automatic Identification methods is commonly used traditional system of bar codes. Leading in this group of technology is graphic representation of information showing lines of different width and spaces between them. It is used to code data that are then read quickly and accurately. Reading is possible thanks to special readers which analyze a particular cod and change it into certain information contained in it. Nowadays there are over 200 kinds of bar codes identified by different international standards. In economic practice only some of them are used, e.g. EAN 13, EAN 8, CODE 128, UPC A and E [Leszczyńska, Łopaciński 2007]. Implementing bar codes improves company's functioning because of such advantages like: decrease of administrative costs, better quality of data, cutting on time of orders realizing, faster client care, quick reaction to market needs [Hałas, Swarcewicz 2002]. However, the usage of bar code is connected with plenty of drawbacks, such as the necessity of optical connection and limitation of the distance between reader and bar code, limited number of data which may be contained in a bar code, decrease in quality of reading as a result of outdoor conditions (moisture, wearing away, tearing), low level of data safety [Baraniecka 2004].

Above mentioned limitations of bar codes cause popularization of a newer and better solution within Automatic Identification of data, RFID technology. It is a method of identifying data using radio rays to remote exchange of data [Muszyński, Borck 2006]. This technology may be applied to identify, follow, sort and find out wide range of objects.

3. RFID functioning

We use Radio Frequency Identification (RFID) technology in our every day activities without being aware of it. It is used on highways, where there are special electronic appliances when paying for the ride. Employees use transponders in order to enter to their plant or office.

RFID is the system of controlling the flow of goods on the base of remote – through radio rays – data reading and writing using special electronic systems fixed to monitored objects. This technology replaces bar codes by a micro system, from which information can be read, but it cannot be seen. Unlike using bar codes, RFID allows reading data from transponders and writing data without optical contact between reading appliance and transponder. By using this technology it is also possible to record data many times.

Each RFID system consists of three basic elements: transponders, readers, which send radio rays, and programming (communicative and usage) – IT solutions which allow reading and processing data [Technologie radiowe... 2005; Technologia RFID… 2006; RFID systems…2006; www.logistyka.pl].

The RFID transponder can also be called tag, transponder or a smart label. The last name refers only to transponders made as self-adhesive paper or other material. RFID transponder is built from electronic chip with memory and miniature antenna.

In case of tags or transponders these elements are hidden in a special basis, a tag has circle, cuboid shape or is a plastic card. In case of smart labels the chip with the antenna is hidden in thin foil, which is connected with top layer of the label. Transponders' memory capacity ranges from tens to several thousands of bits. It is enough for most of RFID applications.

There are active and passive tags. Passive transponders extract energy from the energizing field of the reader. For passive transponders a second category of choice is in the type of protocol, being either a Reader-talks-first (RTF) or a Tag-talks-first (TTF) protocol. RTF protocols generate much higher levels of interference compared to TTF protocols meaning fewer readers can operate in close proximity [http://members.surfbest.net/eaglesnest/rfidweb.htm]. Passive transponders' range varies within reader beam of a few meters (13 m). On the other hand, active transponders have their own source of reinforcement – a battery. Thus, they achieve greater power of transmitted signal and the distance of reading increases to a 100 m. Active tags are larger and more expensive than passive ones. They are used to identify fast moving objects, especially vehicles, such as public means of transport. In other situations passive tags are implemented. Passive transponders operate on frequencies from 860 MHz to 930 MHz allowing international trade, while active ones operate on fixed single frequency. Passive tags are almost invisible, as they are 0.4 × 0.4 mm large and may be used as a small tape or a badge. Passive RFID transponders may receive signals sent from another RFID reader. Passive RFID may be used to Read Only (R/O) or to Read and Write (R/W with the possibility to modernizing recorded information). There are also Write Once, Read Many times tags (WORM). In the Read Only transponders data (merely tag's serial number) are saved during production process and there is no opportunity to save any additional information or alter anything. In WORM transponders apart from unchangeable serial number it is possible to save additional data, but once only. Finally, Read/Write tags contain not only unchangeable serial number, but the user may save and modify data many times. Nowadays the memory space of passive read and write transponders is only about 2 KB, which allows storing only little amount of information. But we can expect that the development of technology will result with increased memory space.

