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# Automatic Vehicle Access System using Ultra-High Frequency RFID

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**Abstract:** Securing and monitoring the territory have become a big challenge for everyone as the number of vehicle users have increased. The premise area must be secure with enforced entrances and exits. It should have an automated and efficient security and monitoring system. For this purpose, an automated vehicle access system with accurate and secure monitoring of vehicle entry and exit was developed with Graphical User Interface (GUI) and vehicle's user database along with the prototype of Ultra-High Frequency RFID. The suitable configuration for the hardware prototype has also been evaluated to maximize the system's capabilities. This system operates on frequencies from 400MHz to 950MHz and is performed at distances of 7 meters. The passive tag was attached to the various condition and sizes of the car. The result shows showed that the system was optimally performed with the speed of the vehicle up to 50 km/h, 7 m of reading range and a maximum 20% tinted windshield. The ideal angle for the reader is around 60° to 70° with 2 meters of mounting pole. For future improvement, it is suggested that the registered vehicle user data was linked with the official premise's database and the data is saved in an off-site location (cloud storage). The GUI is also able to support more than 1 reader at a time depending on demand.

**Keywords:** Access system, UHF-RFID, Passive tag

## 1. Introduction

Radio Frequency Identification (RFID) has been firmly established as one of the leading identification technologies [1]. RFID systems work in a variety of frequency bands, where each of RFID type may be active (powered), passive (unpowered), or semi-passive (both powered and unpowered). Although active or semi-passive RFID has a high read rate of 95%, it has a high maintenance cost and a short lifespan due to its battery operation. RFID systems may save operational costs and make data storage and retrieval easier [2]. Furthermore, an active or semi-passive RFID tag is costly, big, and the communication protocol is unstandardized [3]. There are also few types of RFID devices available in market. The passive RFID device provides the tag with the necessary power to modulate the reader's interrogation signal. As a result, the reader acts as the master and the transponders as the slaves. While RFID scanner are slaves in their own right. Compared to both RFID devices, the readers only read passive or active tags device, but the hybrid RFID readers is kind feature an active/passive mode that allows them to move from passive to active mode and vice versa. Next, in the radio spectrum, there are three major RFID frequency bands that are used around the world such as Low Frequency (LF) with range in 100 kHz to 500 kHz, High Frequency (HF) with range 10 MHz to 15 MHz and 850 MHz to 950 MHz and Ultra-High Frequency (UHF) works in the frequency range is from 2.4 GHz to 5.8 GHz.

Due to large number of cars arrive and depart each day at the premise, manually regulating or managing vehicle entrances and exits is tough. In some situation, the vehicles that entering the area was only being check for identification but not being record into the record book. This manual system does not provide continuous vehicle

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monitoring and ignore the safety measure to identify every passing vehicle. Unauthorized vehicle may have entered the area without alerting assigned security officer and can exit the area undetected.

To overcome those problems, an automated vehicle access system was developed with fast, accurate and secure monitoring of vehicle entry and exit using UHF RFID technology was implemented. A Graphical User Interface (GUI), vehicle's user database along with the prototype of Ultra-High Frequency RFID such as barrier gate was built. This system able to work at the entrance of any territory where the access security can be improved, also applicable at such traffic capacity as it provides user non-stop and quick access to premises experience. The mounting pole is 2 meters which is the standard and ideal height for RFID reader to detect the tag at every vehicle. Thus, for the reader installation, the angle of inclination with the ground plane of the antenna should be approximate in 60 degree to maximum 70 degree [4]. In this paper, the suitable configuration for the hardware prototype has also been evaluated to maximize the system's capabilities. This system operates on frequencies from 400 MHz to 950 MHz and performed at distances of 7 meters. Field tests were conducted by car passed the system at the main entrance of Universiti Tun Hussein Onn Malaysia.

