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RFID Personnel Control System that can be Managed via 4.5 G

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Abstract

The current study aimed to reveal that personnel control by the employer should be conducted using Radio Frequency Identification (RFID) technology in an easier and more modular way. RFID is a technology ensuring that identifiable information of people or objects are transmitted via radio signals. It has some similarities with existing smart card technologies. The most important feature differentiating the RFID from the existing technologies is that it works wirelessly. The hardware used in the study can be managed via Ethernet port. In this study, it is ensured that data be transmitted via Internet by using a mobile cellular communication system. The control of the set up system can be conducted wirelessly via any environment in which an Internet connection can be established. Thanks to the created system, information about arrival and departure dates of the places to where the mobile personnel should go can be monitored 24/7 from anywhere that has internet connection. As a result of the tests and applications that have been conducted, it has been seen that the data could not be transmitted in a radio-frequency environment because of the error caused by the RFID tag. As a result of the calculations made after the application, it has been put forward that the error margin is 7±1%.

Keywords*: Mobile Cellular Communication System, Personnel Control System, RFID*

1. Introduction

Institutions and organizations provide many job opportunities for employees. Supervision of the employees by the employing institutions and organizations is required in order to carry out the necessary work in a shorter time and more efficiently. The required supervision can be conducted by the responsible individuals and personnel monitoring system in only specific workplaces, such as factories.

Personnel monitoring systems are software prepared with the aim of controlling the employees, and they can work as integrated with biometric hardware. With these systems, the employees' entrance/exit times of work can be detected, and the work efficiency can be greatly increased with a fair salary system. Personnel monitoring systems can be used in work areas, as well. When the employer wants the personnel that work in different areas to be controlled from one center, personnel monitoring systems are not sufficient in this situation. The existing personnel monitoring systems ensure the supervision of the personnel in situations in which workplaces are fixed. However, when the workplace of the personnel is not limited, the employers cannot use these systems and have difficulty in the supervision and control of the personnel. With this study, the researchers attempted to eliminate the incapability of the personnel monitoring systems using RFID technology and mobile cellular communication systems.

2. Research Method

2.1. RFID Technology

Radio Frequency Identification (RFID) technology defines the system that transmits the identity of an object or a living being wirelessly by using radio waves [1]. RFID technology is a group under the Automatic Identification (Auto-ID) Technologies. Automatic identification

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technologies include such biometric technologies as bar codes, smart cards, optical character identification system and retina scanning, identification with sound, identification with fingerprint. Automatic identification technology is used to reduce the work force and duration caused by the need of entering data manually and to increase the correctness of the data [2].

RFID is an Automatic Identification System consisted of a microchip (tag) enwrapped by an antenna and a reader. Data and energy transfer are provided without any contact between tag and reader. Needing very low amount of energy, the tags generate energy by benefiting from the magnetic area between the south and north poles in the air. Therefore, they continuously spread the information on them from a radio frequency [1-3]. An antenna, in some cases more than one antenna, is needed for detecting the spread radio frequencies. The antennas receive the electromagnetic waves sent by the reader and activate the circuits on the tag. The tag modulated the waves and sent them back to the reader, and the reader converts the new wave into digital data. A sample RFID system is shown in Figure 1.

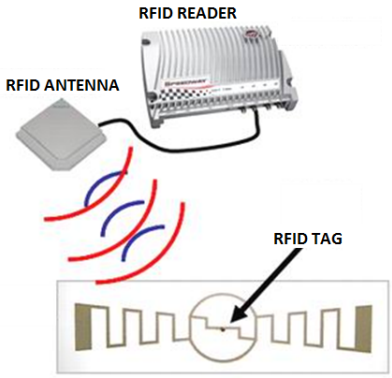

Figure 1. A sample RFID system

Basic Features and Components of the RFID Technology

Various software and hardware are needed for setting up a RFID system. These are:

1) Hardware required for RFID:
a) RFID tag,
b) RFID antenna,
c) RFID reader.
2) Software and interfaces managing the system (interlayer software)

2.1.1. RFID Tag

RFID tags are consisted of a microchip containing identification data and an antenna transmitting these data to a reader wirelessly. Modulated and sent by the RFID reader, RF signal is detected via antennas of the tags. Capacitor in the tag receives the coming signal and charges itself. The circuits in the microchip are activated by charging [4].

