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Monitoring DC Motor Based on LoRa and IOT

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***Abstract*—Electrical energy efficiency is a dynamic in itself that continues to be driven by electrical energy providers. In this work, long-range (LoRa) technology is used to monitor DC motors. In the modern world, IoT is becoming increasingly prevalent. Embedded systems are now widely used in daily life. More can be done remotely in terms of control and monitoring. LoRa is a new technology discovered and developing rapidly. LoRa technology addresses the need for battery-operated embedded devices. LoRa technology is a long-range, low-power technology. In this investigation, a LoRa transmitter and a LoRa receiver were employed. This study employed a range of cases to test the LoRa device. In the first instance, there are no barriers, whereas there are in the second instance. The results of the two trials showed that the LoRa transmitter and receiver had successful communication. In this study, the room temperature is used to control DC motors. So that the DC motor's speed adjusts to fluctuations in the room's temperature. Additionally, measuring tools and the sensors utilised in this investigation were contrasted. The encoder sensor and the INA 219 sensor were the two measured sensors employed in this study. According to the findings of the experiment, the tool was functioning properly.**

Keywords*—*LoRa; Long-Range; DC Motor; IOT; INA219.

I. INTRODUCTION

Most tropical and subtropical nations, particularly those with warm climates like India, China, the US, Brazil, etc., use ceiling fans as a prominent domestic appliance. They make a considerable contribution to household electricity usage [1]-[6]. For instance, it is estimated that the electrical energy used by just one ceiling fan in India in 2000 accounted for 6% of the energy used by all household equipment. In 2020, this consumption is anticipated to increase by 9%. Singlephase induction motors are preferred over other types of motors for 95% of applications due to their straightforward design and low cost. However, the single phase induction's efficiency is only between 30 and 40%. For instance, to create an airflow, approximately 65–75 Watts of electricity are required from the source. However, the actual mechanical power need is 20 W, and single phase induction motor speed regulation is exceedingly difficult. The greatest energy-efficient machine to solve the aforementioned issue is the DC motor. DC motors are widely used in both industry and domestic settings [7]. Electronic systems are supported by DC motors. The benefits of DC motors are their high torque, lack of reactive power losses, and lack of harmonic generation in the electrical power supply from which they draw their power [8]-[14].

The development of low-power wide-area network (LPWAN) technologies has generated a great deal of interest and helped make Internet of Things (IoT)-based applications very popular [15]-[18]. Most LPWANs operate in the unlicensed industrial, scientific, and medical (ISM) bands, depending on the deployment area [19], [20]. A LoRa-based network link is a wireless communication system that transmits data over a great distance using long-range, low-power radio frequency transmissions [21]-[23]. NB-IoT, Sigfox, and LoRa are some of these LPWAN technologies. The benefits of LoRa in terms of ultralong transmission, high stability, ultralow power, and low cost have been established [24]-[28]. IoT devices are used in a variety of applications, such as smart cities, industrial automation, agricultural, and environmental monitoring [29]-[33]. LoRa-based network linkages are intended to enable dependable and affordable communication. LoRa-based network links have two main components, i.e., LoRa nodes and LoRa gateways [34]-[40]. The LoRa nodes are small, low-power devices that can be embedded in IoT sensors and devices to transmit data wirelessly [41]-[45]. The LoRa gateways act as bridges between the LoRa nodes and the Internet, receiving data from the nodes and forwarding them to a cloud-based server or an IoT platform [46]-[50]. Several researchers have implemented LoRa such as monitoring health[51]–[54], electrical [55]-[61], water quality [62]-[68] and coal mine [69]-[71].

This paper will present monitoring of DC motors using LoRa and IOT. LoRa has the ability to communicate up to a certain distance depending on the surrounding environment. In urban areas, LoRa can communicate up to a distance of 5 km, while in rural areas the distance can be up to 15 km. The contributions of this paper are:

- Application of LORA and IOT as DC motor monitoring
- Controlling DC Motor based on Temperature
- The achievement of the proposed method is tested with several variations of cases

This article has a structure, namely the second section, which discusses the ideas of LoRa, WEMOS, and DC motors. The results and discussion are in the third section. Drawing conclusions from the research is the final step.

