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Radio Frequency Identification (RFID) Based Cable Detection System

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Abstract: Cable theft issues have been known worldwide in the past years therefore this paper discusses how to overcome them by using radio frequency identification (RFID) technology in which the RFID reader can detect the unique identifier (UID) number of the RFID tag that is attached on the cable. The main objective is to develop the RFID-based cable detection system using both software and hardware. Additionally, this system will analyze how the voltage received by the reader can be affected when the distance between tag and reader is varied. The system is developed by using RFID RC522 and Arduino UNO as the main components. The RFID reader will read the data from the RFID tag and will be sent to the Arduino UNO for processing according to the codes that have been programmed into the Arduino UNO. Once processed, the OLED display will display the RFID tag's unique identifier number along with the location of the cable. The range analysis is done by analyzing the distance between reader and tag and the voltage received by the reader. From the results obtained, the trend of range analysis shows that the nearer the distance, the higher the voltage received by the reader. In summary, the proposed solution to the cable theft issues which is RFID based cable detection system could improve the user's management by reducing the user's time to locate the cable. However, the system can be improvised by developing a system with the detection range between reader and tag that can reach up to 1m and above.

Keywords: Radio Frequency Identification, Cable Detection System, Cable Theft

1. Introduction

Recently, cable theft has been categorized as a common case that happened globally. This is an activity where people steal cables and use them for the sake of businesses and profits or illegal purposes. Besides, it also refers to metal theft, which is defined as the theft of physical cables for their scrap metal value [1]-[2]. The most common metal when it comes to metal scraps is copper because of its high demand in the market [2]. In this context, such crime gives a significant impact especially in the financial sector and public sector which refers to public transport, internet, electricity, and telephone. For example, in the rail system, it will cause severe damage to the track frame, causing the train to be

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canceled or delayed. In worst cases, cable theft increases the accident statistics caused by power outages and exposed cables which can cause injury or death. These issues lead to the need for a cable identification system to prevent or reduce the cable theft activity.

Cable identification system used to mark or label cable in order to distinguish type and owner of the cable. In some identification systems, the identified cable has its identity code that makes it easier to track and identify [3]. In literature, cable identification systems were made by adding the identity tag to the electrical cable be it a physical tag or using a connector [2]-[3]. These physical tags may seem much easier to utilize, however, it is easily detached from the cable in instance [2]-[3]. Another technology adopted for identification systems is barcode scanning and radio frequency identification (RFID) [5]-[6]. The RFID system overcomes the limitation of barcode scanning that requires line-of-sight access to each barcode. This feature allows the RFID tag to be buried inside the cable insulator for security purposes.

RFID technology has been employed previously in anti-theft detection systems [7]. However, the system is not used for electrical cable application. In this paper, the RFID technology system is adopted for electrical cable anti-theft system. The developed system consists of three main components, which are RFID reader, Arduino controller and LCD display. The system characterization focuses on the impact on obstacle materials towards its sensing range.

2. Materials and Methods

Research methodology is a specific method that involves identifying, determining, processing as well as analyzing the desired topic. The overview for this project is the RFID tag will be attached to the cable thus the RFID reader will scan and read the data through waves that are produced when transmitting the signal between both RFID reader and tag [4]-[6],[8]. The observation will be based on how far the distance can be for the reader to be able to read and collect data from the tag with and without obstacles. To get a better insight on how the cable identification system using the RFID system works, the block diagram and flowchart are illustrated and explained below.

2.1 Materials

The development of RFID-based cable detection systems includes both software and hardware. Below are the main components that contribute to the completion of the system to get the desired results.

Figure 1 depicted the process flow of the RFID tagging system which are briefly explained as follows:

i. Input - RFID tag will be scanned by the RFID reader and the data received is sent to the Arduino microcontroller for processing.

ii. Arduino UNO board is powered up by a 5V supply via USB cable. Upon receiving data from the RFID reader, the programmed Arduino microcontroller will process the data as desired by the prompt set in the coding.

iii. The OLED display is used to display the RFID tag UID along with its location. Therefore, after processing the data, it will be shown on an OLED display.