RFID tag in the Figure 2 that is used in the study is the dimensions of 98.2 x 12.3 mm. Using the Higgs-3 chip, Alien is the most preferred UHF RFID tag in its family. EPC Class 1 Gen 2 / ISO 18000-6C compatible this inlay has an operating licence in the 860-960 MHz global band [5].

Figure 2. RFID tag

2.1.2. RFID Antenna

RFID antennas receive the data in the chip on the tag with the electromagnetic waves they release as a result of the reflection occurring on the antennas on the tag, and they transmit these data to the reader in the system [6]. There are various models of antennas with regard to the reading method (linear, circular) and reading areas (remote area reading, near area reading). Table 1 shows the features of the RFID antenna in the Figure 3 used in the study [5].

Table 1. Features of the RFID Antenna

RF Signal spreading angle of the antenna	40^{o}
Gain of the Antenna (dBi)	5.73 dBi
Dimension	22 x 27 x 4 (cm)
Operating Frequency	902-928 MHz
Polarization	Circular
Weight	0.57 kg

Figure 3. RFID Antenna

Antenna gain is the power concentration during the passing of diffusion (radiation) with polarization over the antenna while signal sending power of the RFID reader is fixed. While calculating the effective radiation power of the RFID system, the power of the transmitter is added by the antenna gain and the power lost in the transmission line is subtracted from this sum. It creates an influence area around itself while radiating with antennas. For making the RFID tag working, it is required to be in this radiation pattern. Figure 4 shows the 3-D radiation pattern of the antenna used in the hardware part of the study [7-8].

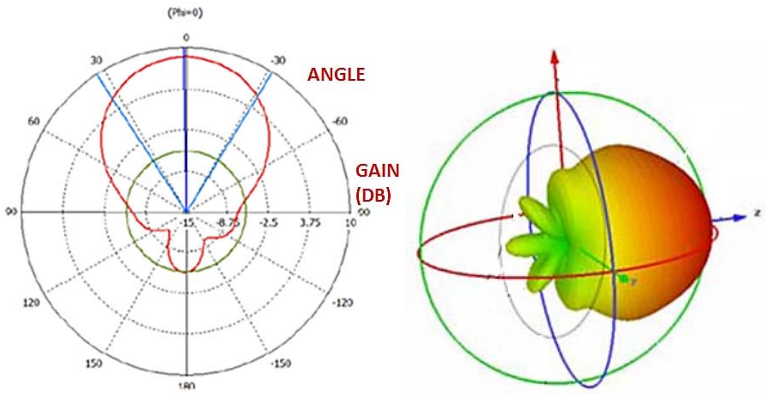

Figure 4. Radiation pattern of the RFID antenna

Figure 5 shows the mathematical model of the relationship between the RFID antenna managed by the reader and spreading RF and the antenna on the tag [9].

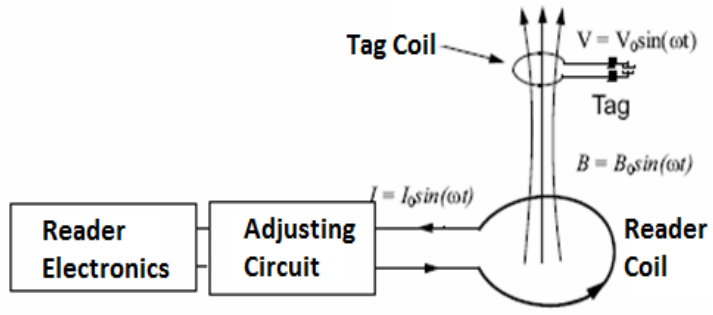

Figure 5. Interaction of the antennas of the RFID tag and the reader

If the tag is in the radiation pattern of the reader antenna in the Figure 4, a voltage is induced from the reader antenna coil to the tag antenna coil. The voltage induced in the coil causes flow of the current from the coil. Induced voltage in the tag antenna coil depends on the change of the magnetic current (Ψ) over time [10].

$$V = -N.\frac{d\Psi}{dt}\text{V(Volt)} \quad (1)$$

N: Number of turn of the antenna coil
Ψ: Magnetic flux in every turn
Magnetic flux (Ψ):

$$\Psi = \int B dS \text{Wb(weber)} \quad (2)$$

B: Magnetic Area
S: Surface area of the coil

is calculated by the formula above. The maximum magnetic flux is obtained in the case that the reader antenna and the tag antenna are parallel.

