LoRa Implementation on One Gateway Cluster Home Security System

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***Abstract*—Cluster housing is a type of housing in one environment with similar house designs that are usually located in urban areas or special settlements. The security system in this housing often relies on a one-gate system. Theft incidents in several cluster housing estates show that this system is not completely safe even though it is equipped with a smart home and a 24-hour security system. This study aims to improve the security of cluster housing by implementing LoRa technology to detect theft. The system developed uses magnetic switches and RCWL sensors installed in the house to detect door openings and movement. Information from these sensors is sent to the device at the guard post via LoRa communication. The test results show that the designed device successfully detects an open door when the magnet moves more than 2 cm from the reed. The RCWL sensor can detect movement within 0 to 4 meters from all directions. LoRa communication successfully sends data even in NLoS (No Line of Sight) conditions up to 90 meters although with some reduction in signal quality. The implementation of LoRa in this security system is expected to improve the security of cluster housing by providing a quick response to indications of theft.**

Keywords*— *Housing Cluster, LoRa, Magnetic Switch, RCWL, Security System.

I. INTRODUCTION

A cluster housing development is a residential area built within a single environment, with homes designed similarly. Cluster housing is not enclosed by fences but is only bordered by short concrete walls. Cluster housing is generally located in bustling urban areas or in designated residential zones [1], [2]. Typically, cluster housing is equipped with various shared amenities such as playgrounds, swimming pools, fitness centers, and green spaces that can be enjoyed by all residents. The layout and infrastructure of cluster housing are designed to create a comfortable and well-organized environment, including wide roads, a good drainage system, and optimal green space planning. A distinctive feature of this type of housing is that the entire area is surrounded by walls and has only one gate with security personnel on duty [3]-[5].

Crime can happen to anyone, anytime, and anywhere. One such place is in cluster housing environments. According to data from the Central Statistics Agency (BPS) of Malang City, the crime rate for theft in Malang City in 2023 recorded 1,334 criminal cases. Of that number, theft stands out as one of the most prominent types of crime. Most of these cases have been resolved, with a case resolution rate of 81.4%, or approximately 1,086 cases successfully handled by the authorities [6], [7]. The report indicates that residential environments do not always provide a sense of safety for their residents. An unsafe environment can affect the sense of discomfort among residents [8].

The increasing frequency of people leaving their homes has driven the need for more advanced and responsive residential security systems. Routine patrol systems that are still widely used today have proven to be less effective in preventing theft. Routine patrol systems that are still commonly used today have proven to be ineffective in preventing theft [9], [10]. According to detikjatim.com, one incident of theft occurred at three houses in the Puri Galaxy Cluster Jasmine housing complex in Surabaya City. Wartakota.com also reported a theft incident in a cluster housing development on Kusuma Utara X Street, Block WBK No. 7, Duren Jaya, Bekasi City, which indicates that the one-gate system does not guarantee security, even though it is equipped with smart home technology and a 24-hour security system [11], [12]. To address this issue, the implementation of modern security technologies such as door security devices, motion sensors, and integrated alarm systems should be considered [13]-[15]. In addition, close collaboration between homeowners and security personnel is also essential to create a safe and comfortable residential environment.

II. METHOD

A. System Block Diagram

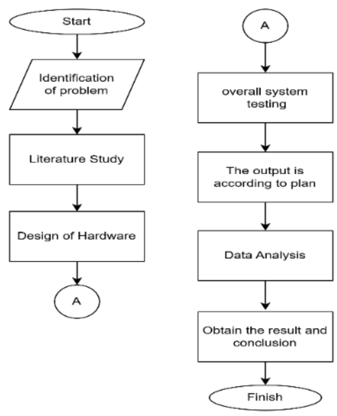

Figure 1. Flowchart of device development.

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The research stages for the development of this device consist of several steps, as shown in the flowchart in Fig. 1.