II. METHODS

A. Long-Range (LoRa)

LoRa, which stands for "Long Range", is a long-range wireless communications system, promoted by the LoRa Alliance [72]-[74]. This system aims at being usable in long-lived battery-powered devices, where the energy consumption is of paramount importance. LoRa can commonly refer to two distinct layers: (i) a physical layer using the Chirp Spread Spectrum (CSS). radio modulation technique; and (ii) a MAC layer protocol (LoRaWAN), although the LoRa communications system also implies a specific access network architecture [75], [76]. The LoRa physical layer, developed by Semtech, allows for long-range, low-power and low-throughput communications. LoRa uses the frequencies 433 MHz, 915 MHz, and 920 MHz to transmit data. The frequency used in Indonesia and Japan is 920 MHz [77]-[79]. The payload of each transmission can range from 2–255 octets, and the data rate can reach up to 50 Kbps when channel aggregation is employed. The modulation technique is a proprietary technology from Semtech. LoRaWAN provides a medium access control mechanism, enabling many end-devices to communicate with a gateway using the LoRa modulation. While the LoRa modulation is proprietary, the LoRaWAN is an open standard being developed by the LoRa Alliance. Table I displays the features of various network technologies utilized for the Internet of Things.

Various end-device kinds are available for LoRa, depending on the communication method used [80].

- Class A: Class A devices are capable of bidirectional communication. The gadget can receive information during the two brief time slots that follow the time slot when it is sending. Devices in this category can only receive data from the server after sending data first. Class A gadgets thus guarantee the highest levels of energy efficiency. One must wait for the next planned slot uplink if they want to transfer data from the server.
- Class B: Devices in this category are capable of bidirectional communication and have an additional time period during which they can receive data. The type B device can use a series of receiving slots initiated by a Beacon-type message delivered by the Gateway, in addition to the random time slots the type A device permits for data reception.
- Class C: Devices in this category are capable of bidirectional communication and have set times during which they can continuously receive information. A class C device can only send information; it cannot receive data at any other time.

Each module must implement the class A communication method in accordance with the LoRa standard, but the particular features of the other categories are optional. The following are some benefits of LoRaWAN technology:

- Use the unlicensed ISM frequency spectrum.
- It is a versatile solution that is simple to modify.
- It can be scaled.
- It enables two-way communication.
- Due to encryption techniques, it offers a high level of security.
- Offers energy effectiveness.

A LPWAN (Low-Power Wide-Area Networks) standard known as LoRa proposes the trade-off of a slower data rate for greater communication ranges. The standard is thus appropriate for applications where little data is sent and the data gathered from the sensors does not change significantly over time. The ERP (Effective Radiated Power) of LoRa devices in the 867-869 MHz range of the European frequency band is restricted to 25 mW. The reduction in communication channel bandwidth has led to the imposition of this restriction. A data transfer rate between 300 bps and 5.5 kbps is the result of this restriction. The duty cycle, another factor, should be less than 1%. The transfer rate is further constrained by these factors. Data flow from the sensor to the Gateway module is facilitated for more effective communication. At the physical layer, the LoRa modulation is utilized with the LoRaWAN protocol. The increased sensitivity of the receiver is the key benefit of utilising this modulation.

B. WEMOS D1 R1

WeMos is a business that creates inexpensive, efficient IoT gadgets for various projects and goods. WeMos D1 R1 is designed for simultaneous electronic controlling of electronic projects, wireless connectivity, interfacing and processing of sensor data, and wireless connectivity. The following are the details of the Arduino Wemos D1 R1:

- It uses 3.3 V as the operational voltage.
- It is includes dedicated pins for i2c, one-wire, PWM, SPI, and interrupt functionalities among its 16 digital IO pins.
- It has a single analogue input or ADC pin and is micro-USB-based for programming purposes.
- 4Mbytes of flash memory.
- Timebase: 80 MHz.
- IC CH340G is used for serial communication.