When the reader antenna and the tag antenna are parallel, the magnetic flux passing from the tag coil is at maximum level. Maximum reading distance is reached by the maximum induced voltage in the tag coil. The equation 2 expresses the mutual coupling between the reader and the tag coils. As the tag is passive and there will be no flow of current from the tag coil outside of the reading area, the equation 3 can be written. The written equation can mathematically model the voltage induced by the reader antenna [11].

$$\begin{aligned} V &= -N_2 \frac{d\Psi_{21}}{dt} \\ &= -N_2 \frac{d}{dt}\left(\int B.dS\right) \\ &= -N_2 \frac{d}{dt}\left[\int \frac{\mu_0 i_1 N_1 a^2}{2(a^2+r^2)^{3/2}}.dS\right] \\ &= -\left[\frac{\mu_0 N_1 N_2 a^2(\pi b^2)}{2(a^2+r^2)^{3/2}}\right]\frac{di_1}{dt} \\ &= -M\frac{di_1}{dt} \end{aligned} \quad (3)$$

N1: Number of turn of the reader antenna
N2: Number of turn of the tag antenna
a: Radius of the reader antenna
b: Radius of the tag antenna
r: The distance between the reader and tag

$$M = \left[\frac{\mu_0.\pi.N_1N_2(ab)^2}{2(a^2+r^2)^{3/2}}\right] \quad (4)$$

a: Radius of the reader coil
b: Radius of the tag coil
r: The distance between the two coil

Tag coil voltage depends on the mutual inductance between the two coils. The induced voltage is decreased by r-3 in the tag coil. The reading distance is decreased similarly.
The induced voltage in the tag coil.

$$V0=2\pi fNSQB0Cos\alpha \quad (5)$$

f: Frequency of received signal
N: Number of turn of the coil in the cycle
S: Cycle area in the m2
Q: Quality factor
B0: Area size of the received signal
α: If the angle between the tag and the reader is α=0, the induced voltage is at maximum.

When the RFID tag antenna coil reaches 4V peak to peak voltage, the voltage is rectified and the device starts to operate in the voltage of 2,4 V DC. It is calculated is calculated by the coil voltage for inducing the B magnetic area in the 4V peak to peak coil voltage in the ISO 7810 standard card dimensions (98.2 x 12.3 x 0,76 mm).

$$V0=2\pi fNSQB0Cos\alpha =4 \quad (6)$$

Size of the tag coil: (98.2 x 12.3) mm2
Frequency: 902 MHz
Number of turn 4
Quality factor of the Tag Antenna Coil: 40
The voltage of the AC coil enabling the working of the tag: Peak to peak 4V

Magnetic area created by the antenna used in the study for the Cos α=1:

$$B_0 = \frac{{}^{4}/_{\sqrt{2}}}{2\pi fNSQCos\alpha} = 0{,}0449\ (\mu wbm^{-2}) \quad (7)$$

has been calculated as shown above.

2.1.3. RFID Reader

As important as tag for the installation of a successful RFID system, receives and interprets the signal sent back by the activated tag by sending the digital information coded via its antennas to the tag in the form of radio wave [12].

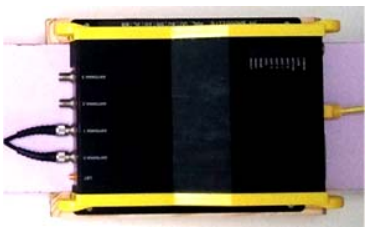

Figure 6. The RFID reader used in the system

Table 2 gives the features of the RFID reader in Figure 6 used in the hardware part of the study [5].

Table 2. Features of the RFID reader

Operating Frequency	902-928 MHz
Hopping channel number	50
Channel Range	500 KHz
Waiting time in the channel	< 0.4 sec
RF Transmitter	30 dBm at the end of the <6m LMR-195 cable.
Modulation Method	Phase reversal - Amplitude Shift Keying
20 dB Modulation Bandwidth	<400 KHz
RF Receiver	2 Channels
Power consumption	45 Watts
Communication Interface	RS-232 (DB-9 F), TCPI / IP (RJ-45)
Input/Output Ports	4 coaxial antennas, 4 inlet / 8 outlets (Optic insulated), RS-232 com connection point, LAN, power
Dimensions (L)	22.9 cm x 28 cm x 5.6 cm
Weight	1.8 kg
Operational Temperature	0 ° C and +50 ° C
LEDs	Power, Link, Active, Antenna 0-3, Processor, Reading, Failure (Red)
Compliance Certificates	FCC Section:15; FCCID: P65ALR9800
EPCglobal Code	GSRN 950110126000000155
Security Certificates	cTUVus, UL: 60950-1:3004, CAN/CSA: C22.2 No.60950-1-03

RFID readers undertake two tasks in the system. Their primary and privileged function is activating the tags in their control area via their antennas and obtaining the information on the tags. Their second function is creating an interface between the systems that collects, analyses and distributes the data in a big amount created by the tags activated in the area in which there are tags [13].