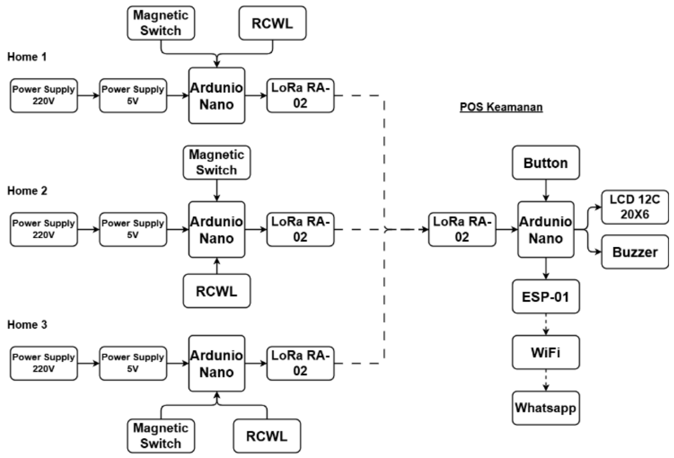

Figure 2. System Block Diagram

In the data collection phase, a magnetic switch sensor and RCWL sensor are used to test their responsiveness in detecting open doors and movement. The detected data is then processed by the Arduino Nano and transmitted to the device at the guard post via LoRa communication. The method chosen for the development of this device is the design method. Testing is conducted to determine the duration of data transmission to the guard post device, aiming to achieve a short response time.

Fig. 2. is a block diagram of the entire system. The Magnetic Switch and RCWL sensors in the house detect changes and send signals to the Arduino Nano. The Arduino Nano in the house processes the signals and sends the data via the LoRa module to the security post. At the security post, the LoRa receives the data and transmits it to Arduino Nano for processing. Based on the data received, the Arduino Nano at the security post can activate the buzzer, display information on the LCD, or send notifications via WhatsApp. The operator at the security post can also use a button to input commands for specific actions.

B. Flowchart of Devices in the House

The system reads the protection mode status from the LoRa device. The system then checks if the protection mode is activated. The system checks if the magnetic switch on the door is open. The system checks if the RCWL sensor detects any motion. If either of the above conditions is met, whether the magnetic switch is open or the motion sensor detects movement, the system will send alert data via the lora network The workflow ends after the alert data is sent. Below is the flowchart display at home, as shown in Fig. 3.

C. Flowchart of the Device at the Security Post.

If the user presses the OK button for 3 seconds, proceed to the next step. If not, continue to the subsequent step. The user is prompted to enter the house number. The user inputs the protection status of the house, where 1 means protection is active (ON) and 0 means protection is inactive (OFF). The protection status data has been updated. The system reads the protection mode from the LoRa at the security post. If yes, the system receives alert data via LoRa and proceeds to the next step. If not, the process is complete. The system displays the location of the house that received the alert. Notification sent via WhatsApp. Did you press the OK button for 3 seconds? If yes, and the user pressed the OK button for 3 seconds, proceed to the next step. If not, the system activates the buzzer. The buzzer is activated. The buzzer is turned off if the user presses the OK button for 3 seconds. The process is complete. Below is the flowchart display at the security post, as shown in Fig. 4.

