The Concept of Implementation of Multifrequency RFID System Industrial Involvement in Laboratory Conditions

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Abstract. People have been dealing with the correct identification of objects for a long time. In industry, we cannot avoid this area, whether it is to identify people, semi-finished products or final products. Therefore, this article deals with the design of a multifrequency RFID system for industry 4.0. The idea of the article is to implement one type of identification technology for tracking objects using the radio frequency spectrum at different wavelengths. We have based our design on the built industrial-assembly line in the SmartTechLab laboratory, where we have implemented LF, HF and UHF systems connected by an industrial PLC into a complex system. In this article, we gradually focus on the selection of RFID systems, their cooperation and the design of connection to one portable box. Using an RFID box, we can monitor different types of objects and verify RFID reading using a single reading device or by creating portal RFID gateways. The implemented system consists of four middleware and four independent antennas that can cooperate. For proper operation, there is necessary implement not only hardware but also necessary software. The system can identify RFID tags in the range of 1 cm to several meters. Also, the advantage of the design is that it identifies all types of tags (industry, label, ceramic, laundry, paper). One of the main benefits of the design is modularity, mobility and the creation of a robust design that can be used for measurements in companies and also for educating students in laboratory conditions. The whole system is designed to meet the requirements of Industry 4.0 and improve the competitiveness of businesses.

Keywords. Frequency, RFID, Implementation, Portable box

1. Introduction

The aim and idea of this article is to use the popularity of Radio Frequency Identification (RFID) as a contactless technology for object identification. Its advantage is largely due to the possibilities that this technology opens up for the management of logistics processes. It is also necessary to emphasize the benefits that RFID provides when used in the supply chain. New tools and technologies do not appear every day and do not take root immediately. [1] But proven solutions can exist for years and can be replicated in large numbers of copies, despite the obvious anachronism. This applies to both hardware and software platforms. [2] The RFID system consists of a program part and hardware. Together, they represent an individual system with integrated hardware and software support. This will allow us to achieve better results in close collaboration between the company and a comprehensive solution provider who can develop and customize their own solutions for a specific task. In our article, we give
priority to the issue of how to harmonize several frequency systems into one unit. [3], [4] We start from a relatively simple principle. To identify the object, it is necessary to be equipped with a small device, a tag, which in the vicinity of the scanning device (from a few millimetres to more than 20 meters) automatically sends the identification data recorded on the tag (identification chip). This is done using different types of frequency. That is why we have proposed combining several RFID systems into one mobile device [5]. The application of RFID technology is in many industries. In the field of logistics and retail chains, there is the possibility of monitoring the product in real time, the efficiency of employees, but also defective products, which eliminates the number of complaints. [6], [7] RFID technology helps meet order deadlines while improving and speeding up managed warehouses. It also allows us to monitor the level of stock in real time. In production, the technology is used to monitor pallets with products in real time, as well as the transition of individual technological operations and logging on to various devices in production. Today, employers use an attendance system, the basis of which is the placement of an RFID sensor in devices (entry cards) that record the entry of employees into the workplace. [8] This technology can be used in many everyday applications, such as tracking animals, vehicles, entering apartment buildings, as well as use in the areas of production, logistics, trade and warehousing processes. [9], [10]

2. Methodology
In this part we want to focus on comparing selected three types of RFID technologies that we want to integrate into an automated line. These are SIEMENS brand systems, namely RF 200, RF 300 and RF 600 training packs. The selection of specific devices was carried out on the basis of market research, where the SIEMENS brand has a relatively strong presence, which has a lot of experience with RFID technology and its implementation into automated lines. It offers the best in terms of quality of workmanship, durability of individual components, but also the uniqueness of the software. In the following subchapters, we will describe the application of individual systems. [11], [12]

As already was mentioned, the design was based on 3 selected RFID systems, which differ in standards and frequencies. The capacity of RFID tags and the reading distance also play an important role. Therefore, our task was to design a method of implementation on a production line. [13]

![Figure 1. Dependence of RFID elements on memory or range](image)