3. Mobile Cellular Communication Systems

Mobile communication systems started to develop in the beginnings of the 1980's. Firstly first generation analog communication systems were started to be used, and second generation digital communication systems were started to be used in the beginnings of 1990's. In the 2000's, the third generation broadband communication systems were started to be used in the developed countries and now it has reached many users [14].

Third generation communication system is the generic name of the cellular communication standards and technology designed for providing the mobile terminals like mobile phones and smartphones with services requiring high speed and broad band width such as high speed internet connection, sending of moving pictures in the fixed network quality such as ISDN and DSL [15].

The speed in the fourth generation mobile cellular communication system is 100 Mbps and it is 1Gbps in the wi-fi networks. A 4.5 G system provides end to end IP solution in order to providing users with the sound, data and continuous multiple mass communication by enabling higher data speed than the previous generations (such as 3G, 2G etc.).

In this study, we benefited from the 4.5 G mobile cellular communication system.

4. Results

In this study, the system is consisted of both software and hardware.

Structure of the Hardware

In this study, the used hardware is consisted of five main components.

Hardware (Figure 7);

- UHF RFID Tag
- UHF RFID Antenna
- UHF RFID Reader
- Mobile Modem
- PC.

Figure 7. Hardware part of the web-based RFID personnel monitoring system

The RFID technology can operate at different frequencies. In this study, UHF RFID technology has been used in the system in accordance with the environment in which the system will be installed and the reading distance. Operating frequency is between 902.75 MHz – 927.25 MHz [5].

We use personnel cards having UHD RFID tag in this study for identifying the personnel and ensuring their control (Figure 8). That personnel carry their card is enough for making identification and ensuring their control [16].

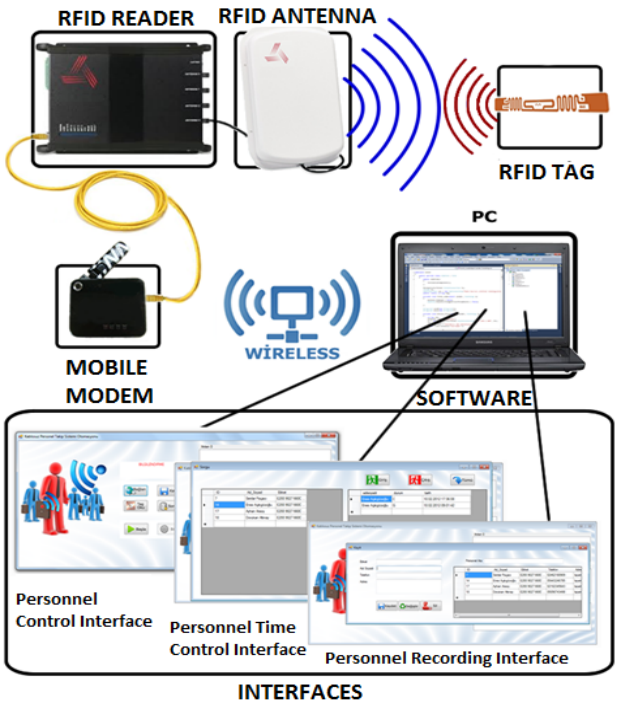

Figure 8. The diagram of the web based RFID personnel monitoring system

In the study, the RFID technology is used and the other components of the system are placed to the area in which the personnel are desired to be controlled. These are UHF RFID antenna and UHF RFID reader [17]. UHF RFID antenna can control whether there is an employee holding a personnel card with UHF RFID tag or not by UHF signal at certain intervals in the area to which it is positioned. When an employee that carries the personnel card comes into the area, the tag in the personnel card detects the signal emitted by the antenna, activates itself and transmits the identification signal to the antenna. The antenna detects the signal containing this responsive identifying information and sends it to the UHF RFID reader. Therefore, the antenna completes its task (Figure 9).