## 1.1 Access Control System

There are few existed technologies for access control system that related to monitoring, authentication, security, and detection features. It is divided into three different technologies which is Internet of Thing (IOT) based, computer vision based, and RFID based. In 2012, Universiti Sains Malaysia (USM) used this RFID technology for four distinct applications: car park entry system, attendance system, library management system, and healthcare management system. The reader's operating frequency is UHF 919-923 MHz, with a reading range of 2-3 meters. The reader connects to computers using a serial communication channel (RS-232) [5]. Moreover, for the Internet of Thing (IOT) based, the system is made up of a Cloud-Based Server that stores resource data supplied by local parking lot units. Each parking lot has a Local Unit that stores information about each parking spot where the Arduino module is used as a control unit of the system. Finally, there is the Software Client, which runs on Android and is installed on the customers' cellphones [6]. The Automatic Vehicle License Plate Recognition (AVLPR), the computer vision-based technology is also used in vehicle access control. AVLPR systems are not easy to implement due to the intricacy of the natural pictures from which license plates must be acquired, as well as the application's real-time nature. The physical components that capture pictures and the algorithms that analyze the pictures define the quality of an AVLPR system. The detection range of interest in the images, such as the license plate, character extraction from the license plate, and identification of the characters are the three steps of a typical AVLPR system [7]–[9].

## 2. Methodology

This section presents the methodology used to develop the proposed vehicle access system using UHF-RFID. The first subsection presents the overall block diagram of the system, followed by the flowchart of the GUI. Next subsections consist of flowchart of the GUI and lastly is the specification of hardware associated with software used to accomplish this project.

## 2.1 Vehicle Access System Setting and Design

For the field testing, the test back was conducted at the main entrance of UTHM and the hardware is set up as illustrated in Figure 1(a) and the prototype of the system is as shown in Figure 1(b). The passive tag is placed at the right side of the car windshield as shown in Figure 1 (d). UHF RFID tag act as input of the system and the UHF RFID reader will read the data from the detected tag. Moreover, as shown in Figure 1(c), the data is then transferred to Arduino Mega 2560 microcontroller to trigger the servo motor to open the barrier gate when the RFID tag is detected. At the same time, the data will be store in the database. MySQL database is connected with phpMyAdmin to manage the created database. Note that the MySQL database and phpMyAdmin are connected by using MySQL connector. Moreover, XAMP control panel (Version 3.2.4) is used as a web server to display website content through storing, processing, and delivering webpages in the PhpMyAdmin. As a result, the GUI will display the data of the authorized vehicle to enter the premise. After the vehicle is out of UHF reader detection range, the servo motor will close the entrance until the next tag is detected. Lastly, the communication between the reader to the computer or GUI was established by using Type A male to type male cable.

