ISSN: 2710-2165

RFID based Infrastructure to Vehicle Communication System for Road Sign Identification

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Abstract

This paper produces an efficient, low-cost solution for communication between Infrastructure and vehicles by exploiting the passive UHF RFID features to deploy a scalable platform that overcomes the limitation of current technology GPS, WIFI and camera used in intelligent transportation system (ITS). The limitations are GPS inaccuracy, camera failure in bad weather, WIFI extra time handshake, and high deployment cost. The suggested system provides fast communication in real time that's required in warning message transmission between Infrastructure and vehicles, like speed limit warning and curve warning that the driver always misses or ignores. The proposed system contains a UHF RFID reader with a built-in antenna installed in the front pamper of the car connected to a microcontroller Arduino UNO by serial interface and a passive RFID tag deployed inside the road surface in the same line of the intended warning signal and this tag store the road information related to the warning signal. When the go over the RFID tag, it will retrieve its information, and a warning message will display on an LCD screen. This paper simulates all possible weather conditions and tries the system under four communication environments: water, dust, asphalt and free Air and compares the result accordingly.

Keywords- UHF RFID, I2V, V2V,road sign, ITS, autonomous vehicle.

I. Introduction

The increasing number of vehicles on the road has resulted in a drastic increase in traffic jams and road accidents[1]. Smart cars are the future of the vehicle business. Most newly manufactured automobiles include communication modules that transmit and receive data for a variety of functions, including insurance policy needs, vehicle security, and safety.[2]. The idea of Infrastructure to vehicles communication is relatively new and still in the first stage. Infrastructure to vehicles communication is expected to develop the concept of transportation and improve travel safety, efficiency and Air quality[3]. Current wireless communication standards are deployed in infrastructure to vehicle (I2V) communication systems like WiFi, Bluetooth, RFID and dedicated short-range communication (DSRC)[4].
There are many limitations to current technologies used to send the warning messages from the road signs to the vehicle[5]. The camera technology where the camera is used to read the information of the signs and send it to the car, the limitation is Cameras can fail because of weather situation like a dust storm, obstacles and heavy rain Camera also fail in a low light condition such as at night when a street light is not distributed correctly.

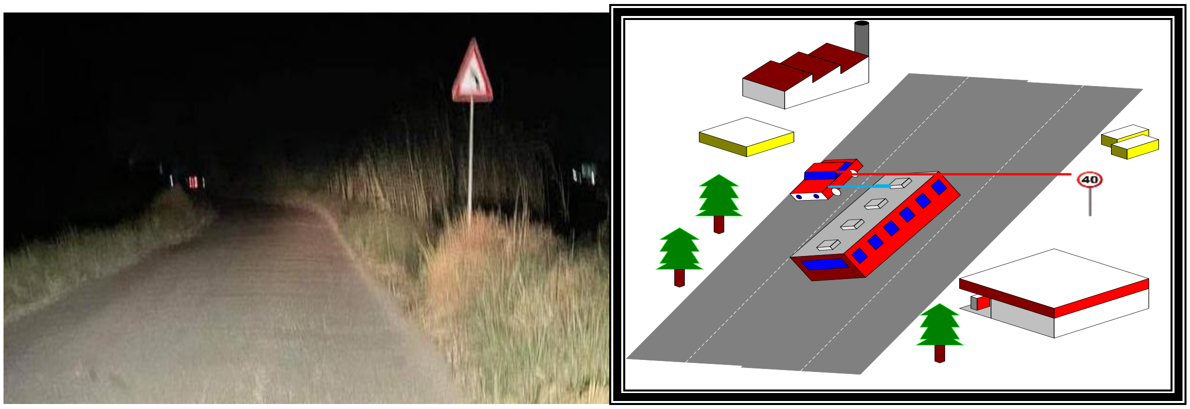

Figure 1: speed line blocking and curve warning sign unclear at night

The second GPS method is a positioning system based on a satellite that provides users with a precise location in three dimensions[6]. GPS has emerged as the leading technology to provide location information to the intelligent transportation system. by installing a GPS receiver in the vehicle that gets signal from the satellite orbiting around the earth, at least four satellites should be available to obtain accurate location measurement. GPS limitations are signal blockage due to weather conditions, poor receiver condition, faulty software, radio interference, a gap in coverage due to satellite maintenance, signals reflected from buildings and other structures, and the presence of large obstacles like buildings, bridges, trees, and tunnels cause inaccuracy in the measurements.[7]The WIFI technology problem is a delay because of the handshake steps required in the connection establishment that adds delay in the communication between vehicle and Infrastructure [8].
This paper chooses the passive UHF RFID-based system because it improves the current technology and does not change them [9]. RFID Tag is a store of information that can be changed. A passive RFID system is cheap and requires no power so it can be deployed easily anywhere [10].