TABLE I. THE TECHNOLOGIES' FREQUENCY AND TOPOLOGY FOR COMMUNICATION

Network Technologies	Coverage Range	Power Consumption	Topology	Tx- Rx Data Size	Limitations/Advantage
BLE	10-100 m	15-30 mA per packet	Ad-Hoc	1-3 Mbps	Short range
Wi-Fi	50-100 m	2 to 20 W	Star	1-9608 Mbps	Short distance, high battery power
ZigBee	10-100 m	150 mA	Mesh	20-250 kbps	Short distance, maintenance costs too much
LoRa	10-20 km	32 mA	Star/Mesh	290 bps-50 kbps	More extended range, low battery power

C. DC Motor

A DC power supply is used to generate torque on DC motors, which have the ability to transform electrical energy into mechanical energy. The two main categories of DC motors are the externally regulated type and the self-exciting kind. An electric motor classified as a DC motor must run on direct current. After that, the generated direct current is transformed into mechanical energy, such as rotation or motion. DC motors are made up of the rotor and stator, among other parts[81], [82].

III. Proposed Methods

This study uses Wemos D1 R1, Arduino UNO, ESP32 and LoRa. Besides that, the use of several software, such as Arduino IDE and IOT OnOff. The control system design developed is shown in Fig. 1. In this design, 2 LoRa modules are used, the first as a LoRa Transmitter and the second as a LoRa Receiver. Before that, it is necessary to know the components contained in the transmitter including Ardunio UNO R3, ESP32, Lora Sx1278 module, L298n driver, DHT11 sensor, INA219 sensor, Encoder sensor and DC motor. Meanwhile, the receiver includes Wemos D1 R1, Buzzer, and Oled. The Detail of hardware LoRa can be seen in Fig. 2.

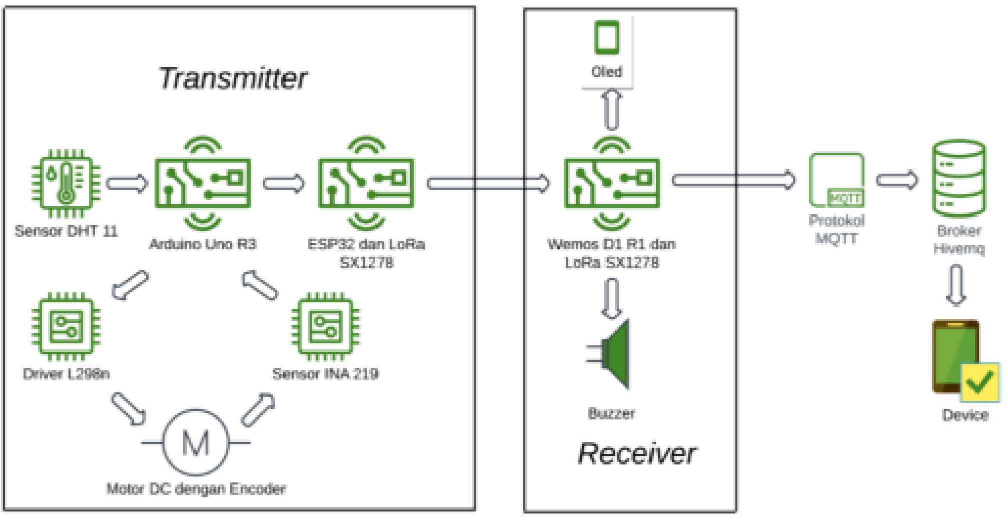
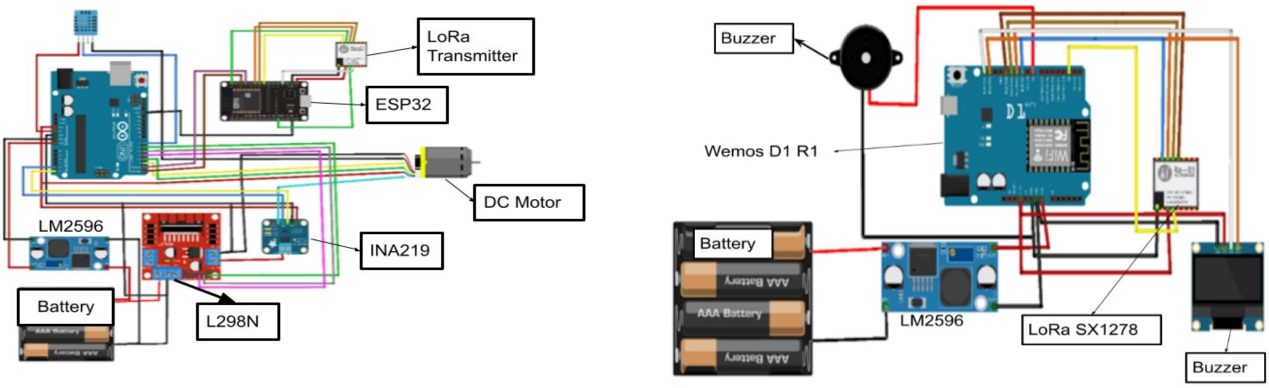