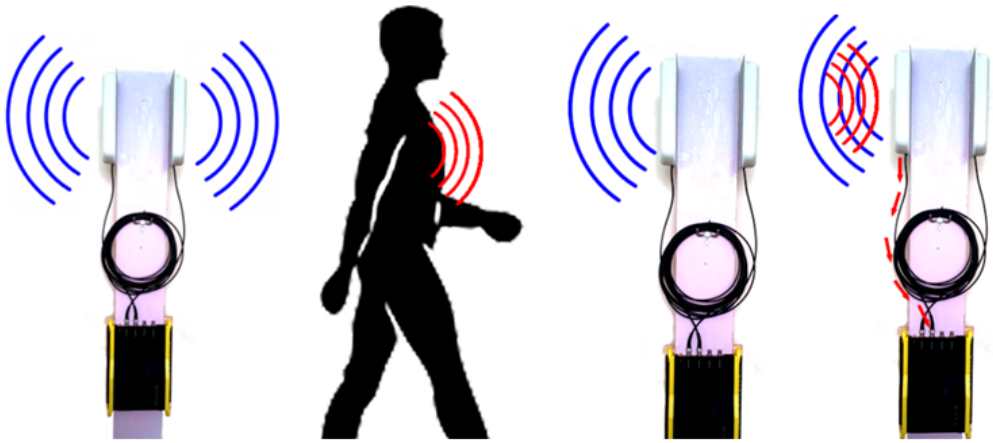

Figure 9. Tasks of RFID antenna in the operation

The antenna tries to detect the existence of other signals coming as response to the signal it sent via UHF signals to the area where it is placed. Antenna cannot identify whose is the signal, in other words the ID information. It can learn which ID the tag hold the coming signal belongs via reader. The reader interprets the information coming from the antenna and enables us to reach the ID information in the signal. After that, the reader transfers this ID information to the PC managing the system by using mobile cellular communication technology (Figure 10).

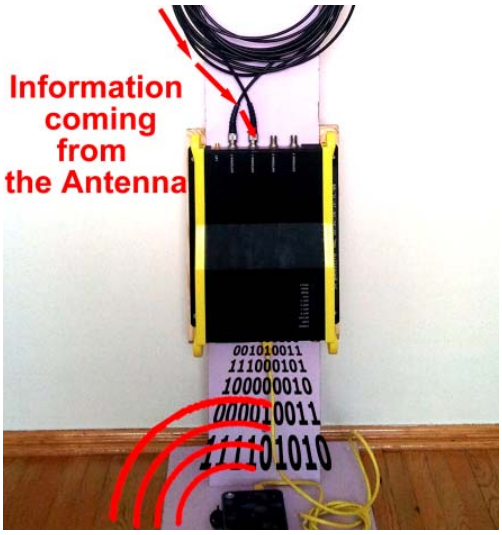

Figure 10. Task of the RFID reader and mobile modem in operation

The software developed for managing the RFID system is operated in the PC. Sent to the software in the PC from the reader, the ID information is transferred by using mobile cellular communication system.

ID information of the personnel is obtained via UHF RFID Tag, antenna and reader used in the system, and the hardware in the operation do their tasks by the transfer of the information to the software in the PC via mobile modem.

The software used in this study is principally consisted of 3 interfaces.
These interfaces are:

- Personnel control monitor
- Personnel registration monitor
- Personnel time control monitor.

Personnel control monitor constitutes the most important part of the developed software. It is the interface in which the communication is enabled via UHF RFID Reader and UHF RFID system is managed (Figure 11).

In the interface shown in the Figure 11, there are buttons in the number one blue frame for enabling the control of the system by the user. In this section, there are six buttons. Information screen is the area in which instant information is given about the done processes. "CONNECT" button enables -in everywhere- the connection to the UHF RFID system with mobile cellular communication technology. Communication is done by TELNET connection to the reader. TELNET is the name of the programs developed for connecting to a remote machine via internet and used for setting up a TCP/IP protocol and connection. The programming structure used in these developed programs are called socket programming [18].

In this study, we make connection to the system and manage it via socket programming and we use SQL database managing system for keeping the record of the personnel. Figure 12 shows the database designed in the SQL database managing system for keeping the record of the personnel information.