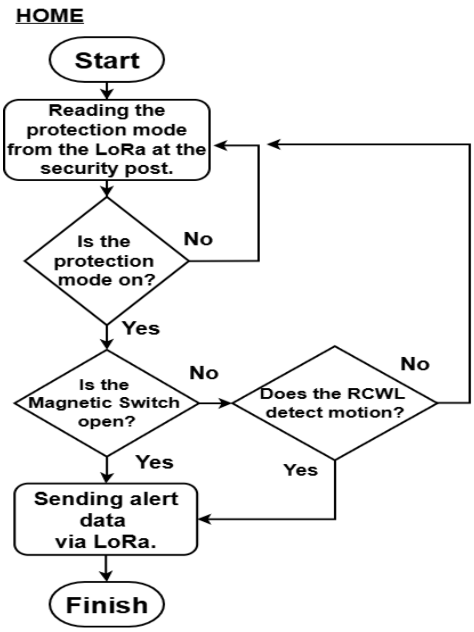

Figure 3. Flowchart of Devices in the House

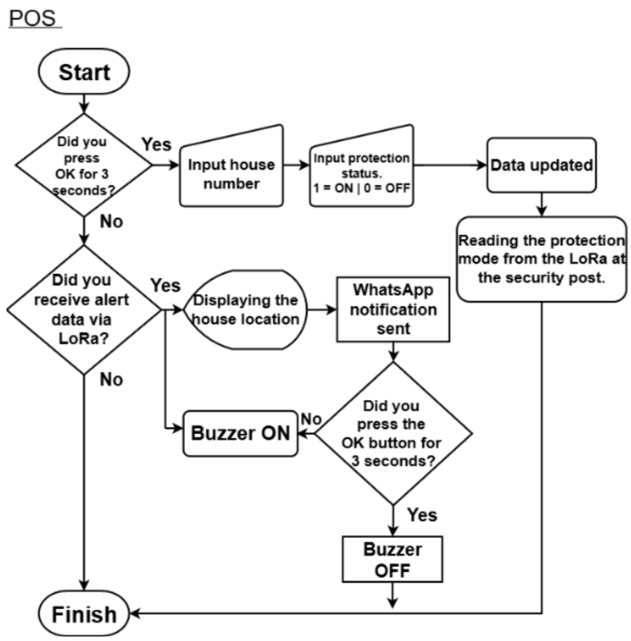

Figure 4. Flowchart of the Device at the Security Post.

III. RESULTS AND DISCUSSION

A. Results of the Receiver Device Implementation

In this system, there is a box measuring 10x5 cm used as the receiving device at the security post. On the outside of the box, there is an I2C LCD that serves as an interface to display the house code indicating a theft. Below the LCD, there are three buttons used to control the activation and deactivation of the security system. Inside the box, there is an Arduino Nano microcontroller that controls the entire system, a LoRa RA-02 for communication between the security post device and the house, a buzzer used for notifications in case of a detected theft, an ESP-01 for sending WhatsApp notifications via Wi-Fi connection, and a power supply used to step down the voltage from 220V to 5V for the device. The overall appearance of the Receiver Device at the Guard Post can be seen in Fig. 5 and Fig. 6.

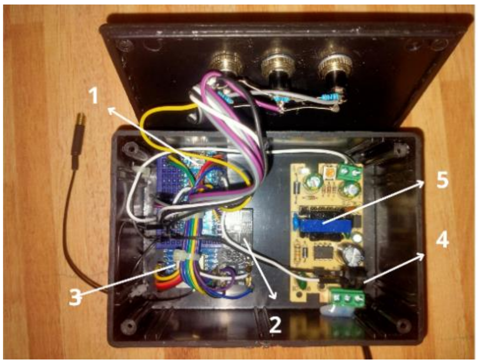

Figure 5. View of the inside of the receiver box.

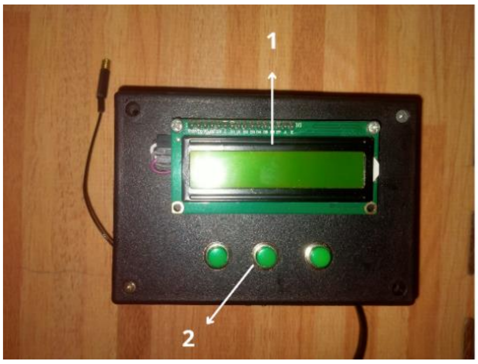

Figure 6. Front View of the Receiver Box.