RFID transponders are available in wide range of signal frequency. For passive transponders the operating frequency choices generally are 125 KHz (magnetic), 13,56 MHz (magnetic), 860 MHz to 956 MHz (UHF) (electric) and 2.45 GHz (electric). Tags of low frequency (LF) work in the area of 30 to 300 KHz, while transponders of very high frequency (Extremely-High Frequency) work in the area of 30 GHz to 3000 GHz [Majewski, Ułasiewicz 2004]. These appliances send information faster and further than transponders which work on low frequency. On the other hand, they are more expensive, because they use more energy and their signals are disturbed when they are fixed to objects containing water or metal. Information registered on passive transponders can be read from 30 cm distance in case of low frequency appliances and even 3-6 m distance in case of UHF transponders. Signals

of higher frequency may function on longer distances but they do not pass through various substances. Readers working on higher frequencies meet more problems when there are obstacles on the signal way.

Reader (decoder) is a sending and receiving appliance which sends and receives appropriately decoded electromagnetic rays saving or reading data in such way. The transmission consists of three stages. In the first stage the reader sends beam of radio rays, inductive current, which is aroused in the transponder, feeds electronic system of the transponder. Then the transponder charged in such a way sends its unique code given by the producer or data saved earlier by the user to the reader. If we want to save data into the transponder, the beam of radio rays is modulated accordingly.

There are fixed, mobile readers and decoders integrated with printer of labels. Fixed readers have large antennae and are implemented in buildings (in assembly plants, in gates near warehouse entries). Mobile readers have smaller antennae and then smaller reach of reading/writing. They are always integrated with appropriate mobile terminal (data storage). The last group of readers are decoders used only to write data and they are parts of label printers. These are not independent appliances, thus only RFID printers may be used to print on RFID labels and equally to write data in transponder's memory.

Communicative programming is responsible for physical side of transmission. Usage programming is responsible for changing, storing and processing data. It can work partly on the reader (depending on the possibilities of the reader itself) and partly on server or PC co-working with the reader.

There are various standards according to technology of RFID making (the type of coding, memory space, speed of transmission, the capacity of identifying lots of in the area of reader). Tiris is one of the first systems, based on FM transmission. It is used in commerce. Unique is the simplest and most commonly used RFID systems. It is used for passive tags in controlling access or registering work time. Hitag (passive tags, enabling data reading and writing) is used in industry area, in systems collecting payments (e.g. in ski-lifts), systems signifying products or animals. Other RFID systems are: Q5, Mifare (applied in banking smart-cards or tickets) and Icode (applied in libraries, selling, stocking) [Steven 2005; Majewski 2006; www.logistyka.net.pl].

RFID technology is wildly used not only in such business areas as distribution and production, but also in other services. RFID is nowadays one of the most quickly developing techniques of Automatic Identification. Thanks to improving the effectiveness of the technology itself, decreasing costs of its implementing and assigning international standards practical usage of this technology has become more ubiquitous.

4. The advantages and areas of implementation of RFID

Thanks to RFID technology it is possible to control lots of various resources within supply chain, mainly multiple usage elements, such as palettes, plastic and metal containers, kegs or gas bottles. Other tools, vehicles, tractors may also be

monitored in such a way. Thus it is possible to apply RFID in managing company's fixed assets. The mentioned objects can be controlled due to tags which are put in forms of labels on products, containers, machines or appliances. Tags contain reference (address, EPC code) to producer's or distributor's data base. In company's IT systems all the information about "labeled" product is stored. Transponders let certain products be accurately followed. RFID technology is utterly beneficial, as the cost of the smart labels is quickly repaid, thanks to unlimited possibilities of making changes in IT system.