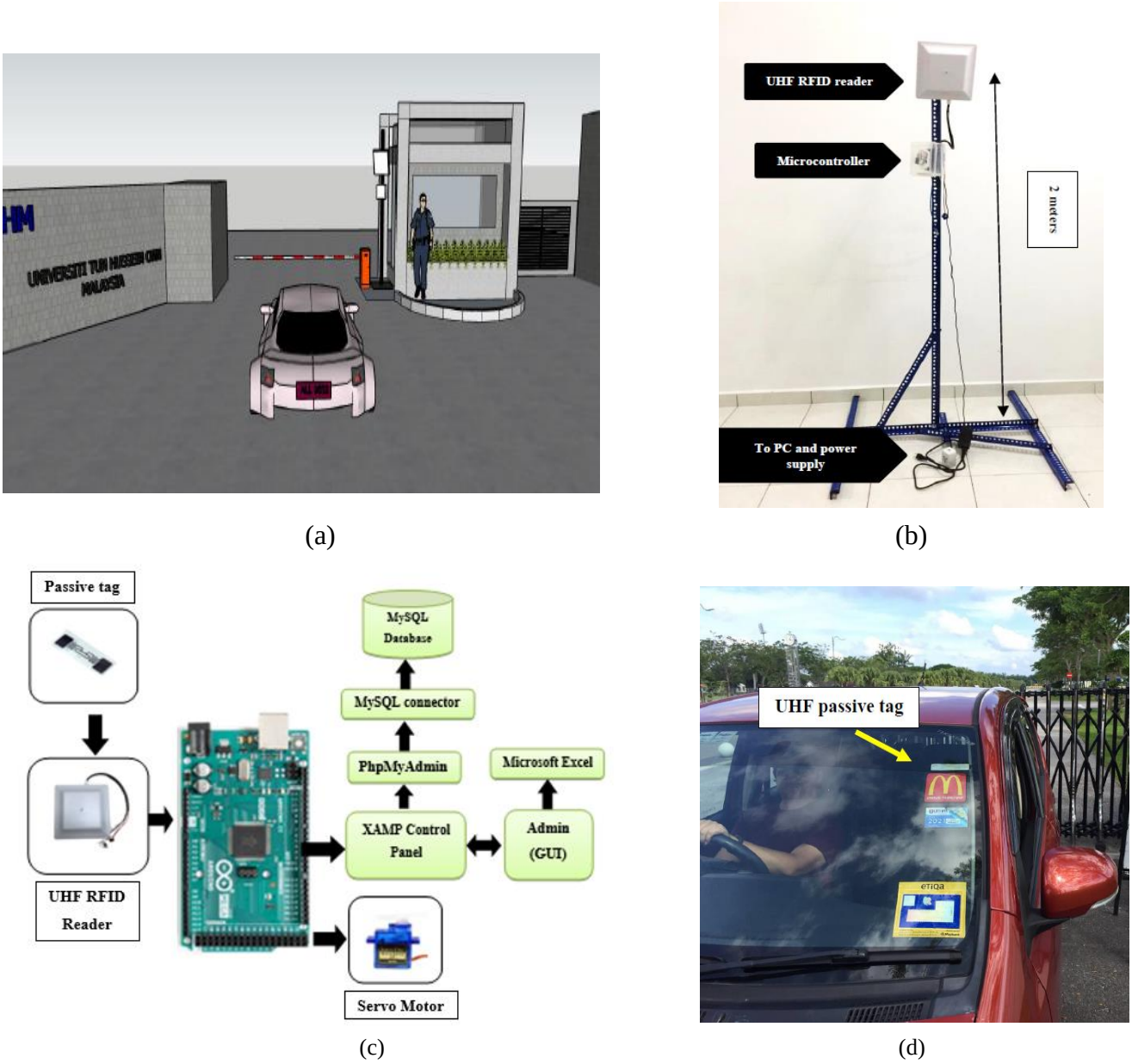



**Fig. 1 - System's set up; (a) Overall system's placement; (b) Front view prototype (c) Block diagram of the system; (d) Passive tag placement.**

## 2.2 Flowchart of the GUI

Visual Basic.NET programming language is used to develop the GUI. The data from the tag was transmitted to the reader in hexadecimal then the data was received by the GUI. For the database, MySqlConnection command was configured to connect to a MySQL server using a connection string which contain several key-value pairs to establish connection to the dedicated database. The data type of the information stored in the database is in variable length string (VARCHAR) for Name, Matric number, Plate number and Faculty. While for the images, binary large object column (LONGBLOB) data type is used in the database.

In the GUI, according to Figure 2, the dashboard of the apps appeared as the main interface. The dashboard showed three options which is connection, user data, and registration. Each option leads to its screen where it appears beside the dashboard. 'Connection' menu is used to make a connection with the connected UHF RFID reader associated with Arduino MEGA 2560. 'User data' menu is functioned to display all the scanned data from the reader on the screen such as the user's image, tag ID, name, matric number, contact number, vehicle plate number and faculty. For 'Registration' menu, the responsible admin able to insert a new user or edit the old user data. While for 'Report' menu, act as log history for the vehicle that passed the entrance of the premise. This menu shows the scanned data at

data grid view from the reader to Arduino. In the data grid view, the real time data such as date/time of the vehicle passing through the UHF-RFID reader and the detail of the driver was recorded.