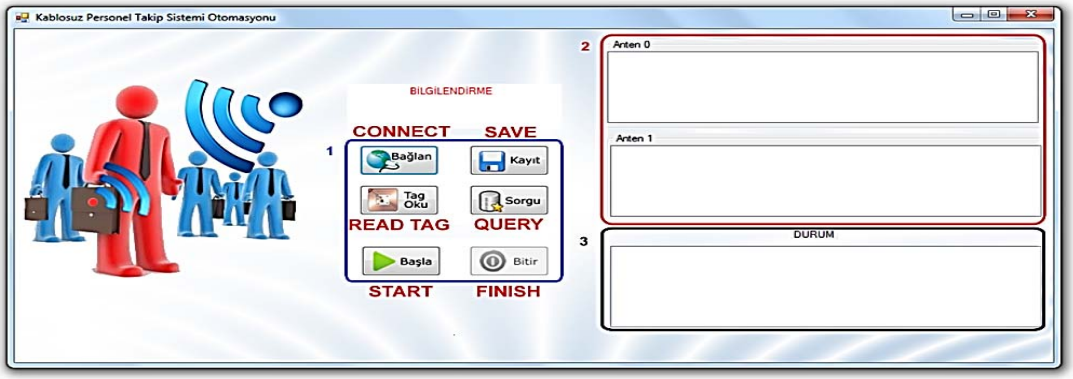

Figure 11. Objects used in the personnel control interface.

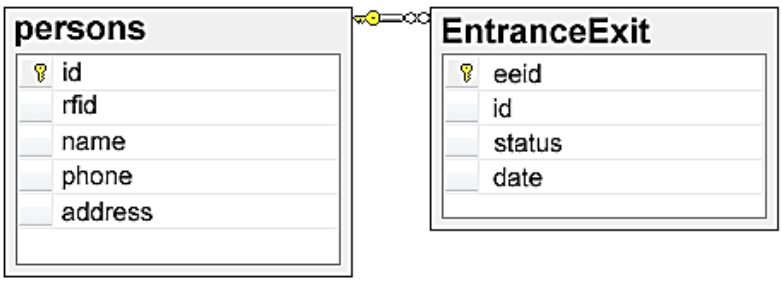

Figure 12. Diagram of the tables created in the database

Personal information of the personnel and the tag information assigned to these personnel are kept in the "persons" table in the database. In the "Entrance/Exit" table, the information of "entrance/exit" time information is kept recorded.

If the "SAVE" button in the personnel control interface is clicked, the personnel recording interface in the Figure 13 is opened and the information of the personnel is recorded.

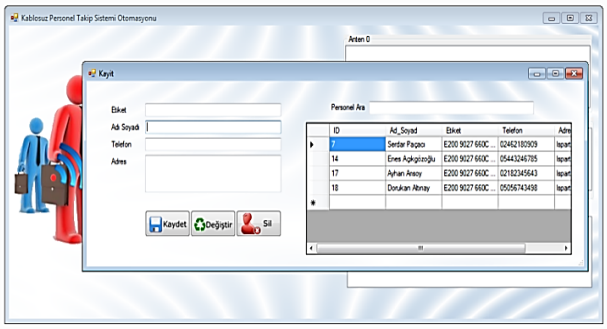

Figure 13. Objects in the personnel registration monitor

"READ TAG" button has been programmed in the personnel control interface for testing the UHF RFID system. After pressing this button, the antenna is activated by establishing TELNET connection with the reader and it is tested whether there is a tag in the surroundings or not. If any tag is detected by the antenna, ID information of the tag is shown to the user in the area shown by two digits in the personnel control interface. ID information of the tag detected by the Antenna 0 is listed in listBox1 in the groupbox named "Antenna 0", ID information of the tag detected by the Antenna 1 is listed in list Box 2 in the groupbox named "Antenna 1" (Figure 14.).