The RFID-based I2V communication System, which includes RFID tags deployed on roads and UHF RFID readers installed on the vehicle's front end, is an important platform for developing intelligent transportation systems (ITS). It can provide important features not available in the current systems low cost, no power required for a passive tag, real-time road sign reading, and location services for GPS less environment[11]. According to these features, scalable vehicular applications can be deployed to improve vehicle safety and efficiency. The suggested method improves traffic safety by efficiently sending warning messages between vehicles and road signs (like speed warning signs and curve warning signs) and overcoming current technology limitations like camera and GPS limitations.
The main contribution of this paper is proposed system includes a UHF RFID reader installed on the vehicle's front pumper and Tag placed inside road signs. The UHF RFID reader is controlled by a microcontroller Arduino Uno and displays the warning message on the LCD screen. In such a system, the tags on the road sign will need no power and will work in different weather conditions.

II. related work

This part presents many types of research on vehicle-to-infrastructure communication for the warning message. Below researchers have produced the most critical work in this field.
Huanjia Yang, Shuang-Hua Yang[12] proposed an RFID-based system that uses a UHF RFID reader in the vehicle, places an RFID tag on the road, and investigated automatic speed limit transmission using RFID technologies. He concludes that both passive and active RFID systems have potential in this scenario but at different scales of application. Identify and classify the problems and benefits for all types, and design a system to demonstrate the benefits of using RFID for speed limit purposes.

Isaac Perper[13] proposed low-cost software-defined radios to overcome RFID positioning systems limitation. The proposed platform is a low-cost, scalable, and portable RFID micro-location platform that can overcome real-world deployment issues such as RFID orientation.
Huanjia Yang, Shuang-Hua Yang in 2007 [14] investigated RFID-based automatic speed limit transmission. In this application, both passive and active RFID systems show promise. A passive RFID system has a low-cost yet dependable tag design, making it suitable for mass implementation in large-scale applications. Using a passive RFID system also has the advantage of being simple to maintain,

as passive tags do not require batteries and can be re-programmed remotely. He has discussed and concluded that placing passive tags on the road surface can prevent passive tag confusion, ghost reading and reader conflicts.

Nash et al.[15] The impact RFID reader and tag placement, car velosity and RFID Tag Reading Count was examined. It was observed that in fast speed the lower the detection rate and RFID Tag Read Count. the reading count of tag and signal strength are both greater when the tag and reader are close.
Wang, Jianqiang, Daiheng Ni, and Keqiang Li, 2014 [16] proposed an RFID-based vehicle positioning approach. When a vehicle passes over an RFID tag, the precise position stored in the tag determines the vehicle's location. When there is no RFID coverage, the vehicle position is estimated using a kinematics integration algorithm from the most recent tag location until the next tag updates. RFID positioning accuracy is empirically validated in two independent ways, one using radar and the other a photoelectric switch. The proposed system is designed to verify whether the dynamic position obtained from RFID tags matches the accurate position measured by radar.

Salim A. Mohammed Ali, Emad H. Al-Hemairy [2]proposed communication modules inside vehicles that has OBDII to transmits and receive data for different function like vehicle security, and vehicles safety via Cellular V2X.

SRAIRI, Salim, and Arnaud GORIN, 2017 [17]created a traceability system to track the historical background of road infrastructure by including significant information generated during the construction, renovation, or operation phases. This can be accomplished by embedding passive tags in the road. They can be activated, read or written by sensors embedded in vehicles, and managed by intelligent control systems. First, the vehicle-infrastructure communication system is described, followed by an explanation of how it works. The developed communication software and the experimentation phase are then described in detail.

Targe, Pallavi A., and M. P. Satone, 2016 [18] propose a real time intelligent transportation system based on VANET to solve traffic congestion. RFID and an ARM controller are used in the proposed system. Every vehicle will be supplied with an RFID tag that will be read by a roadside unit equipped with an RFID reader. The roadside unit will collect information about the traffic strength on that signal node by sensing all vehicles present at that signal via their related RFID tags. Then, via RF transmission, traffic data will be sent to the central server and saved in our database. Then, via RF transmission, traffic data will be sent to the central server and saved in our database. The system can locate a path with the least amount of traffic, according to simulation results. For the system to be more effective, their system can be combined with traffic lights. Furthermore, in complex urban areas, they should consider positioning accuracy to assure path planning accuracy..

Wang, Zhan.[19] Proposed a new and timely vehicle positioning framework, named radio-frequency identification - driverless car positioning system (RFID-DCPS) This system is designed based on a local database of accurately geo-located Radio Frequency Identification (RFID) transponders on roadside furniture near roads and car-based interrogators. When the vehicle drives past the tagged roadside furniture, the interrogator mounted on the vehicle interrogates the location of the tagged roadside furniture within the reading range and determines the real-time positioning of the vehicle.