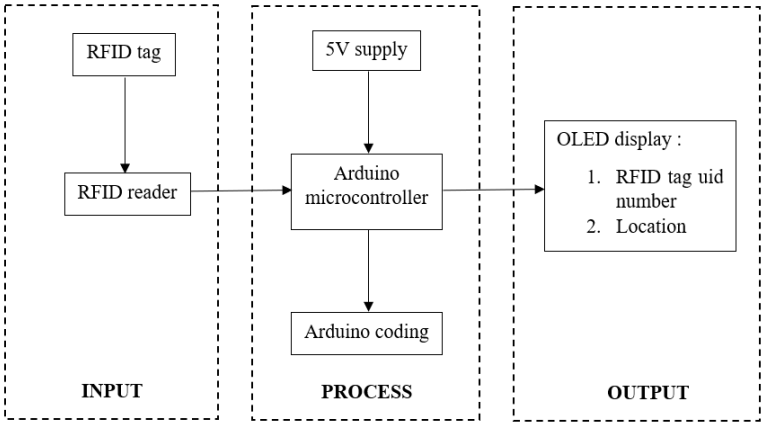


Figure 1: Block diagram of RFID tagging system

2.2 Methods

The method used to complete this project is by developing the software (Arduino and Proteus) and hardware prototype so that the desired result is obtained. The structural process to summarize the project workflow is shown in Figure 2 as it is important in ensuring that this project is done correctly thus makes it understandable.

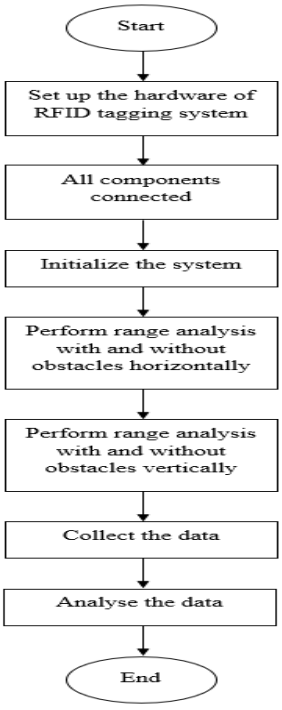


Figure 2: Structural project workflow of RFID tagging system

The passive RFID system is essentially about how the reader transmits the RF waves signal that has been modulated to the tag which consists of an antenna and integrated chip (IC) [4],[6],[9]-[10]. As the name suggests, the passive RFID tag is passive as well, by means, the tag can only receive the signal from the reader that needs to be altered in such a way that the information and data are being read and stored within the tag antenna so that it can be backscattered to the reader.

Before the empirical study is started, the obstacles selection is needed to distinguish which result is better in RFID range analysis. This signifies that the obstacle in which is placed between tag and reader somehow makes the reading distance shorter compared to without an obstacle. This is due to the

material properties of the object itself. In [11], the study discussed how different material surfaces in line with RFID systems affected the range analysis. In this project, various obstacles are selected for the range analysis which are air (free space), thick rubber, and metal. There are six analyses conducted where three different obstacles are aligned with the RFID system in two different positions either horizontal or vertical.