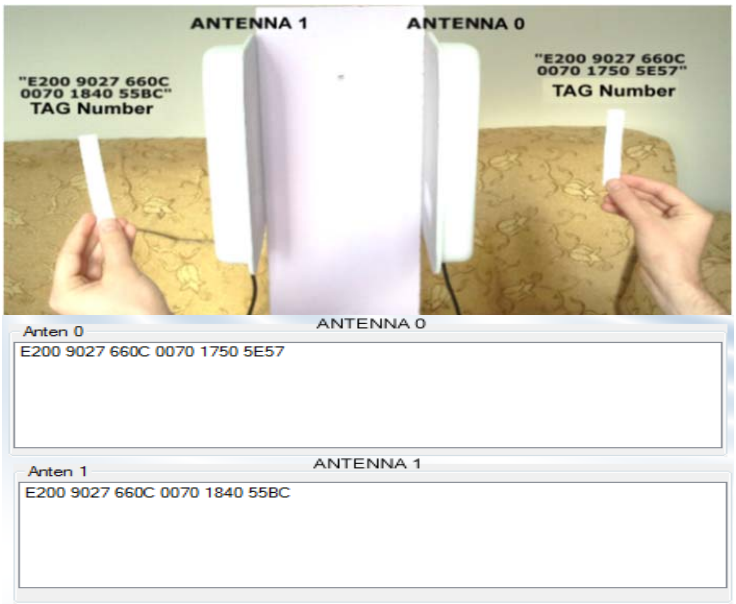

Figure 14. Tag reading process

Personnel control process is done by the button in the personnel control interface named "START". Figure 15 shows the algorithm designed for ensuring the personnel control. This algorithm is operated until the button named "FINISH" in the personnel control interface is

pressed. Situation and time information of the personnel can be reached and recorded thanks to this developed algorithm.

Shown in the Figure 15 for ensuring the personnel control, the algorithm is based on the principle of comparing the reading time period of the antennas. Firstly antenna 0 detects the personnel coming into the area in which the UHF RFID system is installed for the ensuring of the personnel monitoring. After passing from the system, the personnel are identified in the antenna 1. As the antenna 0 did the identification process first, the information about the entrance of the personnel is reached. As first antenna 0 and after that antenna 0 performs identification when the personnel exit from the work place, it is understood that the personnel exit from the work place. Figure 16 shows the operation of the system in accordance with the developed algorithm.