Wei Zhang, Bin Lin [20], proposed RFID-Integrated VANETs to monitor traffic flow, detect road accidents, and help avoiding chain crush. The deployment of Road Side Units (RSUs) at roadsides in VANETs, which send the accident information to the drivers timely on the city road, enhances the road safety. The paper investigates the placement
of Base Stations (B.S.s) and RFID-reader.

Yunlei Zhang [21] Proposed Localization system contain UHF RFID tag is used as a electronic license plate (ELP) and placed on the vehicular front windshield. The RFID reader and antennas are installed on the sign gantry. The phase difference of arrival (PDOA) of RFID backscatter signal is utilized to estimate the distances between the Tag and antennas.

Jianqiang Wang [16] To assist connected vehicle applications, an RFID-based vehicle location technique was presented. When a vehicle passes over an RFID tag, the precise position contained in the Tag determines the car's location. RFID location accuracy is empirically validated in two different techniques, one utilizing radar and the other a photoelectric switch..

From the above survey, we can conclude that there are many methods for send warning message from the Infrastructure to the vehicle and the position of the Tag that can be used to localize and monitor the users, the most famous are the GPS/GPRS and the RFID. The GPS/GPRS has some limitations in coverage and data bottleneck. While in the other hand, the RFID reader can act as a sink to collect all the information and send it to the cloud to be stored in the database. So our proposed work used the RFID technology.

III. Proposed work

The RFID system contains transceiver or RFID reader and the transponder or RFID tag with a scanning antenna. The RFID reader is a device used to collect information from the RFID tag, which is used to store traffic information[21]. This paper suggests a UHF-RFID-based infrastructure to vehicle communication system. The UHF RFID reader with an antenna connected to microcontroller Arduino UNO and LCD monitor the reader installed on the test car by installing exceptional support on the car chase, and mount bracket of the reader antenna angle is 90 and Tag deployed in the road surface each Tag carry 64 bit of hexadecimal data contain the traffic sign need to be read directly by the car distance between the reader and the Tag is 30 CM the system is tested according to vehicle speed variation and environment condition. Different environments are tested free Air, dust, ice and water. Received signal strength indicator RSSI is measured in each environment and with the vehicle speed from 10KM till 60 K.M. according to the road speed limit. When a car crosses a UHF RFID tag, the reader can read the tag information like speed limit and curve warning and send a warning letter to the LCD monitor so the driver can adjust the speed accordingly.