Numerous advantages of RFID tags surpass using bar codes. Bar codes may store limited and fixed amount of information. RFID technology brings increased amount of information (limited only by its capacity) about a product. Radio smart labels have address to its data base.

The same transponders may be used in whole supply chain. It happens that information contained in bar codes cannot be used in following links of supply chain because each bar code is made in different standards. EPC code, created by EPC global organization, is commonly recognized standard for RFID communication technology, thus radio labels can be applied in each link of supply chain.

Another advantage connected with RFID technology is time saving. Radio labels can be read without the need of passing a product near a reader, because radio rays of particular passive tags reach 10 m. There is a possibility of reading numerous tags at the same time.

Implementing RFID technology means safety of information about a product. Everybody may read the information contained in bar codes using adequate reader. RFID standards allow to store data about products in IT systems, to which limited group of receivers have access.

The components of RFID appliances may be used in extreme conditions. Additional tag sensors are implemented to check the parameters of surrounding. Smart labels are then able to remember the records of parameters. Thus tags may for instance control if food is stored in appropriate conditions.

The possibility of implementing RFID solutions into companies' ERP system, thanks to the above mentioned tag features, leads to numerous improvements within logistics, especially supply chain management. Current level of stock may be better controlled. It means convenience not only for deliverers and stock managers, but also accuracy in filling the stock up, which results in better meeting customer needs.

Using RFID by a supplier gives the possibility of monitoring the realization of each order, as it gives information about where, when and what was taken from the deliverer. The distribution may be planned more accurately.

Reduction of costs is connected with lowering the stock level and monitoring of regular flow of supplies. The mere stock control during the production process means decrease by 2-8% of costs of capital from stock. By following current stock levels it is possible to identify points of further orders without having unwilling buffers. Verification of delivery frequency leads to decreasing costs of transport.

SATO company [Mazurkiewicz, Kwaśniowski 2004] improved functioning within Montgomery Wire by implementing RFID technology. Montgomery Wire (a company producing wires) had problems with workers making mistakes in distinguishing wire types. SATO introduced controlling system which began its work from department of goods quality maintenance. By installing tags on rolls of wires it was possible to identify automatically where a certain roll is. The label informs where a roll should be transported. By scanning the roll its weight appears on a terminal. RFID system automatically crosses out the roll from the stock. Implementing RFID technology fastened each processes within SCM. It eliminated "hand work". Data about stock began to be more accurate. The system led to decrease in cataloguing time over four times.

RFID systems are capable of providing "vision" to computer systems. This means they are found in applications where-ever information is to be gathered automatically for computer networks. RFID is the fourth leg of IT systems, after computers, networks and software. Applications are found in areas such as asset tracking, courier parcel tracking, tire identification for hire cars, files and book monitoring in buildings, sports timing, logistics, laundry tagging for automatic processing in a centralized laundry, personnel access control, vehicle access control, toll roads, and even in labeling goods in a supermarket trolley.

The following are applications that could use this universal technology packaged in the appropriate form and delivered at the right price:

- Computer vision for IT systems: IT systems have been built from sophisticated computer networks and application software, but still largely rely on manual or semi automatic data capture. The integration of RFID into labeling objects used with such systems allow the computer to automatically identify objects within 13 m of the reader and process the data automatically.
- Warehousing: tracking of containers and pallets, stocktaking.
- Access control: ability to read the identity of many people at the same time passing through doorways, tube station entrances, lift access and doorways.
- Identifying capital goods: ability to read the identity of transponders mounted inside capital goods or packaging, when in the warehouse, when being transported and even when passing through doorways for an asset tracking system.
- Case lots of low value consumer items: the same system can be used for the producer, wholesaler and retailer at case lot level of consumer goods for transferring via truck, checking in and out of warehouse.
- Vehicles access control: ability to read many vehicles in different traffic lanes for parking, toll and access control.
- Containers labeling: shipping, air freighting and rail movement.
- Courier parcels and documents: implementing RFID technology lets remote and automatic identifying, sorting, routing and track-and-trace information.
- Parcels and mail bags: remote identity, routing, track-and-trace information.
- Airline baggage: identifying, sorting and routing – not confused by the transponders that are read from labeled goods within the luggage due to the use of RFID