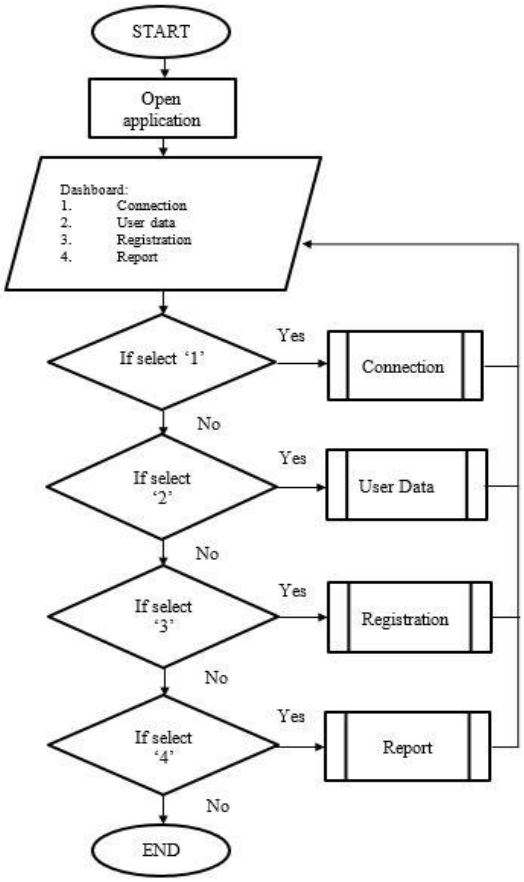



**Fig 2 - Flowchart of the system's GUI**

## 2.3 Specification of Hardware

To accomplish the project, the type of hardware and software have been chosen to fit the system in terms of power, frequency, read range, power supply, hardware, and software for fast and long-distance detection. The specification is described as in the Table 1 below:

**Table 1 - Specification of the hardware and software**

| Criteria | Specification |
|---|---|
| Type of tag | ISO 18000-6C Passive RFID |
| Type of reader | RM9001 UHF-RFID reader |
| Frequency | 400MHz to 950MHz |
| Read range | 7 to 10 meters |
| Power supply | 12V DC |
| Other hardware | Tower Pro SG-90 Servo Motor, Arduino Mega 2560 microcontroller, and RS232 to TTL Converter Module |
| Software | Microsoft Visual Studio 2019, XAMP Control Panel v3.2.4, MySQL connector, PhpMyAdmin, Microsoft Excel and Arduino IDE |

## 3. Results and Analysis

The results that have been obtained from this integrated system using combination of software such as Microsoft Visual Studio, XAMP control panel, phpMyAdmin, MySQL connector and Microsoft Excel Spreadsheet and hardware prototype are analyzed and explained in sub section 3.1 until sub section 3.2.

### 3.1 Graphical User Interface for UHF-RFID Vehicle Access System Acknowledgement

The graphic user interface namely UHF-RID Vehicle Access System (UHF-RFID VAS) is designed to allow admin to interact with electronic devices through graphical icons. In this case, the designed GUI is used to register and monitor the detected vehicle attached with UHF tag. The UHF reader will communicate with designed GUI. The connection menu shown in Figure 3(a) is used to make a connection with the connected UHF RFID reader. The Scan Port button will figure out which network ports are open. The baud rate can be change according to the baud rate on UHF Reader itself. Once the reader and the application were connected, the connection status at the top of the interface will change its status from 'Disconnect' into 'Connected' and the indicator will change from red.