3. Results and Discussion

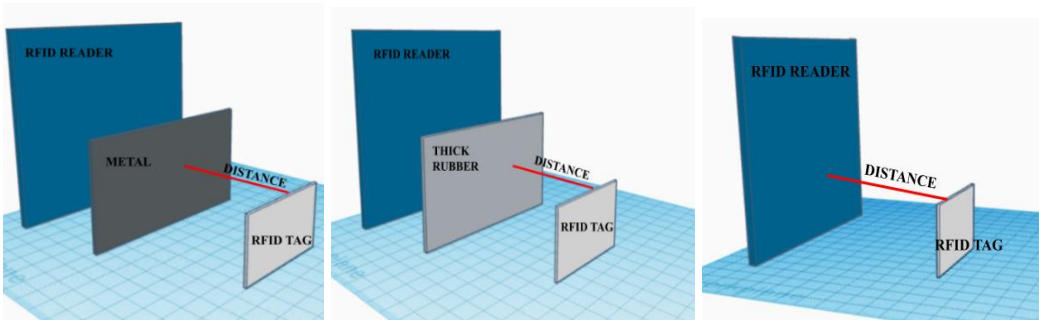
As mentioned earlier, the desired result is obtained by developing the software and hardware of the detection system. Therefore, the system needs to identify the tag that is being read by the RFID reader initially. With this, the circuitry connection has been made in Proteus software and the coding from Arduino IDE is uploaded to the Arduino UNO component. Once uploaded, the system is simulated and the RFID reader will receive the data from the RFID tag when scanned. Then, the virtual terminal in Proteus software as well as the OLED display is displaying the data received. The observation is based on how far the distance between reader and tag can read the data. Additionally, when the RFID tag is being scanned by the RFID reader, the voltage value is also received.

RFID range analysis is conducted and being discussed to determine the ability of the RFID reader to detect the RFID tag with different obstacles and positions. Thick rubber and metal act as the insulation for this project as shown in the figures below. The prototype is also placed in two different positions which are vertical and horizontal. The maximum distance of the RFID system for each obstacle is tabulated in Table 1.

Table 1: Maximum distance read by the reader

Obstacle	Maximum distance (cm)	
	Horizontal	Vertical
Without obstacle	3	4
Thick rubber	3	3
Metal	2	2

The RFID reader is placed horizontally and vertically in which the maximum distance is 4cm from the RFID tag and is scanned with three different types of obstacles. The tests are performed repeatedly so that the results obtained are more accurate. Simultaneously, the voltage received by the RFID reader for each reading is recorded by observing the output waveform from Proteus software. The results obtained for both range analysis and voltage reading tests are shown in the tables below in the order from horizontally then vertically. The hardware testing of RFID tagging system is shown in Figure 3.



(a) (b) (c)

Figure 3: Hardware testing of RFID tagging system – (a) Metal as an obstacle (b) Thick rubber as obstacle and (c) Without obstacle

Table 2 and Table 3 show that the detection of the RFID system is successfully done by scanning the RFID tag whenever the distance is varied in which the maximum distance between reader and tag is 4cm. Meanwhile, the voltage received by the reader is tabulated in Table 4 and Table 5 that is obtained by analyzing the waveforms produced in Proteus software.

Table 2: Range analysis of RFID system for the horizontal position

Obstacle	Distance between reader and tag (cm)				
	0	1	2	3	4
No obstacle	√	√	√	√	-
Thick rubber	√	√	√	√	-
Metal	√	√	√	-	-

Table 3: Range analysis of RFID system for the vertical position

Obstacle	Distance between reader and tag (cm)				
	0	1	2	3	4
No obstacle	√	√	√	√	√
Thick rubber	√	√	√	√	-
Metal	√	√	√	-	-

[1] √ indicates the success of RFID tag detection

Table 4: Voltage received by the reader (horizontal)

Obstacle	0cm	1cm	2cm	3cm	4cm
	Voltage received by reader (V)				
No obstacle	2.85	2.32	2.07	1.43	0
Thick rubber	2.94	2.67	2.23	1.65	0
Metal	2.15	1.81	1.36	0	0

Table 5: Voltage received by the reader (vertical)

Obstacle	0cm	1cm	2cm	3cm	4cm
	Voltage received by the reader (V)				
No obstacle	2.93	2.67	2.14	1.77	1.39
Thick rubber	2.38	1.66	1.15	0.81	0
Metal	1.54	1.43	0.58	0	0

Graphs of range analysis for both horizontal and vertical positions as presented in Figures 4 and 5 respectively. From the trends, the analysis can be concluded that the nearer the distance between tag and reader, the greater the voltage received.