B. Results of the Sender Device Implementation.

This system uses a box of size that functions as the sender device at the house. Inside the box, there is an Arduino Nano microcontroller that manages the entire device. In addition, there is a LoRa RA-02 module for communication with the receiver at the security post, as well as a power supply serving as the power source for the device. On the outside of the box, there is a magnetic switch sensor that detects when the door is opened, and an RCWL sensor that detects movement if someone enters the house without going through the door. The overall appearance of the Transmitter Device at the House can be seen in Fig. 7 and Fig. 8.

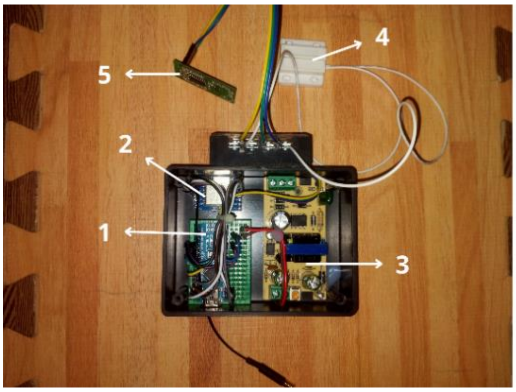

Figure 7. Front View of the Sender Box.

Figure 8. Side View of the Sender Box.

C. Testing the Magnetic Switch Sensor.

This test is conducted by installing the magnetic switch on the door of the house and measuring the distance between the magnet and the reed using a ruler. Data collection is performed over 5 trials with a distance range of 5mm to 20mm. The data collection from the magnetic switch sensor can be seen in Fig. 9.

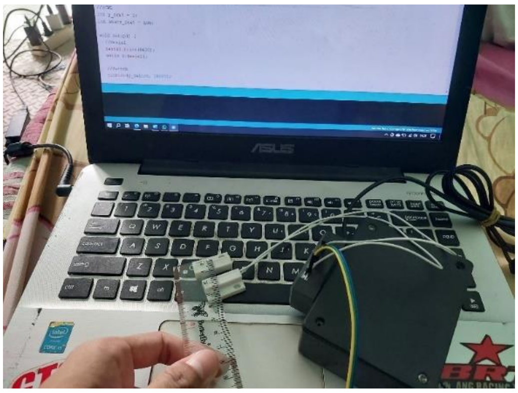

Figure 9. Testing of the magnetic switch sensor.

The testing of the magnetic switch sensor aims to determine the effective distance between the switch/reed that has wires and the magnet. In normal conditions, the circuit will be closed (normally closed). However, when the magnet moves away, the circuit will open (normally open). The results of the testing are shown in Table I.

TABLE I
RESULT OF THE MAGNETIC SWITCH SENSOR

Trial	Distance (mm)	Sensor Value	Result
1	5	0	Not Detected
2	10	0	Not Detected
3	15	0	Not Detected
4	20	1	Detected
5	>20	1	Detected

Based on the test results shown in Table I, data was obtained indicating that at distances of 5mm, 10mm, and 15mm, the sensor values showed '0', which means the magnet was not detected. This indicates that at these distances, the magnet is still close enough to the reed switch, keeping the circuit closed. At 20mm, the sensor value changed to '1', indicating that the magnet was detected. This means that at this distance, the magnet is far enough away for the circuit to be open. At distances greater than 20mm, the sensor value remains '1', indicating that the magnet is still detected. This confirms that the effective detection range of the magnet by the sensor is at or greater than 20mm.

D. Testing the RCWL Sensor.

The testing of the RCWL sensor is conducted by introducing movement within the sensor's range, with the object being human movement. Movement is performed at various distances and angles, and the sensor's ability to detect motion is checked by displaying the results on the serial print of the Arduino IDE. The range of distances tested is between 0 to 6 meters from the sensor, with movement at angles of 0°, 45°, and 315°.

Figure 10. Testing of the RCWL sensor.

One of the tests in Fig. 10 was conducted by waving a hand in front of the sensor at 5 meters, marked by a yellow measuring tape. Overall results obtained from testing the RCWL sensor are shown in Table II.