Fig. 1. Lora Transmitter and Lora receiver communication scheme



(a) (b)

Fig. 2. The Hardware scheme of (a) LoRa Transmitter (b) LoRa Receiver

IV. Results and Discussion

In Fig. 3 it can be seen that the DC motor control in this study is based on room temperature. Arduino UNO has digital pins that can be applied to the PWM method. In setting the PWM there is a range from 0 to 255 to control the speed of the DC motor based on temperature by determining the duty cycle When the room temperature is below 20 ˚C, the duty cycle value is 0%. Because the Duty Cycle value is 0%, the DC motor speed does not rotate. If the room temperature is between 20 ˚C to 25˚C then the duty cycle value is 25%. If the temperature is between 25 ˚C to 30˚C then the duty cycle value is 50%. If the temperature is between 30 ˚C to 40˚C then the duty cycle value is 75%. If the temperature is above 40˚C then the duty cycle value is 100%. the DC motor runs to its maximum and triggers an alarm.

In addition, the application used will provide a notification. Details regarding the speed of the DC motor can be seen in Table II and the chart of output can be seen in Fig. 4. The display of application can be seen in Fig. 5. When the temperature changes, the data is read by the Dht11 sensor, this causes the voltage, current and speed of the DC motor to change. Changes in temperature will result in changes in voltage, current and speed as shown in Fig. 4. When the temperature exceeds the upper limit, namely 40 ˚C, the application will display a notification as shown in Fig. 5 (b).

To ensure accurate data, each sensor used in this study is compared to a measuring instrument. In this study there were 2 sensors to be measured, namely the encoder sensor and the INA 219 sensor. The output of the encoder sensor readings was compared to the tachometer. while the INA 219 sensor is compared to a multimeter.

TABLE II. DC MOTOR TEST DATA

Temperature	Speed	Voltage(V)	Current	Alarm
<20 °C	0	0	1.6	Off
20 °C - 25 °C	551	4.75	107.8	Off
25 °C- 30 °C	596	6.02	148.2	Off
30 °C - 40 °C	830	10.32	150.1	Off
> 40 °C	959	11.24	186	On