2.1. SIMATIC RF200 RFID-System PROFINET 1
Thanks to its compact and inexpensive reader, the SIMATIC RF200 RFID system is particularly suitable for use in industrial production, in the areas of small assembly lines and intralogistics. With SIMATIC RF200, it is possible to implement medium power identification tasks in the HF band (13.56 MHz, ISO 15693) extremely cost-effectively. SIMATIC RF200 readers can be operated with all ISO
15693 transponders. The same communication modules used for all MOBY and SIMATIC RF systems (ASM 456, ASM 475, SIMATIC RF1xxC / CI) can also be used to connect to SIMATIC S7, PROFIBUS, PROFINET, EtherNet / IP and TCP / IP (XML). The high degree of IP67 protection of the SIMATIC RF200 reader enables its use in demanding industrial conditions. Each SIMATIC RF200 reader has a multi-colored LED that indicates the function and status of the reader, as well as the presence of a transponder.[14] The automation level interface can be implemented using communication modules. Pre-assembled cables with M12 plug-in connectors in various lengths are available for fast and easy cabling. Transponders suitable for a wide range of different requirements can be selected from a wide offer, including low-cost SmartLabels for simple identification tasks in a robust format of credit card or screw transponders that robots can automatically attach. [15] The transponders are attached to the object to be identified, for example by means of screws, glue or pre-assembled spacers. The contents of the purchased package include the RF186CI communication module, 2x RF240R reader, 5x MDS D428 transponder and software together with documentation on DVD for training only. Communication module RF 186 CI with features such as Ethernet, possibility to connect 2 readers and weight 0.311 kg. RF240R reader, working environment temperature -25 to +70 ° C, dimensions 50x50x30 mm; with integrated antenna 8 Byte IO; 38.4 kbps, weight 0.000001 kg. MDS D428 transponder, M8 long screw transponder; ISO 15693, chip type FUJITSU MB89R118, user memory 2,000 bytes FRAM, dimensions 24x20 mm (LxH); SW22, weight 0.035kg. [16]

2.2. SIMATIC RF300 RFID-System PROFINET 1

The SIMATIC RF300 RFID system is especially suitable for use in industrial production in the areas of production control, assembly lines and conveyors. SIMATIC RF300 is used to implement medium to high power identification tasks in the HF band (13.56 MHz). Depending on the performance of the identification system, two versions of the system are available. Medium performance - system configuration with SIMATIC RF300 readers in ISO 15963 mode and low-cost MOBY D transponders.
High performance system configuration with SIMATIC RF300 readers in RF300 mode and SIMATIC RF300 transponders. The new generation of SIMATIC RF18xC / CI communication modules enables simple and secure connection of SIMATIC RF300 systems to cloud applications via the IoT industrial gateway, thus increasing the range of potential use of data supplied by RFID transponders. The short cycle time for the individual work steps, thanks to the very high data rate, enables a significantly higher volume of productivity. Production order data can be read by mobile hand-held readers for maintenance purposes. Additional transponders are available for the high-performance RF300 mode, e.g. special refractory transponders for temperatures up to +220 °C or particularly compact rectangular patterns for use on small workpiece holders. The automation level interface can be implemented using communication modules. Pre-assembled cables with M12 plug-in connectors in various lengths are available for fast and easy cabling. The contents of the purchased package include the RF186CI communication module, a 2x RF310R reader, a 5x RF340T transponder and software with documentation on DVD for training purposes only. Communication module RF 186 CI with features such as Ethernet, it is possible to connect 2 readers, weight 0.311kg/pc. RF310R reader, reader features - RS422 interface (3964R); IP67, working environment temperature -25 to +70 ° C, dimensions 55x75x30 mm, with integrated antenna, weight 0.128 kg/pc. Transponder RF 340T, user memory 8 kB FRAM, working environment temperature -25 to +85 °C, dimensions 48x2, weight 0.014 kg/pc. [17]

![SIMATIC RF300 RFID components](image)

**Figure 3.** SIMATIC RF300 RFID components.

### 2.3. SIMATIC RF600 RFID-System PROFINET 1

With the SIMATIC RF600, identification tasks are performed in the UHF range and over very long distances of up to 8 meters. The system is suitable for storing and recording unique identification according to the EPC global (Electronic Product Code) standard on products, containers or transport units. It is also possible to store other, freely definable user data. Various data carriers are available for industrial applications - from cheap SmartLabels to refractory transponders that can be used for several thousand cycles. SIMATIC RF600 can be used with SIMATIC controllers, OPC UA clients, EtherNet / IP-based controllers and PC/IT systems. It can communicate data with cloud systems through the IoT.
industrial gateway. All SIMATIC RF600 readers can be set and diagnosed using a web browser. Pre-assembled cables in various lengths are available for quick and easy cabling. The high degree of protection of the readers (up to IP67) allows their use in demanding industrial conditions. Transponders suitable for a wide range of different requirements can be selected from a wide offer. The transponders are attached to an identified object, e.g. using screws, glue or a pre-assembled spacer. Multi-colored LEDs identify the status of the reader and transponder. The contents of the purchased package are the RF 186 CI communication module, with features such as Ethernet, 2 readers can be connected, weight 0.311 kg/pc. RF 642A antenna, linear (broadband) frequency range 865 to 928 MHz, dimensions 185x185x45 mm (LxWxH) IP65, ambient temperature -25 to +75 °C, weight 0.6 kg/pc. RF615R reader, integrated antenna + 1 external antenna port; 1 dig. entrance, 1 dig. power; 24 V DC; IP67, ambient temperature -25 to +55 °C, weight 0.5 kg/pc. RF 645 transponder, container label; 52x36x12.5 mm; ISO 18000-63, EPC class 1, generation 2, frequency 860 to 928 MHz, chip type NXP UCODE 7Xm-2K EPC 448 bit, 2048 bit additional memory, weight 0.030 kg. [18]

