Evaluation and Implementation of WISE-4051-AE Communications in Process Level Laboratory Module

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***Abstract*—This research discusses the design and implementation of wireless communication using WISE-4051-AE for optimizing process-level practical modules. The WISE-4051-AE wireless device is an integrated IoT (Internet of Things) device that combines data acquisition, processing, and control functionalities. Continuing previous research, this study focuses on creating practical modules for process control, including flow meter calibration, cascade control, feedforward control, and ratio control. By utilizing the WISE-4051-AE wireless device in a plant setting, the processed data can be accessed through laptops, personal computers, and other devices that support communication with the WISE-4051-AE device. To get the data, a device must be connected to the WISE-4051-AE wireless device. By employing the WISE-4051-AE wireless device for data transmission, users of the process-level practical modules can receive real-time plant data, regardless of whether the modules are indoors or outdoors, without encountering any data alteration during the transmission process. In this research, the WISE-4051-AE wireless device has a maximum range limitation. As long as the user's device remains within the signal range of the WISE-4051-AE device, the transmitted data will not undergo any changes. The signal range was tested under two conditions: without signal obstacles and with signal obstacles. The results of the signal range testing revealed a maximum range of 90 meters without obstacles and 40 meters with obstacles.**

***Keywords*— Laboratory module, LabVIEW, process level, WISE-4051-AE, wireless.**

I. INTRODUCTION

In today's digital age, productivity and efficiency in work are crucial; thus, fast data communication is essential for achieving maximum results in industrial processes. Previously, data transmission was done through cables, but now it has evolved into wireless data transmission, eliminating the need for cables. Industries using Industry 4.0 technology already use robots for assembly processes, and this technology is becoming increasingly prevalent. Industry 4.0 is a phenomenon that combines cyber technology and automation technology, assisted by information technology in its implementation. As a result, the effectiveness and efficiency of the working environment can be improved, which significantly impacts the quality of work and production costs in the industry. However, not only can the industry benefit from this system, but all sectors of society can also benefit from it [1].

The ongoing development of Industry 4.0 has led to the adoption of various supporting technologies, such as the Internet of Things (IoT). IoT has found application in numerous industries, including agriculture [2], fisheries [3], waste management [4], and location tracking systems[5]. Industry 4.0 is gradually making its way into education, prompting many academic programs to adapt swiftly to ensure students can keep pace with advancements. Consequently, laboratory modules based on Industry 4.0 or IoT have been developed for practical training. In a previous study [6], a learning module was designed to enhance skills during the industrial revolution, while another study [7] developed an IoT-based microcontroller laboratory module.

IoT-enabled research has also been conducted in process control, such as a study [8] that measured parameters including pH value, water turbidity, the water level in the tank, temperature, and humidity using a microcontroller.

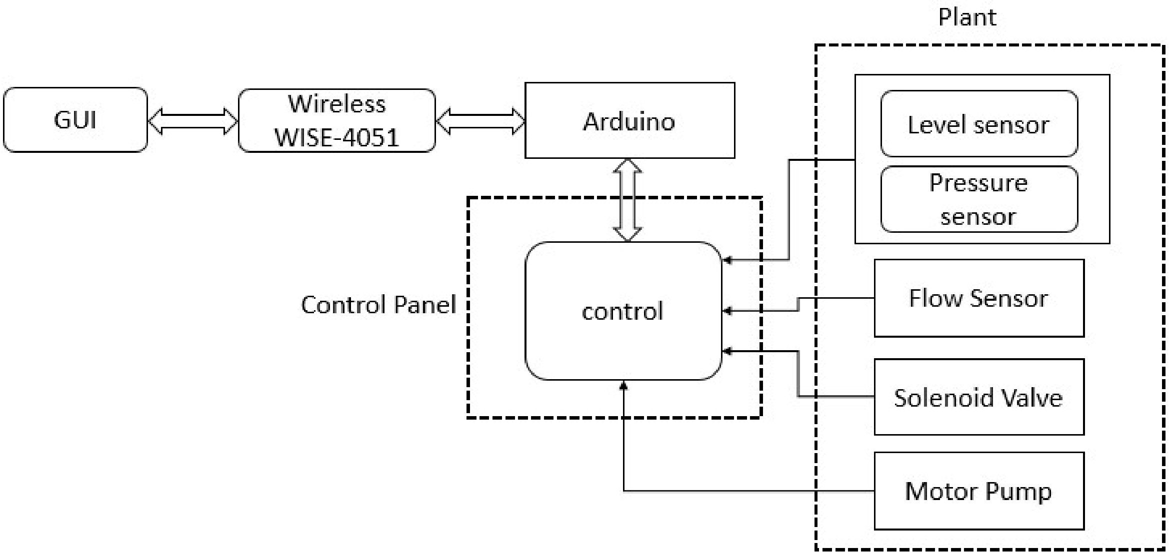


Figure 1. Block diagram of the WISE-4051-AE communication system in the process-level laboratory module