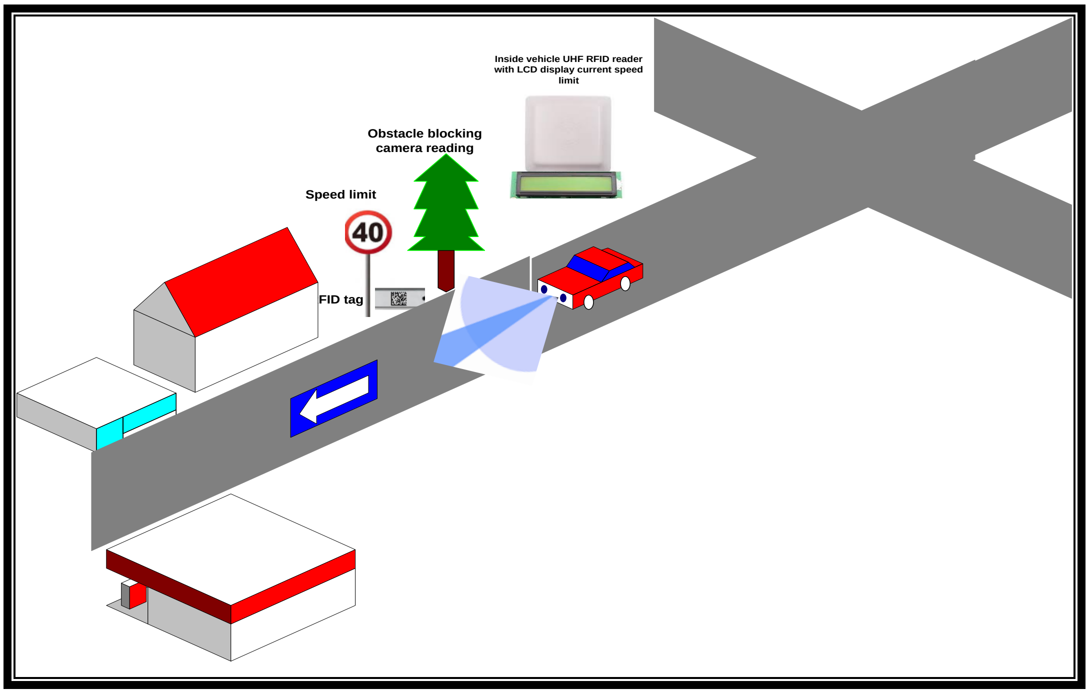

Figure 2: Infrastructure to vehicles (I2V) communication

Figure 3: UHF RFID reader installed to the car and Tag

IV. RFID Readers

The RFID reader reads data from RFID tags and acts as a bridge or a channel between the RFID tags and the control unit. The most significant properties of the reader are how well it reads, which can be affected by several factors like frequency, distance, interference and power. The RFID reader is built in with an antenna responsible for sending and receiving UHF signals. Once the connection between a UHF RFID reader and UHF tags is established, the reader can extract all the information sent and received during user interface software. RFID readers most generally utilize two various kinds of antennas Linear Polarized Antennas broadcast on a single plane to have a long read range while pointed in the direction of the Tag, and Circular Polarized Antennas broadcast signals in two planes two cover all directions but drop about 3 dB of the signal power [22].

V. UHF RFID tags types and their operation

UHF RFID tags contain three types depending on its circuit design active, passive and semi-passive active tags, for example, in Bluetooth tags, the battery is used to power the I.C. and send a signal by an active transmitter.

Battery-Assisted Passive Tag, the battery used only to power the I.C., but requires reader energy to send the backscattered signal [23]. Battery-Assisted Passive (BAP) tags battery only powers the I.C. [15].

Passive Tags are typically classified into inlays and hard tags[24].Stickers and overlays are made of paper, while hard have a hard case shield, which is often used for outdoor applications. The primary components of passive tags are an antenna and an Integrated Chip. The antenna receives R.F. energy, which is utilized to power the integrated circuit, and transmits the modulated signal to the reader. I.C. is accountable for all information operations. . The dipole antenna is the most commonly used for passive tags because it has two wires and is easy to manufacture. Memory types that can be found on a tag include:

1) EPC (Electronic Product Code. It has a limited amount of user-editable memory (96 to 496 bits)

2) Tag Identity (TID) Memory, which cannot be changed.

3). The access and lock passwords are stored in the Reserved Memory Bank.

4) 32- 64 bits memory. [10].

The reading range of a Passive UHF RFID:

1. the amount of power required to power on the Tag's I.C. Its typical threshold value is -10 dBm [16].

2 strengthen of the backscattered signal [25].

3. the smallest signal power that a reader can pick up or hear can be adjusted from reader management software.

VI. System design

The proposed system contains of the following equipment and devices

Table 1 Hardware requirements summary

Hardware item	Purpose
CF-RU5106.5112 UHF RFID Reader (902~928 MHz)	Read the traffic information stored in the RFID tag and send them to the microcontroller. Also, write for the first time
ATmega328P microcontroller	Fetch the data from the reader and display it on the LCD screen
MAX485 TTL to RS485 Converter	Convert RS 485 to TTL
UHF RFID Tags (902~928 MHz)	Store traffic information and send it to the reader
LCD Display	Display the warning letter
Jumper Wires	
DC power Regulator	Convert source power to the device working level
Bread Board	To connect system equipment