Next, User Data Menu in Figure 3(b) shows the User Data menu. In this menu, all the scanned data from the reader will be display in this screen such as the user's image, tag ID, name, matric number, contact number, vehicle plate number and faculty. For Registration menu in Figure 3(c), the assigned admin able to insert a new user or edit the old user data. To insert the data, admin can simply scan the new RFID sticker and write the related information of the user, including inserting the image of the user. The registered data is then displayed at the data grid view and automatically stored in the linked database. Lastly, Report Menu in Figure 3(d) shows the scanned data at data grid view from the reader. In the data grid view, the real time data such as date/time of the vehicle passing through the UHF-RFID reader and the detail of the driver was recorded. At the bottom of the menu, there Reset and Export buttons. Thus, the recorded data of vehicle that exit and enter the premise can be kept by exporting it into Microsoft Excel.

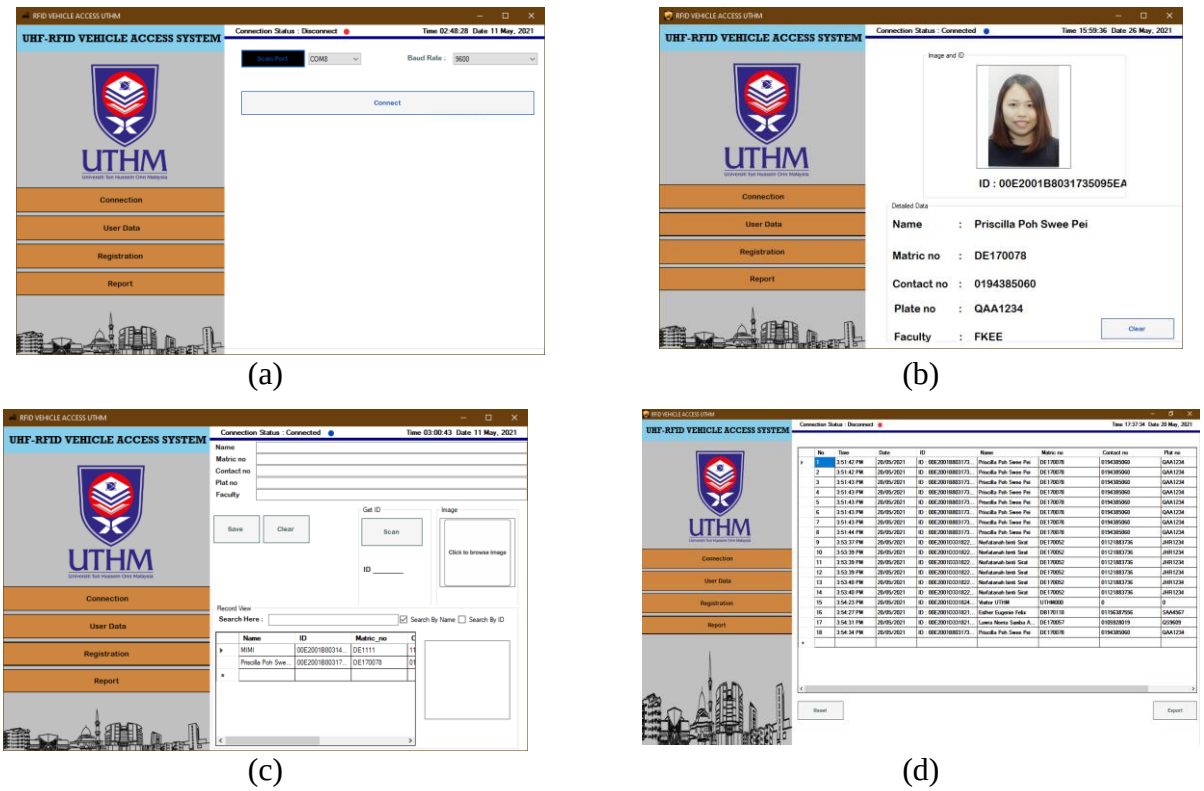



**Fig. 3 - The GUI's dashboard for vehicle access system contain (a) Connection Menu; (b) User Data Menu; (c) Registration Menu; (d) Report Menu**

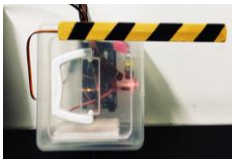
### 3.2 Result of system associate with barrier gate