In this research, the parameters were transmitted and monitored using ThingSpeak in real-time experiments. However, further testing is required to expand the scope of this research by including additional chemical parameters and evaluating the conditions of wireless communication.

The thesis [9] utilizes WISE technology to overcome a significant problem, namely PLCs that are still not ready to communicate using TCP/IP when ethernet is plugged directly, which is used in data acquisition. With WISE as a broker, the problems mentioned above can be solved. Research [10] also utilizes WISE to analyze AMS's performance and reachability for blockchain-enabled edge computing. Furthermore, [11] utilizes the WISE-4012-AE I/O module as an intermediary for sending stack light data to a SCADA server, which applies NTP as signal synchronization. This research also utilizes WISE, which is connected to Arduino UNO and conventional machines, whereas, as a result, all data can be sent properly to the MySQL database.

In 2019, some students in the Instrumentation Engineering and Mechatronics Engineering study program carried out a final research project by analyzing pressure and level on CE33 electronic process control [12], continued by [13] using SKU SEN0257 on Couple Tank Kit to measure pressure in a tank. From this research, the development of a process-level laboratory module was carried out by incorporating Industry 4.0 cyber and automation technology. Therefore, the idea arose to research the design and implementation of WISE-4051-AE communication in the process-level laboratory module, where data communication will be made wirelessly and can be controlled remotely. According to the authors, WISE-4051-AE wireless communication is far more efficient than cable or ethernet communication. In its implementation, the process level laboratory module will use an Arduino board as an input and output data or as a controller. Another method is using PLC (Programmable Logic Controllers) as input and output data but PLC is much more expensive than an Arduino board and WISE-4051-AE device.

II. METHOD

In this research, several steps were undertaken, including the design of the WISE-4051-AE communication system, the design of the GUI, the design of the wiring diagram, and various testing to evaluate the system.

A. Design of the WISE-4051-AE Communication System

The WISE-4051-AE communication system was designed to facilitate wireless data transmission in the process-level laboratory module. The design process involved: identifying the requirements and specifications of the system; selecting the appropriate communication protocol and hardware components; and implementing the necessary software for the system to function correctly. The final design included integrating the WISE-4051-AE communication module, an Arduino board, and a GUI for remote control and system monitoring. The system is centralized on a control system which is then connected to an Arduino UNO as a WISE-4051-AE connector before being connected to the GUI and application.

The plant has several sensors, including a level sensor, pressure sensor, flow sensor, solenoid valve, and pump motor. This control system plant is part of the process-level laboratory module. The block diagram of the WISE-4051-AE communication system is presented in Fig. 1.

B. Design of GUI

The GUI design for the WISE-4051-AE communication system focused on creating a user-friendly interface for remote control and monitoring. The design involved determining the necessary information and controls and optimizing layout and interface elements for ease of use.

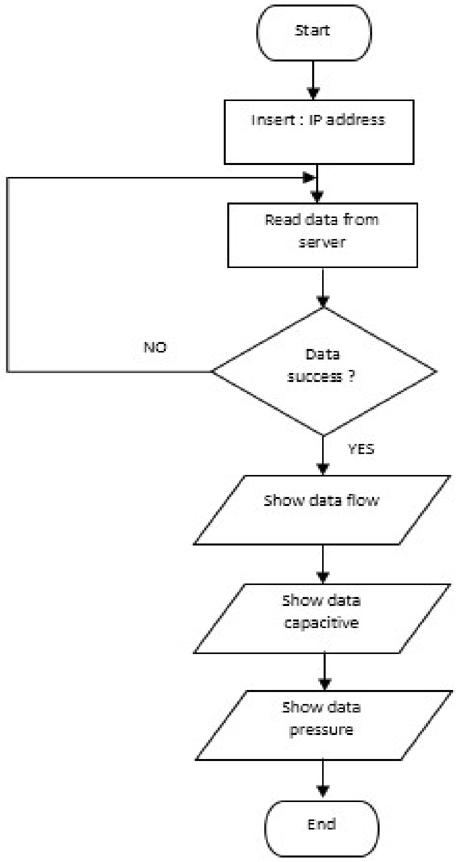


Figure 2. Flowchart of the GUI design

The final GUI design included real-time sensor data monitoring, solenoid valve and pump motor control, and alarm notifications for abnormal conditions. Implementation utilized LabVIEW, ensuring compatibility with the Arduino UNO board and WISE-4051-AE module. Fig. 2 depicts the GUI design process, while Fig. 3 showcases the realized design and implementation.