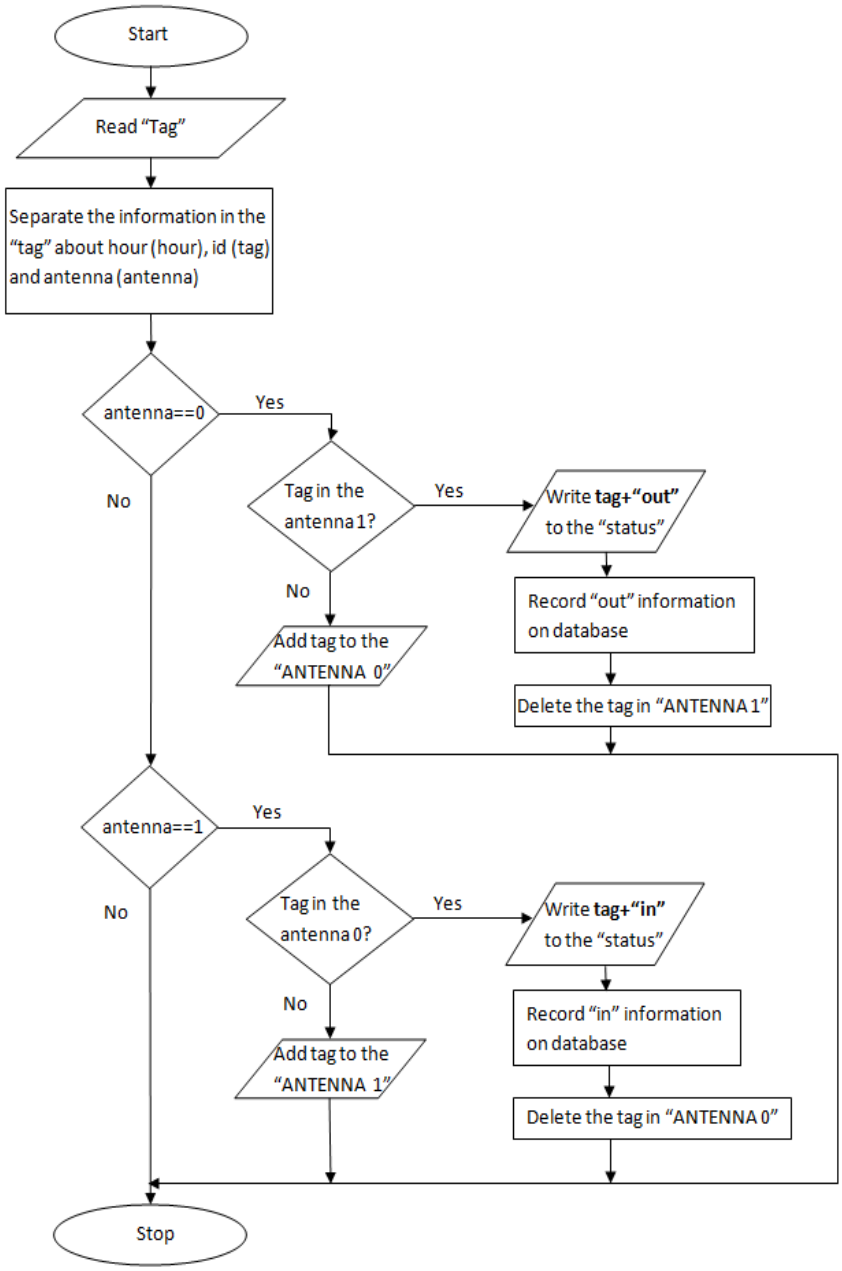

Figure 15. Algorithm used in the interpretation of the entrance/exit of the personnel

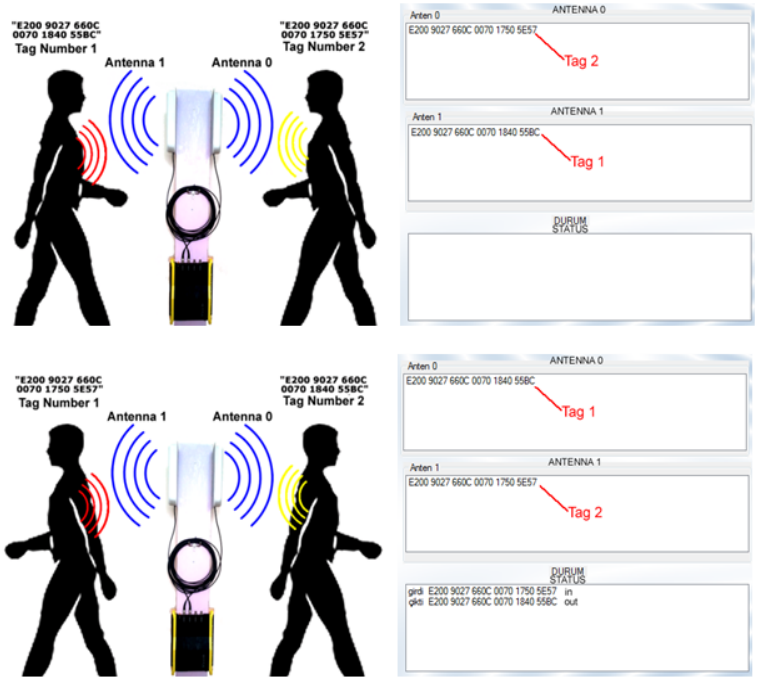

Figure 16. Functioning of the algorithm

5. Conclusions

In this thesis study, a RFID system has been designed and made for real time monitoring and recording of the entrance/exit time periods of the mobile personnel for the places where they should reach.

UHF RFID and mobile cellular communication technology has been used in the frequency interval of 902-927 MHz for the hardware of the system made. The system used for the identification of the personnel is consisted of RFID tag, antenna, reader and mobile modem used for wireless transfer of the data. As the tag reading distance is 1-3 m, RFID communication frequency has been chosen as UHF. When the personnel given RFID tag approaches the area in which the system is installed and enters the detection boundary, he/she is identified and his/her entrance/exit time periods is recorded in the databases thanks to the hardware mechanism. The software has been developed by using C# programming language for managing the hardware mechanism in which the RFID technology is used. Mobile cellular communication technology is provided between the developed software and the reader. Socket programming structure has been used while making this program. Mobile cellular communication technology has been used for accessing the RFID reader in the internet. Hardware mechanism in which the UHF RFID technology is used is controlled by the developed software and connection is made wirelessly by the mobile modem connected to the reader.

Thanks to the system, we can reach the information about arriving and leaving dates of the places where the mobile personnel should go 7/24 from everywhere that has internet connection.

As a result of the tests done, it has been seen that the data has been transmitted with the 7±1% error margin in the RF communication environment. It has been detected that this error caused by the RFID tag.

The reader can perform the reading process without a problem in the passing made in the walking speed of a human. It has been observed that the error margin increases in a direct proportion to the passing speed in the higher speed passing because of the structure of the tag.

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