TABLE II
RESULT OF THE RCWL SENSOR

Distance (m)	Angle of Reading (°)		
	315°	0°	45°
0,5	✓	✓	✓
1	✓	✓	✓
1,5	✓	✓	✓
2	✓	✓	✓
2,5	✓	✓	✓
3	✓	✓	✓
3,5	✓	✓	✓
4	✓	✓	✓
4,5	×	✓	×
5	×	✓	×
5,5	×	×	×
>6	×	×	×

Description of table II:
✓ = Successfully detected motion.
× = Failed to detect motion.

Based on the results from the RCWL sensor testing on table II, as shown in Table II, the RCWL sensor testing is conducted to evaluate the sensor's ability to detect human movement at various distances and angles. Based on the test results shown in Table 4, the sensor successfully detected movement at all angles (0°, 45°, and 315°) from distances between 0.5 and 4 meters. At 4.5 meters, the sensor began to lose its ability to detect movement at the 45° angle. At 5 meters, the sensor was no longer able to detect movement at the 45° and 315° angles, while movement at the 0° angle was still detected. At 5.5 meters, the sensor could no longer detect movement at any angle. Detection at the 0° angle remained consistent up to 5 meters. The 45° and 315° angles began to show detection failure at 4.5 meters and failed completely at 5 meters. Up to 4 meters, the sensor was highly effective at detecting movement across all angles. Starting from 4.5 meters, the sensor's effectiveness decreased, particularly at the 45° and 315° angles. Beyond 4.5 meters, only the 0° angle could still detect up to 5 meters, while the other angles failed to detect movement.

E. Testing the Push Button.

The push button test aims to determine the functions of the OK, Up, and Down buttons on the receiver device. The characteristic of this normally open (NO) push button is that when it is not pressed, it will have a value of 0, and conversely, when pressed, it will have a value of 1. The test results can be seen in Table III.

Based on the results from the push button testing, as shown in Table III, the push button testing shows that all buttons (OK, Up, and Down) function properly according to their respective purposes, which are to change the display, increase, and decrease the protection conditions in the system. No issues were found during this testing.

TABLE III
RESULT OF THE PUSH BUTTON TEST

Test	Button	LCD Response	Description
PB Ok	Pressed	Display Changed	Correct
PB Up	Pressed	Adding Condition	Correct
PB Down	Pressed	Reducing Condition	Correct

F. Testing Data Transmission between the Sender and Receiver LoRa.

In this test, data is collected from the sender LoRa, triggered by the RCWL sensor and the magnetic switch present in each house. The data is then received by the receiver LoRa installed on the device used by the security personnel at the post, which will activate the buzzer. The data transmission success rate is shown in Table IV.

TABLE IV
RESULTS OF DATA TRANSMISSION TESTING.

Node	Test Scenario		Result	Buzzer Condition
	Magnetic Switch	RCWL		
Unit 1	1	0	Sent	Active
	0	1	Sent	Active
	1	1	Sent	Active
	0	0	Sent	Not Active
Unit 2	1	0	Sent	Active
	0	1	Sent	Active
	1	1	Sent	Active
	0	0	Sent	Not Active
Unit 3	1	0	Sent	Active
	0	1	Sent	Active
	1	1	Sent	Active
	0	0	Sent	Not Active

Based on the test results in Table IV, all data from the transmitting LoRa was successfully received by the receiving LoRa in every test scenario for all three units. This indicates that the LoRa system has a high data transmission success rate. The buzzer is activated in all scenarios where at least one of the two sensors, either the magnetic switch or the RCWL, triggers a value of 1 on either or both. The buzzer is inactive only when both sensors do not trigger, resulting in a value of 0 on both sensors. The test results show consistency across all tested units. Each unit displayed the same pattern regarding the buzzer's condition based on the applied test scenarios. Overall, these tests indicate that the data transmission system using LoRa functions well and aligns with the expected design. The system successfully transmitted data from the transmitter to the receiver and activated the buzzer according to the established sensor conditions.