C. *Wiring Diagram Sistem*

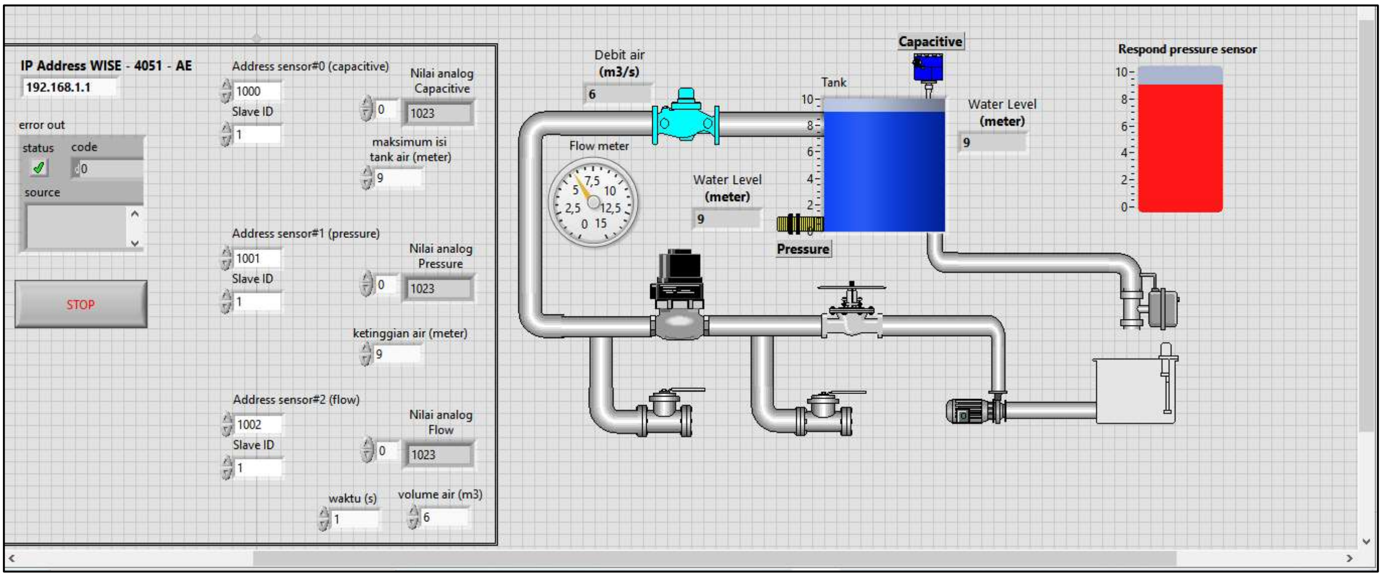
The wiring diagram of the WISE-4051-AE communication system was created to provide a clear and detailed representation of the connections between the various components of the system. This included the connections between the Arduino UNO board, the WISE-4051-AE communication module, the sensors, the solenoid valve and the pump motor, and the power supply. The wiring diagram also detailed the pinout connections and the signal flow between the components. The wiring diagram was an essential part of the system design, as it provided a clear understanding of the system's operation and the potential issues that might arise during the implementation and testing phases. All cable connections of each component can be seen in the following Fig. 4.

III. RESULTS AND DISCUSSION

Device testing was using Labview as a GUI (Graphical User Interface). The following Fig. 5 presents the system configuration at the time of testing.

A. *Testing of the WISE-4051-AE Wireless Unit Line-of-Sight (LOS) Range*

The Line-of-Sight (LOS) range of the WISE-4051-AE wireless unit was tested to evaluate its maximum communication range when there is no obstruction between the transmitter and receiver.