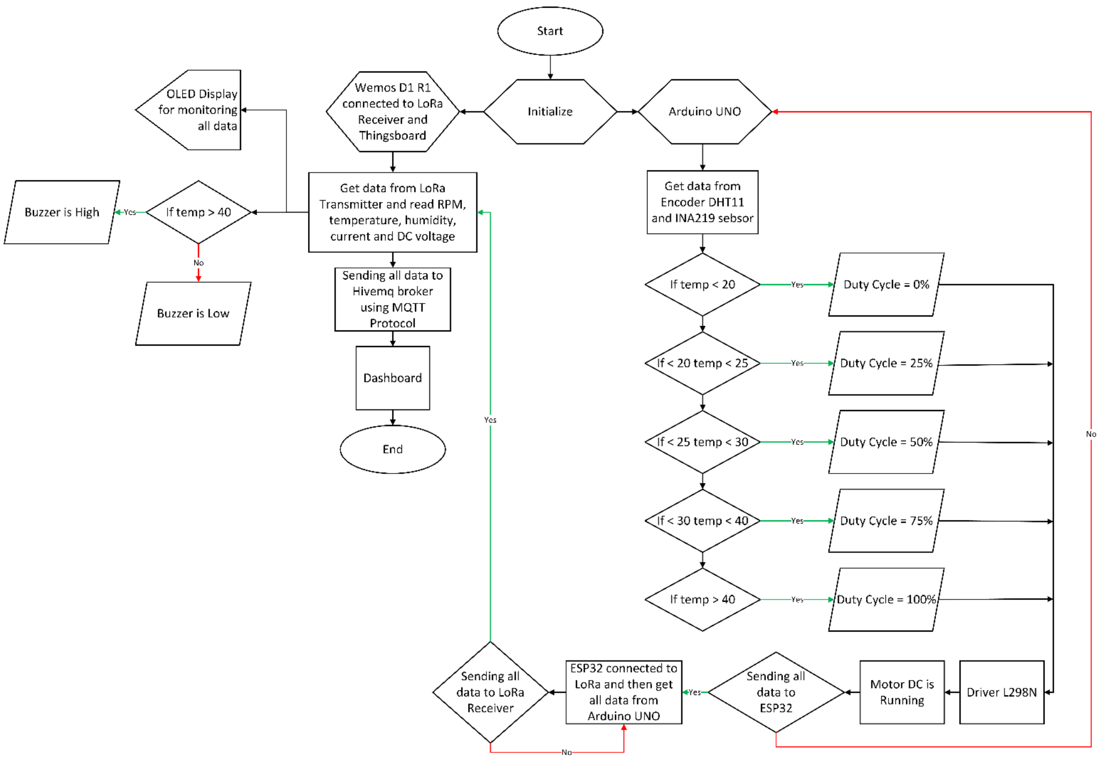


Fig. 3. Flowchart Of The system

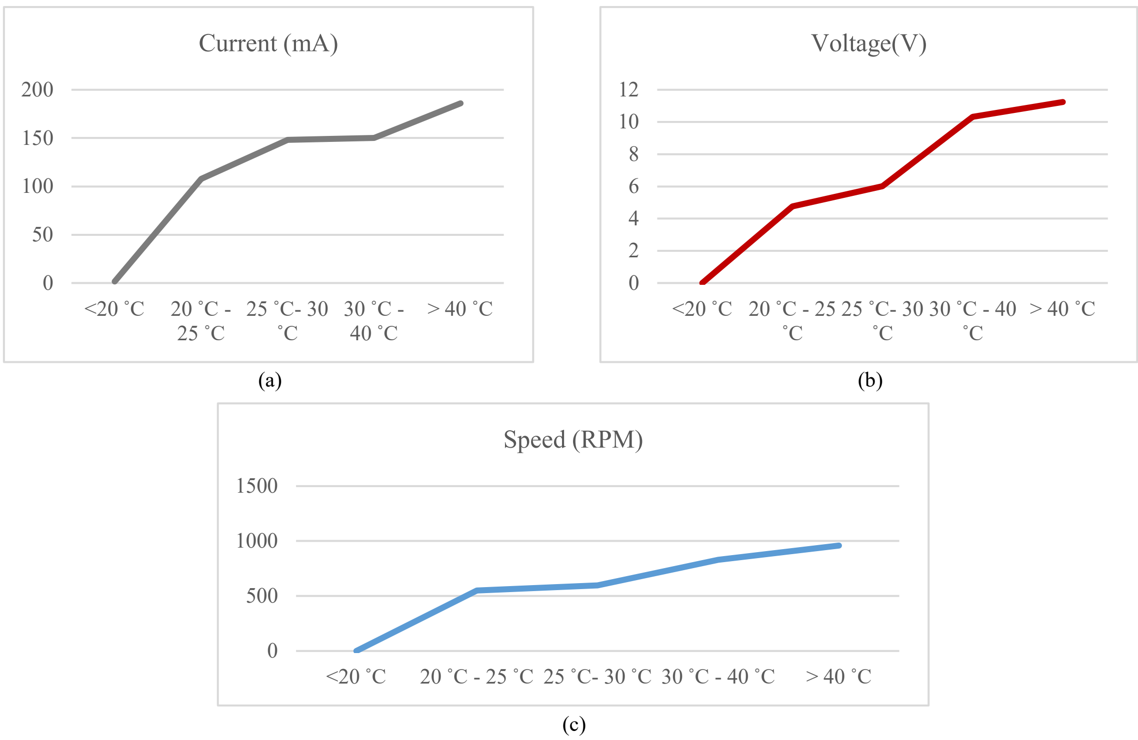
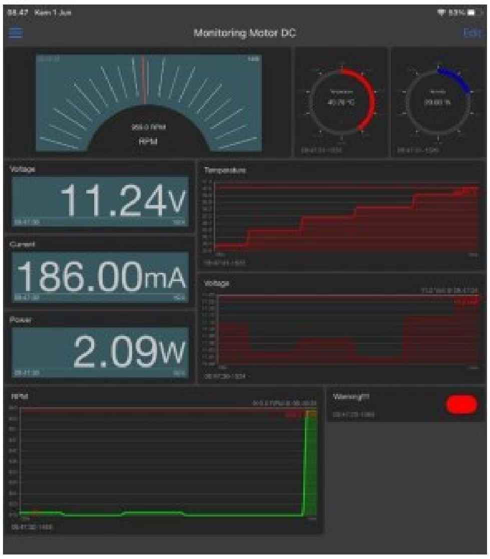