When the vehicle approached, the UHF RFID reader will detect the tag attached on the vehicle and the servo motor will be triggered. Then, the serial monitor will display "Authorized access" indicated that the barrier gate is

open for the vehicle to enter. After the vehicle has passed through, the barrier gate will close while the serial monitor will display 'waiting' and until another detection of authorized access. From the observation in the serial monitor in Figure 4(a), when vehicle passing around 10 km/h to 50 km/h of speed, the gate is open for 9 seconds as shown in Figure 4(b) until the vehicle has fully passed the barrier gate. Then, the barrier will close (Figure 4(c)). However, the barrier gate open status will depend on the proximity of the car where the barrier gate will be kept open if the vehicle's tag is within the UHF-RFID reader detection area.


(a)

(b)



(c)

**Fig 4 - (a) Serial monitor display for barrier gate status; (b) Barrier gate when tag is detected; (c) Barrier gate when no tag is detected.**

## 3.3 Field test Result

There are four (4) types of testing that has been conducted for the UHF-RFID Vehicle Access System. The testing is to measure the performance of the system with different speed of vehicle, observe the performance of UHF-RFID reader, investigate the maximum detection distance between reader and distance of tag in static condition at 60-degree angle and 2 meters height of reader and measure the readability of the passive UHF tag with different density of tinted windshield. All the testing is conducted around 2pm until 4pm and the weather is mostly sunny.

### 3.3.1 Measure the Performance of the System with Different Speed of Vehicle

The performance of the system in various speed shown in Table 2. This testing aims to observe the speed of the moving car passing the reader at a 60-degree angle and 2 meters height of reader with the windshield tinted percentage of approximately 10% to 20%. The result shows the stable state of the system from speed 20 km/h until 50 km/h of the passing vehicle. It can be considered as stable state when there is no redundant data is read by the UHF reader into the system once the vehicle is passing. The repetition of reading would not downgrade the reliability of system as the repetition of the reading cannot affect the following vehicle's detection but only generated large data streams. Furthermore, the UHF reader was unable to read the tag on the passed vehicle when the speed of the vehicle reaches 50 km/h and above. In conclusion, the ideal speed of the passing vehicle is between 20 km/h to 50 km/h as it will save the system resources due to the repetition data.

**Table 2 - The performance of the system in various speed of vehicle**

| Speed (km/h) | Detection | Repetition reading | Stability |
|---|---|---|---|
| <10 | Yes | 8 | Not stable |
| 10 | Yes | 6 | Not stable |
| 20 | Yes | 1 | Stable |
| 30 | Yes | 1 | Stable |
| 40 | Yes | 1 | Stable |
| 50 | No | 1 | Stable |
| 60 | No | 0 | Undetected |
| 70 | No | 0 | Undetected |

### 3.3.2 Maximum Detection Distance between Reader and Distance of Tag in Static Condition at 60-Degree Angle and 2 Meters Height of Reader

Table 3 shows the maximum detection between the UHF-RFID reader and the passive tag that attached to the right side of the front windsheld of the vehicle with tinted density approximately 10% to 20%. Within 7 meters range, the system is stable and able to read the data into the application from the tag no undetected error. At 8 meters distance, the reading is unstable as the data somehow fails to load into the application. The chances of the reader able to read the tag from 8 meters distance are 50% depend on the surrounding environment and the best position of the tag. The testing is conducted around 3pm and the weather is sunny and windy. In conclusion, the reading distance when the tag is static condition and moving condition from 20km/h to 50km/h is identical under the same environment.