IP Address WISE - 4051 - AE
192.168.1.1

error out
status ✓ code 0
source

Address sensor#0 (capacitive)
1000
Slave ID
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Nilai analog Capacitive
0 1023
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Address sensor#1 (pressure)
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Nilai analog Pressure
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Address sensor#2 (flow)
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waktu (s)
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volume air (m3)
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Debit air **(m3/s)**
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Water Level **(meter)**
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Water Level **(meter)**
9

Figure 3. The GUI design display in LabVIEW

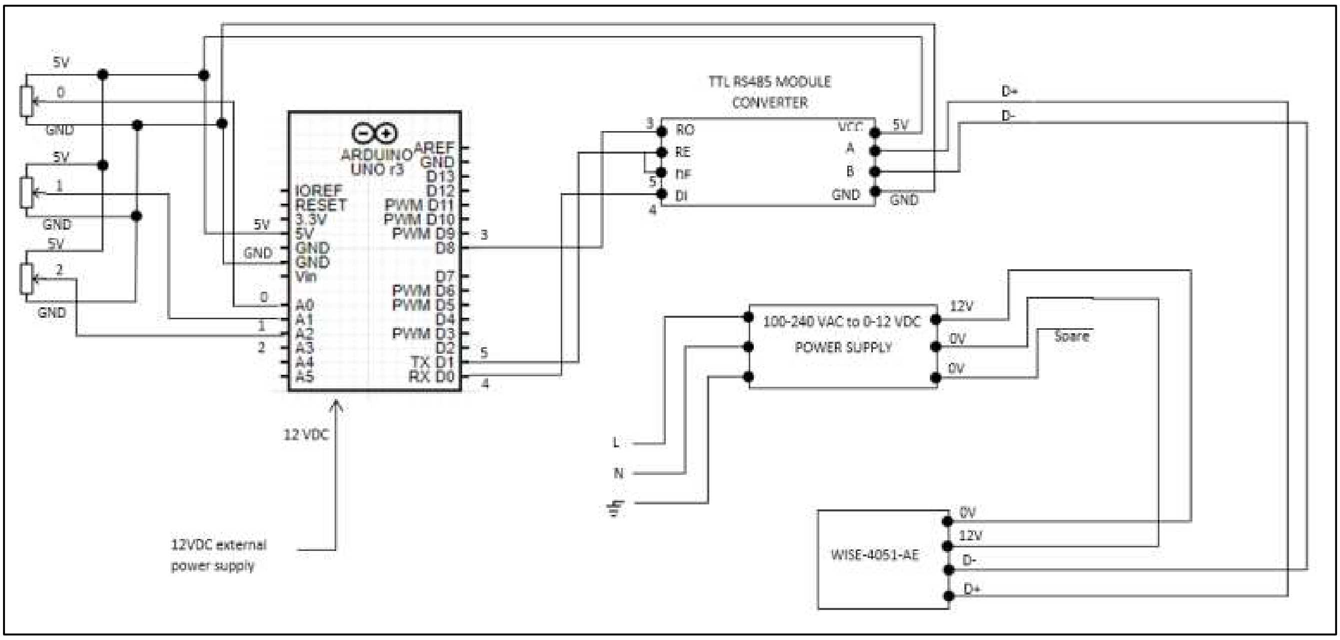

Figure 4. Circuit wiring diagram

The test was performed by placing the transmitter and receiver at different distances and measuring the signal strength and data transmission rate, shown in Fig. 6.

In this scenario, the transceiver (transmitter and receiver) is placed in a clear condition. WISE-4051-AE is shifted every 10 meters, and analog data is taken for each of the three sensor readings: capacitive, pressure, and flow sensors. The shift is carried out as far as 110 meters to see how far the reading range of WISE-4051-AE can be reached. The results presented in Table 1 show that the wireless unit's LOS range met the system's specifications and requirements (38 – 75 m coverage radius [14] or 300 feet ≈ 90 m [15]).

This test is essential to understand the operating range of the wireless unit in clear line-of-sight conditions. This information can be helpful when planning the placement of the wireless unit in the process-level laboratory module.

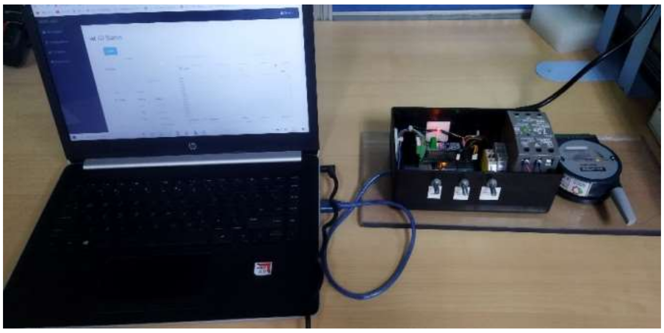

Figure 5. Testing configuration system

B. *Testing of the WISE-4051-AE Wireless Unit Non-Line-of-Sight (NLOS) Range*

The Non-Line-of-Sight (NLOS) range of the WISE-4051-AE wireless unit was tested to evaluate its maximum communication range when there are obstacles between the transmitter and receiver, shown in Fig. 7.