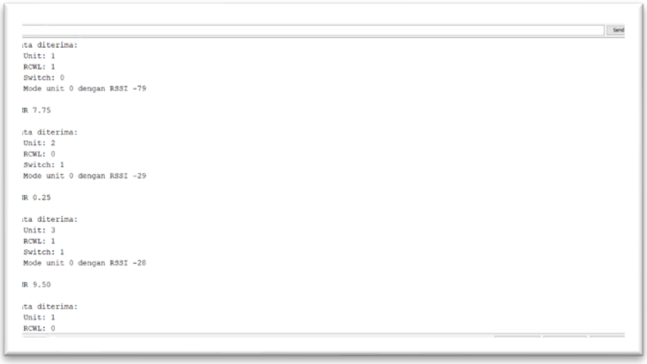

Figure 11. The serial monitor display on the LoRa TX.

Fig. 11 shows the serial monitor on the receiving device displaying data from each transmitting device, such as the conditions of the RCWL sensor and the magnetic switch sensor.

G. Testing WhatsApp Notifications.

This test is conducted to determine the success and functionality of the security device in sending warning notifications when the house is in danger. WhatsApp notifications are sent to the homeowners detected in the event of a burglary. The testing procedure involves triggering the sensor on the sender's side.

Figure 12. Testing WhatsApp notifications.

Fig. 12 shows the test results displayed in the WhatsApp application, indicating that notifications can be sent according to the triggers from the sensors on the device at home.

TABLE V
RESULTS OF WHATSAPP NOTIFICATION TESTING

Node	Test Scenario		Delay (ms)	Whatsapp Notification
	Magnetic Switch	RCWL		
Unit 1	1	0	3 - 5	EMERGENCY UNIT 1
	0	1	3 - 5	EMERGENCY UNIT 1
	1	1	3 - 5	EMERGENCY UNIT 1
	0	0	3 - 5	No notification
Unit 2	1	0	3 - 5	EMERGENCY UNIT 2

Node	Test Scenario		Delay (ms)	Whatsapp Notification
	Magnetic Switch	RCWL		
	0	1	3 - 5	EMERGENCY UNIT 2
	1	1	3 - 5	EMERGENCY UNIT 2
	0	0	3 - 5	No notification
Unit 3	1	0	3 - 5	EMERGENCY UNIT 3
	0	1	3 - 5	EMERGENCY UNIT 3
	1	1	3 - 5	EMERGENCY UNIT 3
	0	0	3 - 5	No notification

Based on the notification testing with the WhatsApp application in table V, it can be concluded that notifications on the WhatsApp application work smoothly, with some delay in sending and receiving messages depending on the internet speed connected to the device.

H. Results of the RA-02 LoRa Testing in Non-Line of Sight (NLoS) Conditions

The LoRa transmission testing under NLOS (Non-Line of Sight) conditions is conducted to determine the maximum distance for successful data transmission using the LoRa RA-02 at a frequency of 443 MHz and a 3 dBi antenna, with a spread factor setting of 7. LoRa 433 MHz was chosen because it has a long range, is more resistant to obstacles, is energy efficient, has minimal interference, and is legal, making it very suitable for remote monitoring and security systems. The 3 dBi antenna was chosen because it provides the best balance between range, signal stability, ease of use, and accuracy of LoRa RA-02 test results at 433 MHz. The testing under NLOS conditions is conducted by transmitting signals along a path that is partially obstructed, typically by physical objects such as trees and buildings. The testing is performed with five trials at distances of 30, 60, and 90 meters from the receiver.