Fig. 4. Graph of (a) Current, (b)Voltage and (c) Speed

(a)



(b)

Fig. 5. Monitoring DC Motor by IOT (a) room temperature < 40 ˚C (b) room temperature > 40 ˚C

From Table III it can be seen that the largest error value is 0.023%. while the smallest error value is equal to 0.002%. while the average value of the encoder sensor test for a temperature of 20˚C < t < 25˚C is 0.0114. Testing of the encoder sensor for a temperature of 25˚C < t < 30˚C can be seen in Table IV. The average error value in Table III is 0.0338%. Table V is a detail of the encoder sensor test at a temperature of 30˚C < t < 40˚C with an average error value of 0.07%. The final encoder sensor test is for temperatures >40˚C. Table VI is a detail of the test for temperatures > 40˚C with an average error value of 0.0418.

TABLE III. ENCODER SENSOR TEST RESULTS WITH TEMPERATURE 20˚C < T < 25˚C

Encoder (RPM)	Tachometer (%)	Error (%)
562	561	0.002
556	565	0.016
564	567	0.005
564	570	0.011
577	564	0.023
Average		0.0114

TABLE IV. ENCODER SENSOR TEST RESULTS WITH TEMPERATURE 25˚C < T < 30˚C

Encoder (RPM)	Tachometer (%)	Error (%)
601	623	0.035
647	697	0.072
638	675	0.055
721	724	0.004
646	648	0.003
Average		0.0338

TABLE V. ENCODER SENSOR TEST RESULTS WITH TEMPERATURE 30˚C < T < 40˚C

Encoder (RPM)	Tachometer (%)	Error (%)
879	800	0.098
927	885	0.047
925	874	0.058
925	881	0.049
881	802	0.098
Average		0.07

TABLE VI. ENCODER SENSOR TEST RESULTS WITH TEMPERATURE > 40˚C

Encoder (RPM)	Tachometer (%)	Error (%)
901	898	0.003
923	902	0.023
954	902	0.059
959	904	0.061
963	906	0.063
Average		0.0418

From Table VII, the average error percentage of the INA219 sensor voltage obtained at a temperature of 20˚C < t < 25˚C is 0.0994%. Testing at a temperature of 25˚C < t < 30˚C can be seen in Table VIII with an average error percentage of 0.0724%. Table IX is a detail of testing the INA219 sensor voltage with a temperature of 30˚C < t < 40˚C with an average error percentage of 0.0154%. Testing the voltage on the INA219 sensor for temperatures > 40˚C can be seen in Table X.