TABLE I
ANALOG DATA ON LOS CONDITION

Distance (meters)	Capacitive sensors		Pressure sensors		Flow sensors	
	WISE-4051-AE	**LabVIEW Received**	**WISE-4051-AE**	**LabVIEW Received**	**WISE-4051-AE**	**LabVIEW Received**
10	137	137	214	214	177	177
20	309	309	478	478	255	255
30	599	599	653	653	470	470
40	322	322	297	297	338	338
50	484	484	519	519	546	546
60	401	401	364	364	382	382
70	600	600	496	496	577	578
80	599	600	496	496	577	577
90	461	461	300	300	378	378
100	NULL	NULL	NULL	NULL	NULL	NULL
110	NULL	NULL	NULL	NULL	NULL	NULL

The test was performed by placing the transmitter and receiver at different distances and measuring the signal strength and data transmission rate while simulating different obstructions, such as walls and equipment. In this scenario, the transceiver (transmitter and receiver) is in an obstacle condition. Obstacles in the form of boards and walls are shifted every 10 meters. WISE-4051-AE is placed behind the barrier, and analog data is taken for each of the three sensor readings: capacitive, pressure, and flow sensors. The shift is carried out as far as 110 meters to see how far the reading range of WISE-4051-AE can be in the presence of an obstacle. The results showed in Table 2 that the NLOS range of the wireless unit was lower than the LOS range but still met the specifications and requirements of the system (38 – 75 m coverage radius [14]).