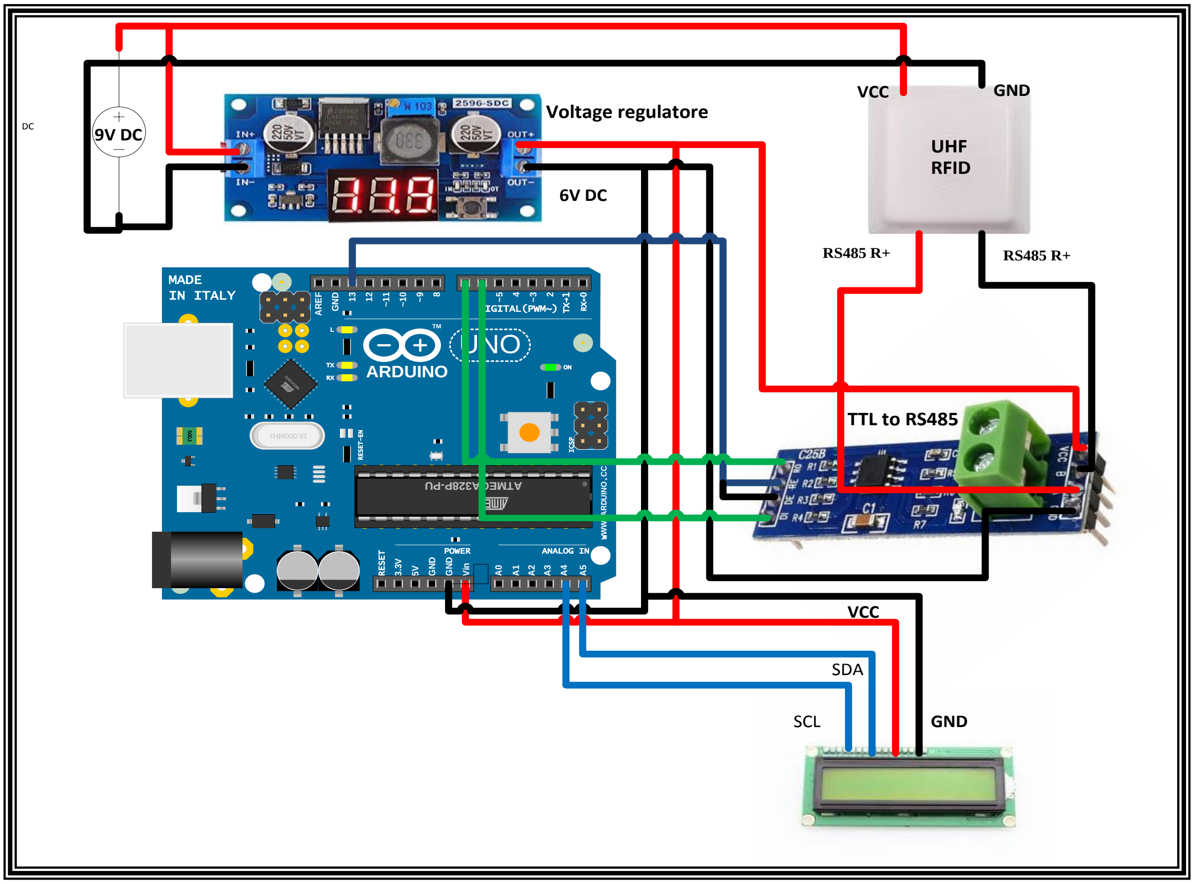

Figure 4: system connection and mapping

a. CF-RU5106.5112

UHF RFID reader (902~928 MHz) is the system's primary device that read and write the data on the Tag with high-performance UHF RFID integrated reader. It supports fast Tag read/write operation with a high identification rate.

- Self-intellectual property;
- Support ISO18000-6B, ISO18000-6C(EPC C1G2) protocol tag;
- 902~928,865~868MHz frequency band (frequency customization optional);
- FHSS or Fix Frequency transmission;
- RF output power up to 30dbm(adjustable);
- 8dbi/12dbi antenna optional with effect distance up to 3m/10m*;
- Support auto-running, interactive and trigger-activating work mode;
- Low power dissipation with a single +9 D.C. power supply;
- Support RS232, RS485, Wiegand interface; or TCP/IP

b. The AT mega 328P

It is the basis for the Arduino Uno Rev3 328P. It has 14 digital input/output pins, six analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to start.

Features

1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels 1x USART with fractional baud rate generator and start-of-frame detection
AVR CPU at up to 16 MHz
32 K.B. of Flash memory which 0.5 KB used by the bootloader
2 K.B. Static RAM
1KB EEPROM

c. UHF RFID Tags

860~960 MHz Long Range UHF RFID Passive tags working on ISO18000-6C Class 1 Gen 2 used Alien H3 chip and according to manufacture working life is Write 100,000 times and Data save for ten years and reading distance is 1-10m (12 dBi antenna) depend on reader Antenna.

d. MAX485 TTL to RS485 Converter Module

Convert UHF RFID reader output signal from (Transistor-Transistor Logic) TTL to RS485 signal.
Feature
– Operating voltage: 5V
– On-board MAX485 chip
– A low power consumption for the RS-485 communication
– Slew-rate limited transceiver
– 5.08mm pitch 2P terminal
– Convenient RS-485 communication wiring
– All pins of the chip have been led to can be controlled through the microcontroller
– Board size: 44 x 14mm