TABLE VII. VOLTAGE TEST RESULTS ON THE INA219 SENSOR WITH A TEMPERATURE OF 20˚C < T < 25˚C

INA219(V)	Multimeter(V)	Error (%)
4.68	4.55	0.029
4.62	4.2	0.1
4.94	4.74	0.042
5.55	4.69	0.0183
5.44	4.76	0.143
Average		0.0994

TABLE VIII. VOLTAGE TEST RESULTS ON THE INA219 SENSOR WITH A TEMPERATURE OF 25˚C < T < 30˚C

INA219(V)	Multimeter(V)	Error (%)
9.47	9.58	0.011
10.26	9.87	0.039
10.92	9.45	0.155
9.62	9.53	0.009
10.88	9.48	0.148
Average		0.0724

TABLE IX. VOLTAGE TEST RESULTS ON THE INA219 SENSOR WITH A TEMPERATURE OF 30˚C < T < 40˚C

INA219(V)	Multimeter(V)	Error (%)
10.84	11.15	0.028
10.92	11.15	0.021
11.01	11.15	0.013
11.11	11.15	0.003
11.02	11.16	0.012
Average		0.0154

TABLE X. VOLTAGE TEST RESULTS ON THE INA219 SENSOR WITH A TEMPERATURE OF > 40˚C

INA219(V)	Multimeter(V)	Error (%)
10.99	11.21	0.019
11.09	11.25	0.014
11.22	11.15	0.006
11.22	11.19	0.002
11.22	11.18	0.003
Average		0.0088

The research also conducted an experiment on the distance between the receiver and transmitter using the line-of-sight (LOS) model. Line-of-sight is presented as a testing ground for qualitative reasoning techniques developed in the temporal and spatial domains and also have potential applications in the field of computer vision. The experimental scheme uses 2 variations, namely without obstacles and with obstacles. Without obstacles, namely the condition of the transmitter and receiver are not obstructed by walls or roofs. on the other hand, with obstacles, namely the presence of obstacles, namely walls and roofs.LOS scheme horizontally can be seen in Fig. 6. Based on Table XI with the same distance every 1 meter with obstacles or no obstacles. LoRa Transmitter and LoRa Receiver can connect and communicate properly.

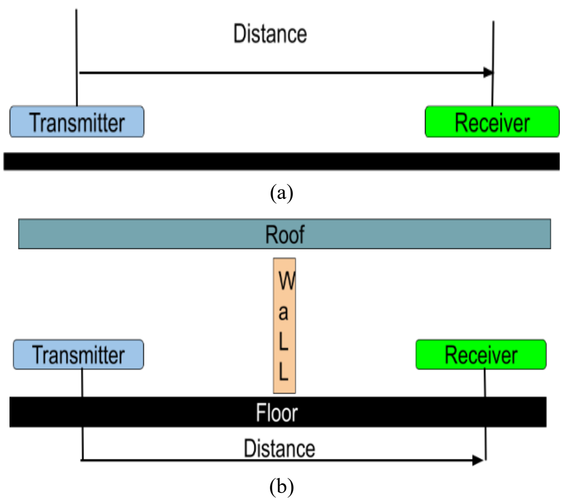


Fig. 6. System testing scheme with horizontal LOS case studies (a) Without Obstacle (b)With Obstacle

TABLE XI. HORIZONTAL LOS (LINE OF SIGHT) TESTING

No	Distance (M)	Response	
		Without Obstacle	Without Obstacle
1	1	Connected	Connected
2	2	Connected	Connected
3	3	Connected	Connected
4	4	Connected	Connected
5	5	Connected	Connected

V. CONCLUSION

This research presents DC motor monitoring using Long Range (LoRa) technology. The LoRa used in this research consists of a LoRa Transmitter and a LoRa receiver. In this research, LoRa device testing uses various problems. The first problem is the unobstructed condition. while the second condition is with obstacles. From these two experiments it is known that communication between the LoRa Transmitter and LoRa receiver runs well. Apart from that, the sensors used in this research were also compared with measuring instruments. This research used two sensors to be measured, namely the encoder and the INA 219 sensor. From experiments on the encoder sensor, an error was obtained with an average error of 0.03925%. Meanwhile, in the INA 219 sensor experiment, by comparing the voltage, the average error was 0.049%. From the experimental results it is known that the tool works well. Research using LORA needs to sharpen the complexity of the problem, such as distances that approach the LORA distance limit. In addition, it is necessary to study disturbances that have a major contribution. Application in rural or urban areas needs to be deepened.

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