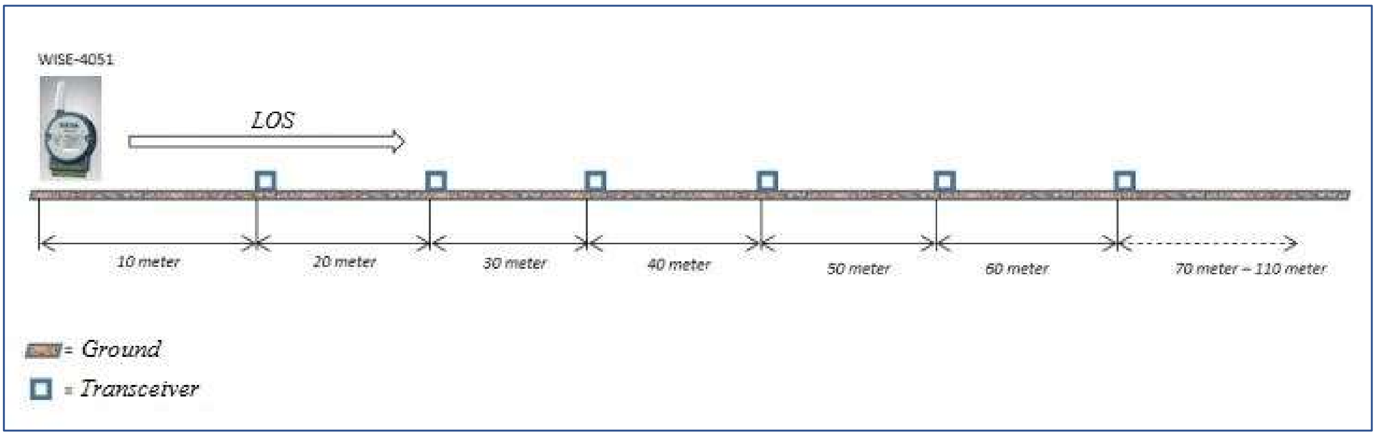

Figure 6. LOS measurement scenario

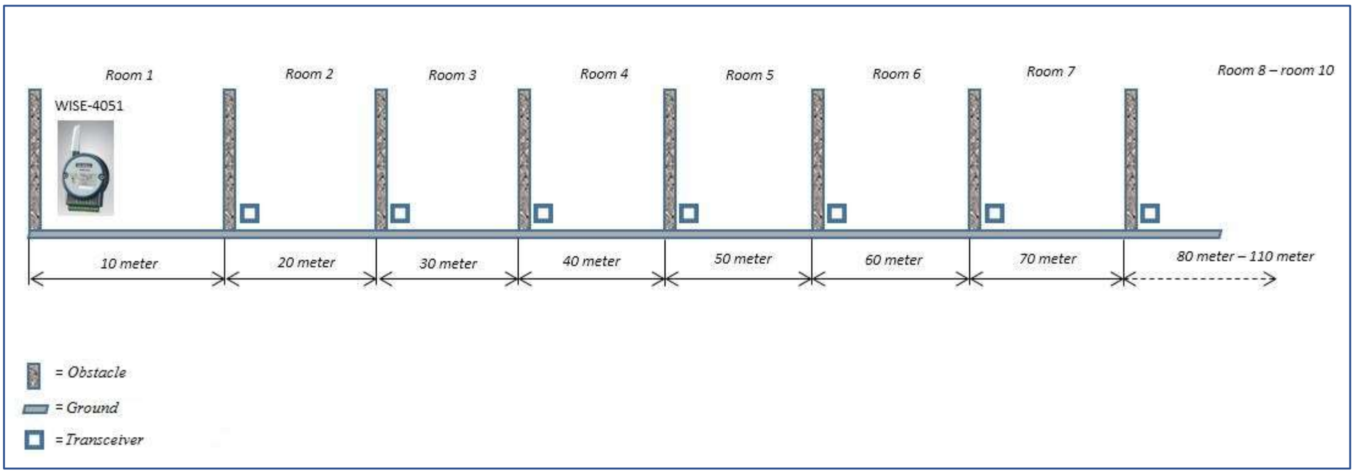

Figure 7. NLOS measurement scenario

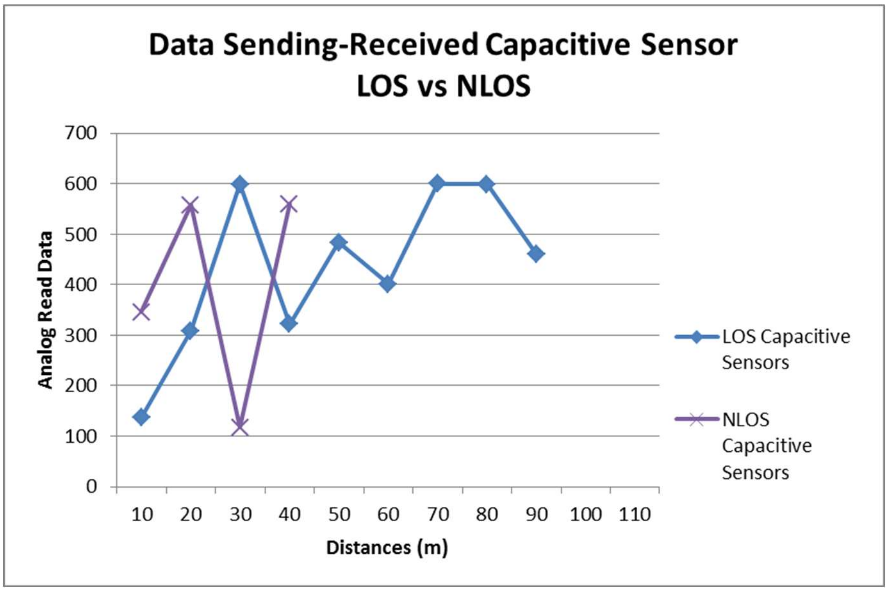

Figure 8. LOS vs. NLOS Distances of Analog Data Capacitive Sensor

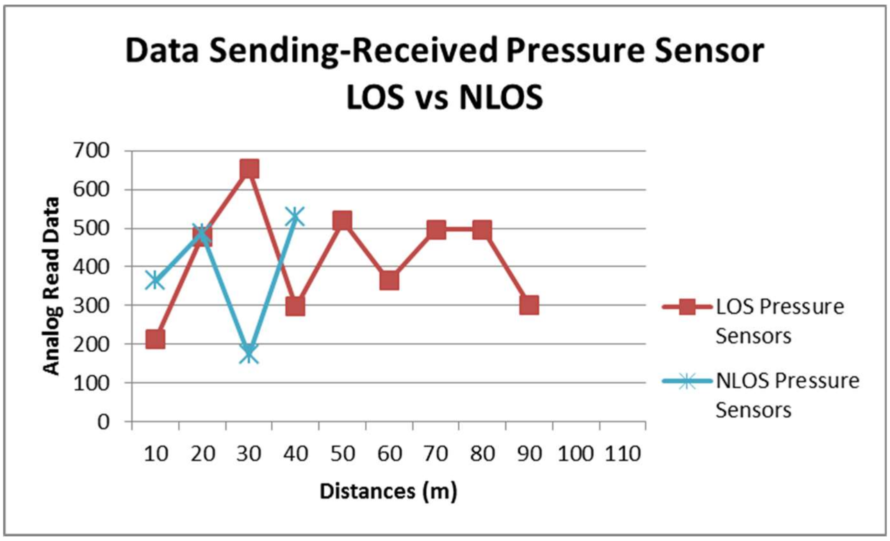

Figure 9. LOS vs. NLOS Distances of Analog Data Pressure Sensor

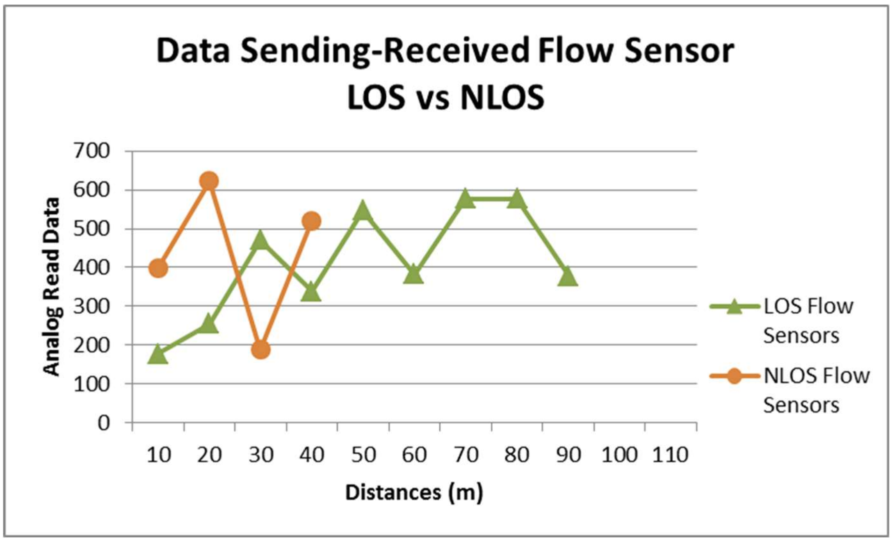

Figure 9. LOS vs. NLOS Distances of Analog Data Flow Sensor

TABLE II
ANALOG DATA ON NLOS CONDITION

Distance (meters)	Capacitive sensors		Pressure sensors		Flow sensors	
	WISE-4051-AE	LabVIEW Received	WISE-4051-AE	LabVIEW Received	WISE-4051-AE	LabVIEW Received
10	346	346	365	365	397	397
20	558	558	488	488	623	623
30	117	117	173	173	188	188
40	560	560	529	529	521	521
50	NULL	NULL	NULL	NULL	NULL	NULL
60	NULL	NULL	NULL	NULL	NULL	NULL
70	NULL	NULL	NULL	NULL	NULL	NULL
80	NULL	NULL	NULL	NULL	NULL	NULL
90	NULL	NULL	NULL	NULL	NULL	NULL
100	NULL	NULL	NULL	NULL	NULL	NULL
110	NULL	NULL	NULL	NULL	NULL	NULL

This test is essential to understand the operating range of the wireless unit in non-line-of-sight conditions. This information can be useful when planning the placement of the wireless unit in the process-level laboratory module and in real industrial environments where obstacles are common.

C. Comparison Line-of-Sight (LOS) and Non-Line-of-Sight (LOS) Condition

If we compare the results of sensor data retrieval, it can be seen that the communication range during Line-of-Sight (LOS) conditions is farther than during Non-Line-of-Sight (NLOS) conditions. Comparisons for each sensor are presented in Fig. 8, 9, and 10 graphs.

The curve in Fig. 8 shows that in scenarios without obstructions or Line-of-Sight (LOS), analog capacitive sensor data can still be received up to a distance of 90 meters. In the presence of obstacles or Non-Line-of-Sight (NLOS), data can only be received up to 40 meters.