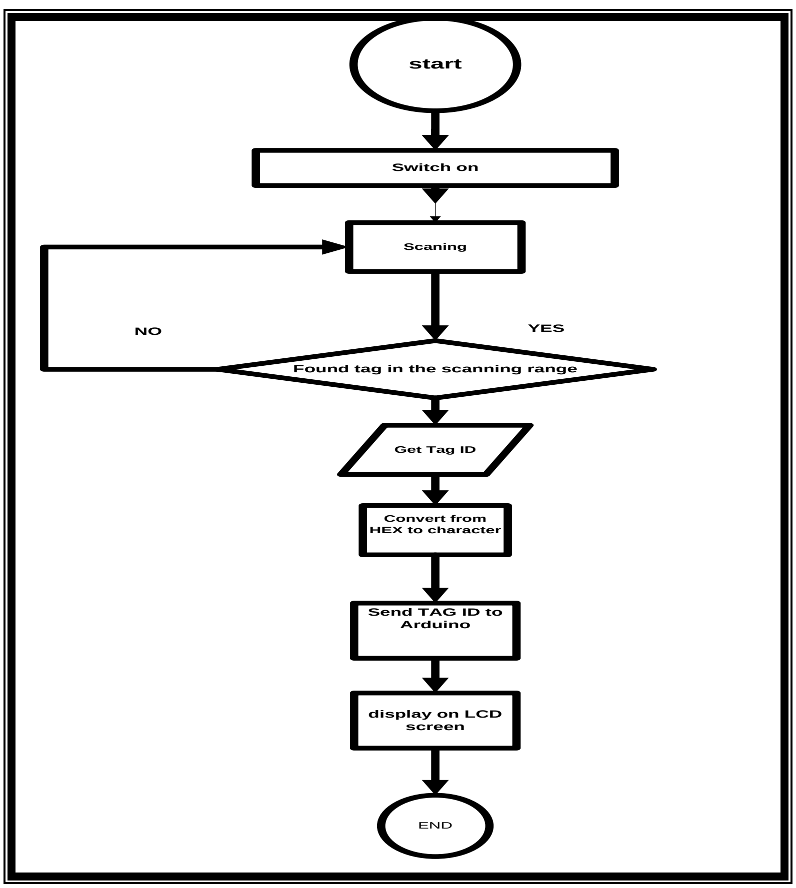

Figure 5: Data flow of the proposed system mode

VII. RESULTS

This paper produces an infrastructure to vehicle communication technology based on a UHF RFID reader and antenna in a vehicle and a Tag deployed on the road in the same line as the traffic sign. According to the manufacturer, the reader can identify all traffic signs and road information remotely, and the maximum distance from the reader to the Tag is 7 M. According to the result, the distance decreased when the vehicle speed increased; four scenarios were tested.

A. Senario1: Free Air

The proposed scenario simulates a clean environment without any obstacles or weather effects. The comparison between different scenarios is taken according to the reading and RSSI results. This scenario showed the best result and good RSSI reading compared to the remaining scenario.

Figure 6. UHF RFID Tag in Free Air environment

distance	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10**
RSSI	**-50**	**-55**	**-48**	**-60**	**-54**	**-62**	**-65**	**-70**	**-68**	**-71**	**-74**	**-75**	**-73**	**-77**	**0**	**-80**	**0**	**0**	**0**	**0**

Table 2: RSSI Reading results in a free air environment

speed	10	15	20	25	30	35	40	45	50	55	60	65	70	75
RSSI	-40	-40	-45	-43	-46	-48	-53	-50	-55	-65	no detect	not test	not test	not test

b. Scenario 2, Dust

This scenario simulates one of the potential weather conditions that usually happen because of the weather-long effect or dust storm. According to the reading result and RSSI output, this scenario is shown less reading range and RSSI result

Figure 7: UHF RFID Tag in Free Dust environment

Table 3: RSSI Reading result in Dust environment

distance	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10**
RSSI	**-58**	**-55**	**-65**	**-70**	**-66**	**-71**	**-75**	**-73**	**-77**	**0**	**-75**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

speed	10	15	20	25	30	35	40	45	50	55	60	65	70	75
output	-45	-48	-47	-50	-53	-60	-61	-65	-68	0	-69	0	0	0

c. Scenario 3, water

In this proposed scenario, the heavy rain or flooding effect is simulated to show their impact on our system. The result shown below is the reading and RSSI result.

Figure 8: UHF RFID Tag in Free Air environment

Table 4: RSSI Reading results in water environment

distance	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**	**10**
RSSI	**-60**	**-62**	**-64**	**-63**	**-66**	**-68**	**-72**	**-75**	**-77**	**0**	**-79**	**-78**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

d. Scenario 4, Asphalt

This scenario simulated one of the expected locations of the UHF RFID tag, which is inside the road itself to be near the RFID reader and protected from external effects. The test reading result and RSSI showed a low reading range and low RSSI value
And that because of the effect of the UHF signal loss, some power en penetrates the asphalt.

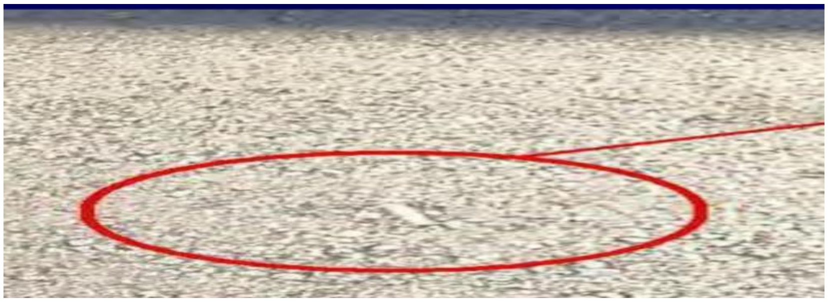

Figure 9: UHF RFDI tag Inside Asphalt

Table 5: RSSI Reading result in Asphalt environment

distance	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
RSSI	-65	-70	-66	-71	-75	-73	-77	0	-75	0	0	0	0	0	0	0

speed	10	15	20	25	30	35	40	45	50	55	60	65	70	75
RSSI	-50	-53	-52	-55	-57	-60	-63	-65	-68	0	-69	0	0	0

According to the result, the free Air gives better RSSI result and reading response than the remaining environment according to table []. The best result of the RFID tag response and RSSI value detected at the low speed of the vehicle with a free air environment. The reading result is processed by Arduino UNO and displayed on the LCD screen to indicate the vehicle driver about the road conditions.