Based on the test results shown in Table VI, VII, and VIII, there is a decline in the signal quality of RSSI and the signal-to-noise ratio (SNR) as distance increases. At 90 meters, the RSSI and SNR values show significant degradation, indicating that the signal reception capability decreases at longer distances. There is a significant variability between the different testing units. For example, unit 1 has a lower SNR value at 90m compared to unit 2 and unit 3. This difference could be attributed to environmental variations, different NLoS conditions, or hardware variations. The testing was conducted under NLoS conditions that could be affected by physical objects such as trees and buildings obstructing the signal transmission path. The test results indicate that under NLoS conditions, the signal can still be received up to 90 meters, albeit with reduced quality. Negative SNR in some measurements indicates that noise is more dominant than the received signal, which may suggest poor reception quality or environmental conditions with numerous obstacles affecting the LoRa signal transmission.

TABLE VI
LORA RA-02 TESTING UNDER NLOS CONDITIONS FOR UNIT 1

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-87	-2.25	-85	-5.50	-87	-5.00
2.			-86	-6.00	-90	-2.50	-89	-9.25
3.			-87	3.00	-90	-4.00	-90	-15.00
4.			-85	3.00	-85	-2.00	-88	-18.25
5.			-83	5.00	-90	-6.00	-90	-19.25

TABLE VII
LORA RA-02 TESTING UNDER NLOS CONDITIONS FOR UNIT 2

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-88	1.25	-89	-3.00	-88	-12.50
2.			-85	1.75	-89	-2.75	-91	-5.25
3.			-83	3.50	-89	-2.00	-88	-6.50
4.			-80	4.50	-90	-4.50	-85	-1.50
5.			-81	4.25	-89	-3.00	-87	-0.75

TABLE VIII
LORA RA-02 TESTING UNDER NLOS CONDITIONS FOR UNIT 3

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-82	6.00	-90	-3.37	-85	-4.00
2.			-83	3.25	-90	-1.50	-86	-8.25
3.			-85	2.50	-84	1.75	-86	-4.25
4.			-85	2.25	-84	0.25	-86	-10.50
5.			-89	1.50	-87	-5.75	-86	-6.00

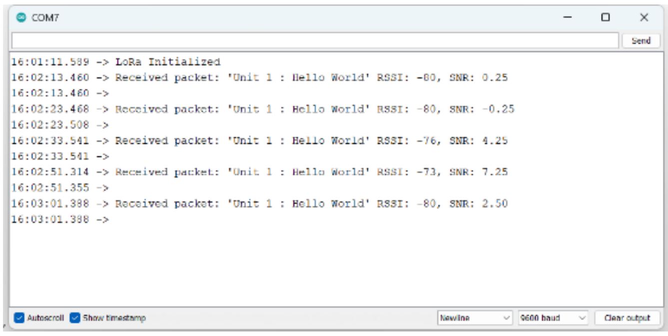

Figure 13. Test results of the LoRa RA-02 in NLoS conditions.

Fig. 13 shows the results of one of the tests displaying the RSSI and SNR values on the transmitting device, as shown on the serial monitor of the receiving device.

I. Results of the RA-02 LoRa Testing in Line of Sight (LoS) Conditions.

The LoRa transmission testing under LoS (Line of Sight) conditions aims to determine the maximum distance for successful data transmission using the LoRa RA-02 at a frequency of 443 MHz and a 3 dBi antenna, with a spread factor setting of 7. LoRa 433 MHz was chosen because it has a long range, is more resistant to obstacles, is energy efficient, has minimal interference, and is legal, making it very suitable for remote monitoring and security systems. The 3 dBi antenna was chosen because it provides the best balance between range, signal stability, ease of use, and accuracy of LoRa RA-02 test results at 433 MHz. The testing under LoS (Line of Sight) conditions is conducted by transmitting data between two nodes in an area with no obstructions or clear visibility. The testing is performed five times at distances of 30, 60, and 90 meters.