Second, the graph in Fig. 9 shows a trend of results that are almost the same as in the previous figure, where in conditions without obstructions or Line-of-Sight (LOS), analog pressure sensor data can still be received up to a distance of 90 meters. Whereas in the scenario of obstacles or Non-Line-of-Sight (NLOS), data can only be received up to a range of 40 meters.

Moreover thirdly, the graph in Fig. 10 shows a trend of results similar to the previous figure, where in a scenario without obstructions or Line-of-Sight (LOS), analog sensor flow data can still be received up to a distance of 90 meters. Whereas in an obstacle or Non-Line-of-Sight (NLOS) scenario, data can still be received up to 40 meters.

The three graphs above do not emphasize the comparison of sensor reading data but show the range that can be achieved if we compare LOS and NLOS. Sensor data indicate that it can still receive data sent by the transmitter at a certain distance. For a comparison of sensor data obtained alone, it shows a 0% error if we refer to Table I and Table II to compare data sent via WISE-4051-AE and received at LabVIEW.

D. Testing of Sensor Data Acquisition in the Process Level Laboratory Module

The sensor data acquisition in the process-level laboratory module was tested to evaluate the accuracy and reliability of the sensor readings. The test measured the sensor output and compared it to the known input. The tests included measuring the sensor output under different conditions, such as varying levels, pressures, and flows. The results showed that the sensor data acquisition was accurate and reliable and met the system's specifications.

TABLE III
WATER LEVEL DATA (CAPACITIVE SENSOR)

The maximum water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)
0	0	0	250	0	1023	0
3	1	0.0029	100	0.2932	1023	3
5	10	0.0488	150	0.4398	1023	5
7	20	0.1368	180	1.2316	1023	7
9	45	0.3958	115	1.0117	1023	9
12	55	0.6451	245	2.8739	1023	12
15	80	1.1730	230	3.3724	1023	15
18	75	1.3196	300	5.2785	1023	18
20	48	0.9384	220	4.3010	1023	20
25	15	0.3665	270	6.5982	1023	25

The results, represented in Tables III, IV, and V, showed that the comparison data from the actual water level to the data read sensors is equal or accurate. The volumetric flow rate also indicates that the sensors present the data nearly similarly if we calculate using (1).

$$Q = \frac{v}{t} \tag{1}$$

Whereas,

Q = flow rate (m^3/sec)

v = water volume (m^3)

t = time (sec)

The WISE-4051-AE communication system effectively improved the efficiency and productivity of the process-level laboratory module. The ability to control and monitor the system remotely significantly reduced the need for manual intervention and provided greater flexibility in the module's operation. The WISE-4051-AE communication system also demonstrated the potential for further development in wireless communication and automation technology. The system could be adapted for use in other industrial applications and other areas, such as smart homes and buildings. Overall, the design and implementation of the WISE-4051-AE communication system in the process-level laboratory module successfully achieved its objectives and provided proof of concept for future developments in the field.

TABLE IV
WATER LEVEL DATA (PRESSURE SENSOR)

The maximum water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)	Analog Data Read	The actual water level in the tank (meters)
0	0	0	250	0	1023	0
3	1	0.0029	100	0.2932	1023	3
5	10	0.0488	150	0.4398	1023	5
7	20	0.1368	180	1.2316	1023	7
9	45	0.3958	115	1.0117	1023	9
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15	80	1.1730	230	3.3724	1023	15
18	75	1.3196	300	5.2785	1023	18
20	48	0.9384	220	4.3010	1023	20
25	15	0.3665	270	6.5982	1023	25

TABLE V
WATER FLOW DEBIT (FLOW SENSOR)

Full Tank Time (seconds)	Water Volume (m^3)	Analog Data	Volumetric Flow Rate (m^3/sec)
1	0	0	0
3	1	1	0.0003
5	10	10	0.0195
7	20	100	0.2792
9	45	570	2.7859
12	55	680	3.0465
15	80	890	0.3691
18	75	1000	0.5139
20	48	945	2.2170
25	15	877	0.5143

IV. CONCLUSION

Based on the testing and data collection conducted in the study on the design and implementation of WISE-4051-AE communication for process-level practical module optimization, the author concludes that the wireless device WISE-4051-AE can be implemented and used for practical outdoor modules without signal obstacles within a range of 0-90 meters. The data received and transmitted by the WISE-4051-AE wireless device to the user can be processed by the LabVIEW GUI. In essence, as long as the user's device can still capture the WISE-4051-AE signal, there are no issues with data transmission. The received data remains unchanged, whether using the WISE-4051-AE device without obstacles or with obstacles.

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