**Table 3 - The performance of the system in various distance in meter**

| Distance (m) | Detection |
|---|---|
| 1 | Yes |
| 2 | Yes |
| 3 | Yes |
| 4 | Yes |
| 5 | Yes |
| 6 | Yes |
| 7 | Yes |
| 8 | Unstable detection |
| 9 | No |
| 10 | No |
| 12 | No |

### 3.3.3 Measure the Readability of the Passive UHF tag with Different Density of Tinted Windshield

The experiment is implemented on six different vehicles with different density of tinted windshield. Ten (10) times of passing trial with 20 km/h average vehicle speed have been set. Hence, the vehicle is randomly picked to satisfy the actual situation when this system is implemented. The testing is conducted around 3pm and the weather is sunny. The collected data are shown in Figure 5, the tag is most readable at the range of 0% until 20% of the tinted windshield density without any detection failure when the vehicle was moving at the 20km/h of average speed. At approximately30% to 60% tinted windshield density, only at a single time of trial was unreadable. While approximately at 70% to 80% tinted density, three times of trials unreadable. At 90% and above, the performance is expected to keep decreasing. The tag readability performance on tinted windshield is decreased due to the high metal material (metal microparticles) contain in the tint.

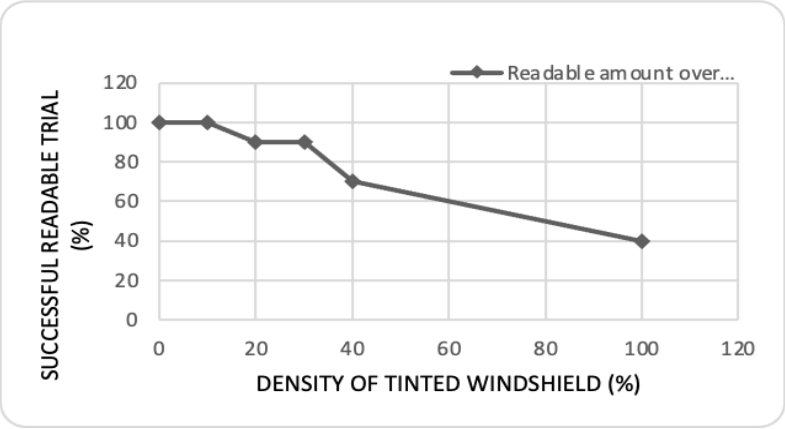



**Fig 5 - Readability of tag in various density of tinted windshield in day time**

### 3.3.4 Performance of UHF-RFID Reader Testing

Table 4 shows that the detection is only limited to 7 meters distance between the tag attached on the right side of the vehicle windshield. For daytime, the testing is conducted at 2pm and the weather is sunny while the testing for the nighttime was conducted at 8pm. For this testing, the vehicle is not moving to observe the performance of the system in

term of detection distance when the tag is attached on the vehicle windshield. This UHF-RFID reader detection is not affected by the brightness of the surrounding environment when the vehicle is moving around 0 km/h until 50km/h. As a conclusion, the reading distance when the tag is static condition (0km/h) and moving condition from 20km/h to 50km/h is identical.

**Table 4 - Day time versus Nighttime detection distance**

| Distance (m) | Day time | Nighttime |
|---|---|---|
| 1 | Detected | Detected |
| 2 | Detected | Detected |
| 3 | Detected | Detected |
| 4 | Detected | Detected |
| 5 | Detected | Detected |
| 6 | Detected | Detected |
| 7 | Detected | Detected |
| 8 | Not detected | Not detected |
| 9 | Not detected | Not detected |
| 10 | Not detected | Not detected |
| 12 | Not detected | Not detected |

## 4. Conclusion

Overall, the vehicle access system using UHF-RFID was able to allow the authorized vehicle to enter the premise. This system was successfully developed as the detected vehicle's data can be read and transmitted to the GUI associated with the database so that only the registered vehicle has authority to enter the premises. The barrier gate triggered to open when the registered vehicle was detected. Furthermore, the vehicle was able to be detected by a UHF-RFID reader at a maximum distance of 7 meters with the maximum speed of passing vehicle until 50km/h with the tinted of the vehicle windshield should not be more than 20% filtering and the UHF RFID reader at 60-degree angle and 2 meters height from the ground to maximize the system's capabilities.

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