TABLE IX
LORA RA-02 TESTING UNDER LOS (LINE OF SIGHT) CONDITIONS FOR UNIT 1

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-70	9.00	-80	0.25	-77	5.25
2.			-70	9.00	-80	-0.25	-89	-4.50
3.			-69	8.25	-76	4.25	-85	-1.75
4.			-66	9.25	-73	7.25	-89	-5.50
5.			-66	9.25	-80	2.50	-80	2.50

TABLE X
LORA RA-02 TESTING UNDER LOS (LINE OF SIGHT) CONDITIONS FOR UNIT 2

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-78	4.00	-82	0.00	-81	2.00
2.			-77	4.50	-77	5.50	-80	2.50
3.			-70	8.25	-74	7.75	-77	6.25
4.			-69	8.25	-79	2.75	-80	3.75
5.			-78	3.75	-75	6.25	-84	-4.75

TABLE XI
LORA RA-02 TESTING UNDER LOS (LINE OF SIGHT) CONDITIONS FOR UNIT 3

NO	Spread Factor	Bandwidth	Distance (30m)		Distance (60m)		Distance (90m)	
			RSSI	SNR	RSSI	SNR	RSSI	SNR
1.	7	125KHz	-82	0.50	-78	2.75	-85	-6.50
2.			-75	6.00	-83	-0.75	-80	1.50
3.			-78	3.25	-84	-2.00	-83	-1.5
4.			-76	5.00	-75	5.75	-83	-1.75
5.			-76	5.50	-84	-3.75	-80	1.25

Based on the test results shown in Table IX, X, and XI, the RSSI values tend to decrease as the distance between the transmitter and receiver increases. At 30 meters, the RSSI values vary from -66 to -82 dBm. At 60 meters, the RSSI values vary from -73 to -84 dBm. At 90 meters, the RSSI values vary from -77 to -89 dBm. The SNR also decreases as the distance increases. At 30 meters, the SNR values vary from 0.50 to 9.25 dB. At 60 meters, the SNR values range from -0.25 to 7.75 dB. At 90 meters, the SNR values vary from -6.50 to 6.25 dB. In NLoS conditions, the test results show that transmission can still be performed despite a decline in signal quality and signal-to-noise ratio. From the data obtained, it can be concluded that the LoRa RA-02 module can still perform data transmission in NLoS conditions at distances of up to 90 meters, despite a decline in signal quality.

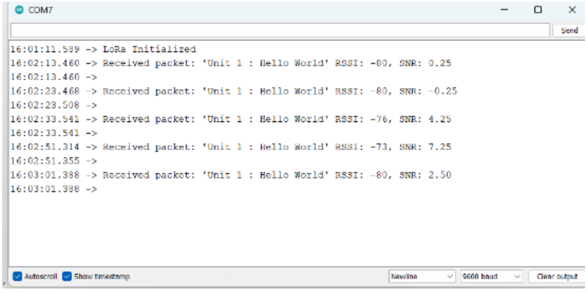

Figure 14. Test results of the LoRa RA-02 in LoS conditions.

Fig. 14 shows the results of one of the tests displaying the RSSI and SNR values on the transmitting device, as shown on the serial monitor of the receiving device.

IV. CONCLUSION

The system designed using magnetic switches and RCWL radar sensors has proven effective in detecting theft actions. The magnetic switch sensor cannot detect the door opening when the magnet is at 0 to 2 cm, but it can detect it when the magnet moves more than 2 cm away from the reed. Meanwhile, the RCWL sensor can detect movement at distances of 0 to 4 meters from all directions, and at distances of 4.1 to 5 meters, movement can only be detected at an angle of 0 degrees. However, the RCWL sensor cannot detect movement beyond 5 meters from any angle. The device using LoRa communication successfully transmitted data from the sensors at home to the guard post. The tests show the success rate of data transmission, with signal quality RSSI ranging from -66 dBm to -77 dBm in LoS conditions and from -89 dBm to -91 dBm in NLoS conditions. The receiver device can also send information to the LCD and activate the buzzer in the event of a burglary indication. The test results show that the device operates effectively across various testing scenarios. The RCWL sensor demonstrates effectiveness up to 4 meters at all angles, and the LoRa communication successfully transmits data even in NLoS (No Line of Sight) conditions up to 90 meters, albeit with some signal quality degradation.

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