Table 6: reader results for all environmental situations

distance	RSSI Air	RSSI Asphalt	RSSI dust	RSSI water	RSSI Air	RSSI Asphalt	RSSI Asphalt	RSSI water
0.5	yes	yes	yes	yes	-50	-65	-58	-60
1	yes	yes	yes	yes	-55	-70	-55	-62
1.5	yes	yes	yes	yes	-48	-66	-65	-64
2	yes	yes	yes	yes	-60	-71	-70	-63
2.5	yes	yes	yes	yes	-54	-75	-66	-66
3	yes	no	yes	yes	-62	-73	-71	-68
3.5	yes	no	yes	yes	-65	-77	-75	-72
4	yes	no	yes	yes	-70	no	-73	-75
4.5	yes	no	yes	yes	-68	no	-77	-77
5	yes	no	yes	yes	-71	no	no	no
5.5	yes	no	yes	no	-74	no	-75	-79
6	yes	no	yes	yes	-75	no	no	no
6.5	yes	no	no	yes	-73	no	no	no
7	yes	no	yes	yes	-77	no	no	no
7.5	no	no	yes	yes	no	no	no	no
8	yes	no	no	no	no	no	no	no
8.5	yes	no	no	no	-85	no	no	no
9	yes	no	no	no	no	no	no	no
9.5	no	no	no	no	no	no	no	no
10	no	no	no	no	no	no	no	no

Table 6: RSSI results for all environmental situations

speed	RSSI Free Air	RSSI asphalt	RSSI dust
10	-40	-50	-45
15	40	-53	-48
20	-45	-55	-47
25	-43	-51	-50
30	-46	-56	-53
35	-48	-60	-60
40	-53	-53	-61
45	-50	-55	-65
50	-55	-65	-68
55	-65	-68	no detect
60	no detect	-72	-69
65	no detect	no detect	no detect
70	no detect	no detect	no detect
75	no detect	no detect	no detect