systems. Implementing RFID within airlines customer care reduces the risk of mistakes.
- Compact discs and video retailing and rental: EAS, identifying and stock taking.
- Laundry for hospitals and hotels: identity, sorting and routing after bulk washing.
- Motor vehicle tires: transponder embedded into tire provides positive identification of case for identifying, wear tracking, usage tracking, anti-theft.
- Files and documents: identifying, track-and-trace, locating, association with person carrying documents past doorways – suitable for insurance industry/government records.
- Passport, driver license: anti-counterfeiting, identifying.
- Manufacture: labeling components for JIT manufacture, storing, routing, warehousing, identifying.
- Library books: identifying, EAS, self service checkout/check-in, book location.
- Labeling clothes and shoes: identifying, stocktaking, size distribution, self service, EAS, reading clothes washing properties for an automated washing machine. Implementing RFID transponders in the process of producing more expensive clothing (fur or leather coats) or alcohols and cosmetics gives guarantee of their originality, and decreases the risk of stealing.
- Dismantling items: for green legislation requiring the dismantling and sorting of old capital items, robot identification of parts and type of material.
- Grocery retailing: high speed scanning of baskets, trolleys and carts, stock-taking, EAS, goods receiving – the ultimate application.
- Marking hotel possessions: remote identity of possessions in clients luggage.

Forestry: tracking logs and products. Inventory control of trees and plants in a nursery [http://members.surfbest.net/eaglesnest/rfidweb.htm; Majewski, Ułasiewicz 2004].

Implementing RFID technology results in faster communication within supply chain. Therefore, more actual and accurate analysis of demands can be obtained.

5. Future trends in RFID technology

RFID at present is a rapidly changing technology. Originally transponders were expensive to produce and had very short operating ranges. Recent developments allow cheap UHF transponders to be made that can operate at distances further than 10 m, read up to 1000 transponders in a zone at a time, and can be produced at prices that make it economical to use them for use in applications that need low price labeling. In this sections we detail trends that are occurring in this industry.

There are some industry driving issues that will steer the future of RFID technology. Manufacturing methods need improving. Tags consist of antennae, electronic circuitry, and energy sources. Passive tags, that is those that receive their energy from the energizing field, can dispense with the need for energy sources. Electronic

circuitry has already advanced to the stage where the electronic circuitry is implemented on a single circuit. The last major manufacturing hurdles are the antenna system and the packaging.

Whereas initially RFID tags were based on magnetic coupling techniques, assisted by the then limitations in semiconductor design methods, and the desire to operate at frequencies below the minimum licensing frequency (135 KHz), resulting in tags that could only be read single and over short distances, requirements for distance are resulting in new technologies coming to the fore. Major applications are starting to appear in 433 MHz band, 915 MHz band and soon in 2.45 GHz and 5.6 GHz band. The latter two bands are still technically challenging for the semiconductor industry. With increasing range, it is necessary to be able to read many transponders at the same time, as the chances of finding a volume in which only one transponder will be present is ever reducing.

When deciding to operate above 135 KHz, it is necessary to acquire an operating frequency allocation from the regulatory bodies. As RFID becomes more popular, this allocation will become a valuable asset.

Due to current manufacturing techniques, pricing in the different RFID technologies seems to have reached a plateau. Current developments that will see the light of day in the next few years, are likely to drastically reduce the production price, allowing far greater commercial penetration of RFID technology. This reduction will allow EAS and identification features to be merged into a single product suitable for the retail labeling market.