![Figure 4. SIMATIC RF600 RFID components.](image)

It was necessary to select the correct PLC in order to successfully connect RFID systems. Based on the complex connection and the need to connect RFID sets via Ethernet, a Switch was subsequently selected for successful connection. Training pack CPU 1512SP F-1 PN consisting of: S7-1500 CPU 1512SP F-1 PN, 300 KB/1 MB, 1x BusAdapter BA 2xRJ45, 16 DI, 16 DQ, 4x BASE UNITS, Ethernet cable RJ45 /RJ45 6 m was added as a PLC set, mounting rail, 483mm, labelling strips, colour identification labels, software for training STEP 7. [19] As Switch we used SCALANCE XB008 Unmanaged Industrial Ethernet Switch for 10/100 Mbit/s for setting up small star and line topologies, LED diagnostics, IP20, 24 V AC/DC power supply, with 8x10/100 Mbit/s twisted pair ports with RJ45 sockets. SIMATIC ET 200SP is a compact, energy-saving, state-of-the-art distributed peripheral station. The construction of the station is optimized for quick and easy installation. The ET 200SP system modules have a degree of protection IP20 and are designed for installation in control cabinets of indoor installation. The operating temperature range for natural cooling is from 0 to + 60 °C. With SIMATIC ET 200SP we can optimal use space in the cabinet because it is compact and the system is 50% narrower than comparable distributed peripherals. The system is mounted on a standard 35 mm profile and passes without the use of tools. A big advantage is the full support in the TIA Portal program. The ET 200SP allows us to manage the configuration from a user program. The electronic modules of the ET 200SP
station are designed for input and output of discrete or analog signals in standard automated systems, as well as in emergency protection and safety systems. All electronic modules are mounted on base units, which are mounted on a standard 35 mm DIN rail. The first installation of the electronic module on the base unit is automatically accompanied by the mechanical coding of the base unit. We use 4 HF (High Feature) class modules with support for diagnostic functions at the level of individual channels and the ability to change settings during operation. [20], [21]

A network switch (or switch) is a device designed to connect several nodes of a computer network in one or more network segments. The SCALANCE XB-008 switch is equipped with 8 RJ45 electrical ports. SCALANCE XB-008 switches are usually installed in the same box or control box with the device connected to the network. The industrial Ethernet switches of the SCALANCE XB-008 series are mounted on a standard 35 mm DIN rail, for example, as a PLC.

![Figure 5. PLC and Switch](image)

2.4. Software application - TIA Portal

The most important part of an RFID system is the software that temporarily interacts with all other parts of the system, such as identifying and integrating RFID tag data or managing RFID printers. For a particular system, it is different depending on the components. The most important goal of the software part is to save time, money and effort in all phases of working with automation components. The TIA Portal (Totally Integrated Automation Portal) is a unified development environment for application software for industrial automation systems for discrete manufacturing from SIEMENS. [22] TIA Portal provides an integrated working environment for the development of complex automation projects based on various software and hardware products from the SIMATIC, SINAMICS, SIMOTION, SENTRON and SIRIUS series. TIA Portal uses a single interface for software products, which has a positive impact on the user experience. The main functions of the TIA Portal are:

- support for navigation functions in the project,
- a unified concept of the use of libraries,
- centralized data management and ensuring their full consistency,
- run the necessary editors, save projects, diagnostics and many other functions

This software allows us to achieve a high level of efficiency in the development of any automation projects, significantly reducing the cost of configuring and organizing the interaction among controllers, units, devices and human-machine interface systems. All controller settings, program blocks, tags and messages can be entered only once, which significantly speeds up and reduces the cost of developing a complex automation project.
3. Results

In the proposed solution, we started from a newly built laboratory focused on Industry 4.0 on the premises of the Faculty of Production Technologies based in Prešov, Technical University in Košice. The concept of element layout in SmarTechLab for Industry 4.0 is shown in Figure 7. The concept consists of 2 parts. One is the location of antennas and readers, the other is the location of middleware and PLC with a switch. [23]