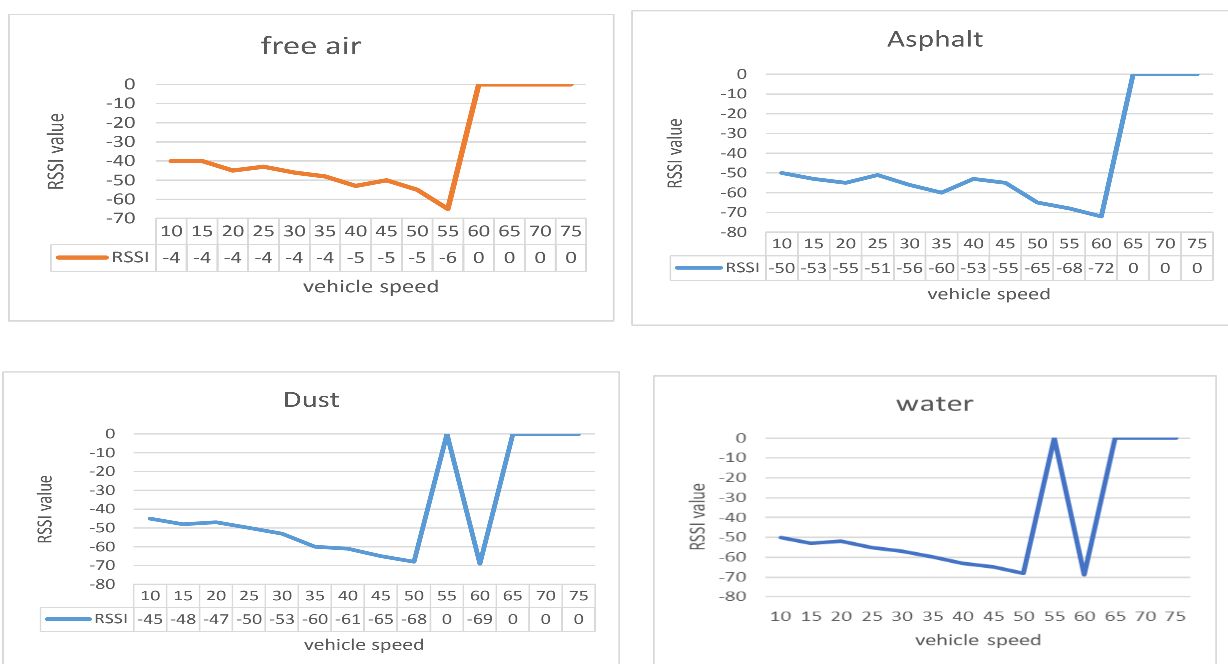

Figure 10: speed variation test for all environment

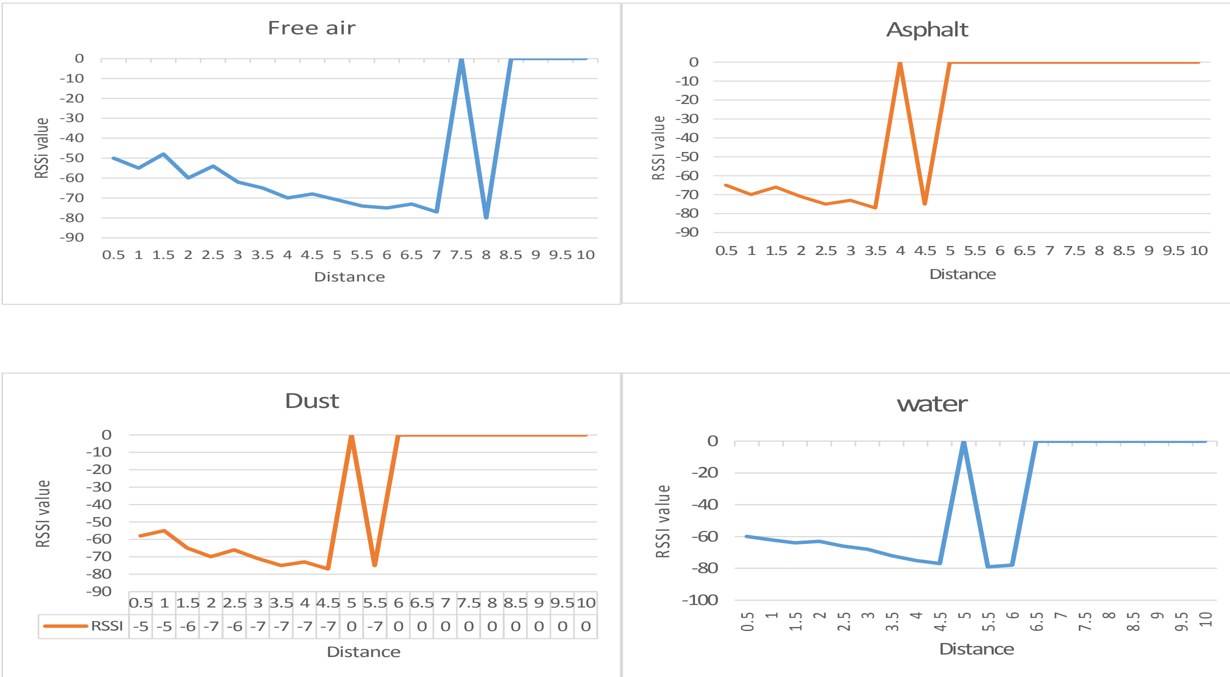

Figure 11: distance variation test for all environment

The reader used in this paper is CF-RU5106.5112 UHF RFID reader (902~928 MHz) and the power adjusted to the high level of 30 D.B. with a single antenna built in the reader. This paper uses two tag types: synthetic Polypropylene waterproof and Poly vinyl Chloride (PVC). The reader is connected to the Arduino UNO by TTL to RS485 convector because the power level of the output signal from a reader is not TTL, and we use the RS485 interface instead of RS235 because RS485 can deliver the signal perfectly to the remote distance more than 800m also we keep the RS 235 interface of the reader for computer management in the same time. According to the above results, the RSSI value decrease when the distance between the reader and the Tag increases until it reaches the maximum distance of 7m in the free air environment, and when put RFID tag inside another environment like dust, asphalt and water, the observed result indicates that the reading range decreased accordingly depending on the different environments.

VIII. Conclusion

The communication between Infrastructure and vehicles is the main challenge in the development of the transportation system because of the massive increase in the car density that leads to increased accidents and requires a fast and reliable information exchange between vehicles and Infrastructure. This paper suggests a system based on a UHF RFID reader installed on the vehicle and Tag deployed in the road because the tags can help with current intelligent transportation system (ITS) limitations like camera occlusions, GPS signals interrupting, maintenance and deployment costs. RFID readings were successfully obtained over various speeds from 10 to 90 km/h and across multiple propagation mediums such as free Air, water, dust, and underground with different distances from 0.5 to 10 M. Speeds greater than 70 kilometers per hour might be risky.

not be attempted because of road speed limits Furthermore, one research was capable of reading the Passive tags at speeds more than 220 km/h. RSSI, number of Tag Read Count, and Time Per Tag Read were discovered over a variety of speed ranges and propagation media. The road information stored in Tag, and when the vehicle passes through the tag range, the reader will extract tag information and display it on the LCD inside the car dashboard. The best result concluded from free air situation because of no communication path obstacle.

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