RFID technologies are more and more often implemented. In the next few years there will be rapid expansion of the EAS market penetration. Particularly in the western world, shoplifting has become a major problem and has created a massive need for low cost anti-shoplifting solutions. At present there are a variety of technologies ranging from amorphous magnetic strips, to destructible tuned circuits. The primary issue is to develop very low cost techniques in view of a transponder being needed on every item.

With more local authorities funding their motorway development by taxing users, toll booths have been established on many of the countries highways. Unfortunately a motorway is there to move traffic relatively quickly between points, and slowing the traffic down at pay points to collect funds is very disruptive. Major attention is being focused on trying to use RFID techniques to recognize and automatically charge the drivers of the vehicles at pay booths without requiring them to slow down. Unfortunately these efforts are fragmented and few global standards are in place.

Governments are keen to monitor automatically the efficiency of their postal systems. Companies are developing transponder systems that can be incorporated into dummy letters and pass through the postal system being monitored by readers remotely to estimate actual system efficiency.

Developments are taking place and patents being granted for systems where the postage stamp will contain a transponder that can be used by the postal authorities

for routing, and for canceling the stamp after use. No cost effective system yet seems to be in place.

A recently granted patent finally shows an effective method of finding lost golf balls on a golf course. For conventional transponders, the antenna placement and orientation with regard to the reader has always been a problem. The new system proposes fitting a radar corner reflector in the golf ball and using a search beam which can detect the reflection of the radiation beam over a short distance. Developments are happening in the gaming industry to incorporate transponders in gaming chips, thereby allowing slot machines to play with "coins" of a larger value than that of the highest coin value of the countries currency, to limit counterfeiting, and to allow machines to accurately "read" the value of the chip.

Recently systems are being tried out to monitor the presence of a convicted criminal within a zone. The system would be used to impose and monitor house arrest imposed by the courts, rather than sending the criminal to prison. One system under test involves a transponder in a band attached to the person's ankle, and an associated receiver in the house, which monitors the presence continually.

Recent developments and published patents detail improvements in home appliances using RFID technology. In one case a company has developed an intelligent fridge which uses transponders attached to the bottles to detail the contents of the fridge on a TV screen or PC. Such developments would have application in situations such as bar fridges in hotel rooms. A recent patent details the concept of embedding transponders into clothing and encoding the transponders with washing, folding and ironing information. Appliances can then interrogate the garment and set up the correct washing cycle, water temperature and spin cycles for the garments. A feature is to write back to the transponder the number of washing cycles the garment has been exposed to compensate for the age of the garment.

An interesting development recently from the US is the concept of adding a transponder to the clothes of the operators of a PC, which presence is sensed by a reader in the PC allowing the PC to lock up the computer system and unlock the computer system whenever the operator leaves or approaches his workstation. This system prevents others tampering with the computer and data providing RF controlled security.

With the suitability for automatic sorting and routing of luggage within the air terminals, the tagging of airline luggage using RFID transponders is an ideal application. As the luggage can be tagged when it is accepted and its details linked to a data file in a computer system, it is then viable for the luggage to be routed to the correct aircraft luggage loading bay, and for the progress of the luggage through the transport system to be monitored for later queuing if it is necessary. A complication for RFID tagging in this application, is that the RF field used for reading the RF tags, will also penetrate the luggage and would read any tags contained in the luggage. These other tags will provide confusing signals, or even provide interfering signals that might jam the reader system for the luggage tags. To minimize these effects, tag

systems that are able to read multiple tags at a time might be used together with an organized numbering system so that the luggage tags might be differentiated from any goods that are tagged.

6. Conclusions

Although the RFID technology was invented in 1946, its potential is still discovered by those who work on logistics information systems. Nowadays RFID is believed to make a revolution functioning of supply chains. There is no doubt the RFID will be used in the nearest future. There are still new possibilities of implicating this technology. Big concerns purchase production or distribution of RFID technology. Investing in these systems may bring soon huge profits. RFID technology is quite more modern than bar codes technology and is becoming to be equally cheap.

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