The proposed state assumes the placement of RFID gates as control elements identifying assembly pallets moving on conveyor belts. We then had to modify the actual layout of the antennas and all their types and layout is shown in Figure 8. The lengths and widths of the conveyors are given in centimetres.
To create a laboratory framework for the laboratory system, we use support profiles with a square cross-section of Bosch Rexroth with dimensions of 40 mm x 40 mm and a groove size of 10 mm. Due to its high strength, profiles with a 10 mm groove can be used to create structures. The Bosch Rexroth modular profile system with a profile groove of 10 mm and a profile cross-section of 40 mm covers all necessary needs. They provide high strength when using a minimum amount of material thanks to computer optimization of their construction, which is an economical and reliable solution. For each reader and antenna, standardized construction profiles were subsequently constructed. A view of the arrangement of the antennas can be seen in Fig. 9. From the RF 200 and RF 300 systems, gates were created from 2 antennas placed opposite each other. For the RF 600 System, a single placement on a separate structure is sufficient. [24]

The second part of the design is the creation of a modular box in which the power supplies, middleware, PLC and switch are located. All these units are stored in one modular box. Equipment
designed to automate technological processes must be protected from adverse factors. A control automation housing is used for this purpose. The cabinet is of plastic construction, with a metal plate to which the individual components are attached. Relay modules, controllers and other devices can be located inside. In our case, the dimensions of the cabinet will be 70x50x25cm, which is enough to accommodate all the components and cables that connect them. Finding most of the components in the cabinet significantly speeds up the installation and simplifies further maintenance of the devices installed in it. The box will contain:

- Power supply for the two systems Simatic RF180C and Simatic RF186CI, which are inside the cabinet and which supplies two RF310R readers and 2 RF240R readers, which are outside the cabinet.
- Power supply for 2 RF615R readers outside the cabinet, which supplies two RF642A antennas.
- Power supply for PLC and Switch, which are in the box.

Also at the top of the cabinet are standard openings designed for efficient routing of cables from the cabinet to readers and antennas in the laboratory system.

So far, we have implemented the hardware in the design. The present proposal also includes a software side. The advantage of the given design is that the whole design is connected via Ethernet to the PLC and as an output we need a LAN connection to the local network or directly to the PC / laptop. After connecting, all we need to do is start Tia Portal and configure the device for connecting RFID systems. We used the following settings for IP configuration.

- Configuration of IP address PLC 198.168.0.95
- RF 186 CI (communication module) type of device RF 200 - 2x external antenna, IP address 192.168.0.96
RF 186 CI (communication module) device type RF 300 - 2x external antenna, IP address 192.168.0.97

RF615R configuration, internal antenna + external RF642A (RF600) IP address 192.168.0.98
The second device RF615R, internal antenna + external RF642A (RF600) applies to the IP address 192.168.0.99

Figure 11. Configuration of TIA portal of RFID box

As is obvious from the illustration of the software interface for loading, a direct connection to the PLC is sufficient and we can extract all the data we need from its interface. From the presented knowledge it is obvious that our chosen set of RFID systems can identify almost all types of RFID tags, not only from Siemens but also from other manufacturers.

4. Conclusion
The concept of "Industry 4.0" or the Fourth Industrial Revolution provides for the complete digitization of all the company's physical assets and their integration into a single ecosystem. The digital transformation enables not only a significant increase in productivity, quality and the level of resource efficiency, but also the formation of new information flows based on business models. Digitization processes will attract a significant amount of funding to industry and reduce added value. At the heart of the fourth industrial revolution is the use of the latest technologies, such as RFID, to create intelligent factories. Such companies can implement production processes of any complexity, while minimizing the risk of failures and ensuring maximum efficiency.

The article deals with the possibilities of using RFID technology in the context of Industry 4.0. The aim of the article was to create a practical connection of a multifrequency RFID system and to show how it works in connection to a line oriented to Industry 4.0. Subsequently, we pointed out what parts it consists of and how they communicate with each other. The aim was also to develop an RFID system for laboratory conditions but also its use in practice. In the theoretical part were described the principles of 3 RFID systems: what elements they consist of, how they work with each other and at what frequencies. Specific variants of software and hardware connection from which a complex RFID box was created were also described. In the practical part, we took over the installation and placement of all parts of the RFID system on the conveyor system. We installed readers and antennas directly on the line to achieve the maximum reading result. We have also installed components in an RFID box for further convenient testing and maintenance over a longer period of time. The contribution of this work is the
possible future use of the laboratory system and RFID technology in the context of industry 4.0 to visually demonstrate the use of technology on the production line in conjunction with software. In the future, the research team wants to focus on testing the reading of RFID tags using the software page presented in this article.

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