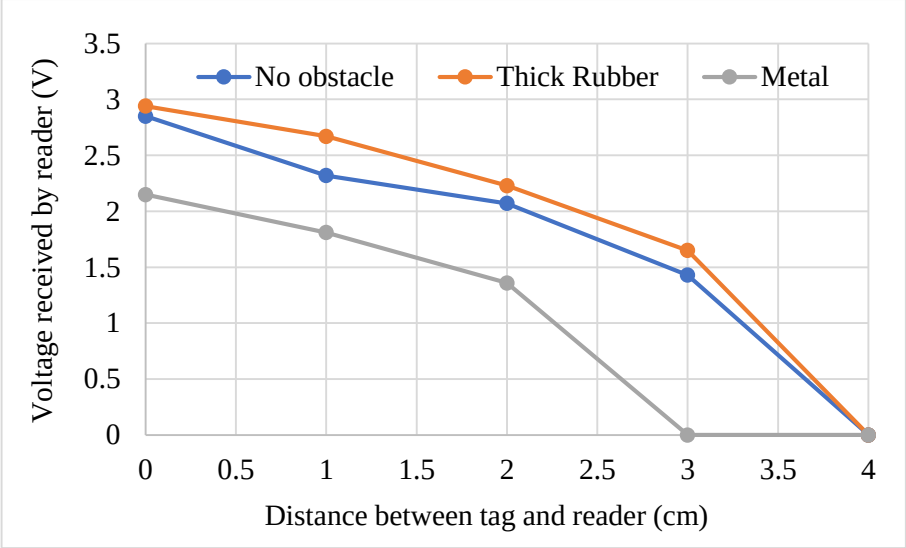


Figure 2: Graph of voltage received by reader vs distance (horizontal)

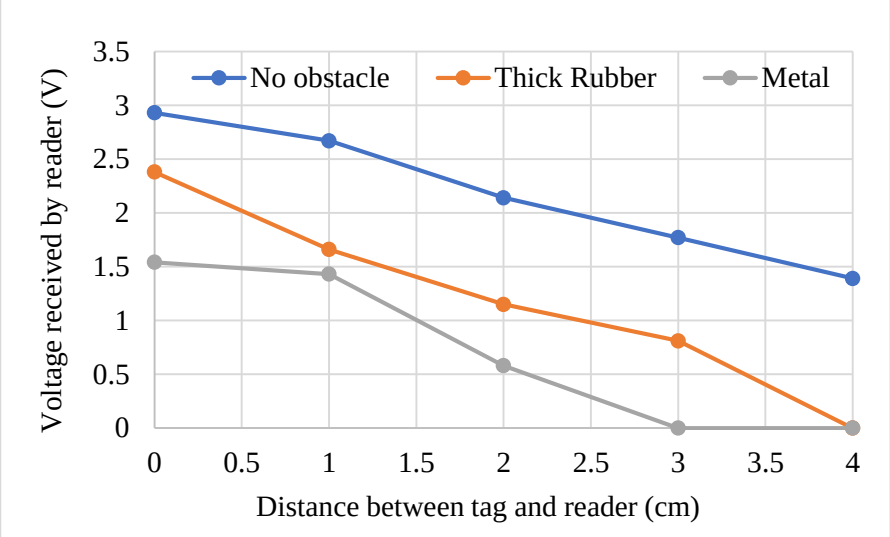


Figure 3: Graph of voltage received by reader vs distance (vertical)

4. Conclusion

In conclusion, RFID based cable detection system has been successfully developed and characterized in this work. The RFID RC522 reader is used in this project in which there are a lot of features to improve the performance as well as energy-saving and power optimization. The maximum distance that can be obtained by the RFID reader after the analysis is 4cm and the reader can also identify the cable even with the presence of obstacles. The proposed solution to cable theft improves the user's management by reducing the user's time to locate the cable. However, the system can be improvised by future researchers in which it can increase the range detection of the RFID system. For instance, instead of using RC series RFID reader (RC522), the PN series RFID reader (PN532, PN5180 etc.) can be the substitute due to its reliable range detection which can be up to 10 meters.

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