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LONG-RANGE UHF PASSIVE RFID TAG TO MANAGE FINISHED PRODUCT INVENTORY IN OUTDOOR STOCKYARD

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Abstract. *The development of data communication technology is very important in the field of informatics in this era of industry 4.0. In the precast concrete manufacturing industry, marking and tracking of data on inventory management is done manually with paint or QR code. In this research, large quantities of product were marked in inventory in a large area using Radio Frequency Identification (RFID), making it easier to obtain data from long distances. This research resulted in reading RFID data from a distance of more than 20 m on precast concrete inventory, which perfected previous research on steel plant inventory using RFID at a distance of 7 m. This research uses Reader and Passive Tags on the market. The results obtained in this research show Passive RFID Tags are able to get a reading distance of 20.60 m or an area of 1.333* m^2 *accurately without a barrier or with a concrete barrier, but with a metal barrier it is only able to reach a distance of 7.50 m or an area of 177* m^2.
Keywords: Radio frequency identification, Remote reading, Passive Tag, Inventory management, Outdoor stockyard

1. **Introduction.** In this era of industry 4.0, the use of IoT in the manufacturing industry is growing rapidly, and along with the development of emerging Internet technologies such as the Internet of Energy (IoE), Internet of People (IoP), Internet of Media (IoM), Internet of Services (IoS), it will provide business solutions with infrastructure towards a digital society based on knowledge and innovation. One of the goals of IoT technology with wireless sensor and actuator network technology, IoT devices, BLE, QR code, and RFID is to leverage real-world information into networks, services, and applications. Embedded devices, such as RFID or Wireless Sensor Networks (WSN), are part of the Internet of Things, but as stand-alone applications (Intranets), they have at least a certain standardized information architecture that all Internet communities can refer to, a global WSN infrastructure that can still be developed [1].

1.1. **Background.** In the precast concrete manufacturing industry, finished goods inventory is generally placed in a large stockyard area and outside the room or field, where the type of product tends to be the same for each customer with the type and number of units required relatively large. It will cause its own difficulties in tracking and collecting data. The process of tracking and collecting data on inventories of finished goods, in general, still uses manual methods, namely by using labeling/codes/product identities that are affixed to the product in the form of paper, metal plates, or using paint, which will later be carried out during inventory and tracking when distribution, and the officer will look for and read the labeling. Another way is to develop using IoT technology, one of which is with a barcode/QR code affixed to the product.

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With the above conditions, there is a desire for authors to be interested in utilizing RFID technology in the designation of manufacturing precast concrete products in Indonesia, because according to authors, there are not many, or even no use of RFID technology in product inventory management precast concrete, which currently exist using manual labeling or using a QR code.

1.2. **Objective.** The use of RFID technology is very helpful for companies/business owners in inventory management, especially in monitoring inventory validity, finding product inventory in the stockyard area, stock placement, preventing misplacement, etc. RFID really helps the speed of finding the right product and making the right decision. The use of RFID technology in inventory management is superior to other traditional technologies such as barcodes/QR codes for several aspects [3]. The advantages in supply chain with RFID technology are increasing the speed of material flow, reducing staff work activities, reducing work in process and inventory, easier management, due to real-time information, reducing losses, and preventing counterfeiting and theft [4,5].

With the use of Passive RFID Tags which have limitations in the range of data reading, the authors wish to experiment so that with RFID and Passive Tags it can be used in inventory management of precast concrete products with the ability to read data for long distances (more than 20 m) at the stockyard wide outdoors.

1.3. **Scope.** This research is limited to the use of frequency allocation that is applied in Indonesia, which is 920-923 MHz [6], the use of Passive RFID Tags, the application of the inventory of precast concrete products with outdoor stockyards, and the testing process is only limited to the process of reading data from the tag by the reader through software certain data, without doing any further data processing.

2. **Related Works.** Previous studies that were used as studies were measurement strategies to assess the optimal design of navigational aids based on the Passive RFID Tag module with a frequency of 868 MHz, using an Arduino microcontroller with three tag height tests with results [0.40-1.00] m with an accuracy of 100% [7]. Another research by evaluating the compass algorithm comparing the results with those obtained using the tracking algorithm at Landmarc at a frequency of 433 MHz, was obtained with a distance of 1.47 m for a confidence level of 80% [8].

The RFID is also utilized in product logistics industries by modifying the architecture of existing RFID solutions based on the EPCglobal/GS1 reference framework. It is used in tracking product history and for planning the location of individual products while in a steel mill warehouse, on their way to the client, or at the client. In its application, it utilizes a production equipment unit, namely a gantry/overhead crane, as an RFID Reader that can read RFID Tags placed on a product 7 m away [9]. With a program via Arduino with SMS as a data transmission medium, the farthest distance the tag can still be detected by the RFID Reader is 9.5 cm. Meanwhile, if an obstacle is given in the form of rubber between the tag and the RFID Reader, the reading distance will be reduced to almost half [10].

Research on RFID remote reading was implemented using the backscatter Phase-Shift Keying (PSK) modulator. Two separate tests, with and without antenna, were performed with a working frequency of 868 MHz. The test results show that the reading range of the test without antenna is 11.3 m and with antenna is up to 12.7 m. However, the reader has been shown to be capable of working up to a maximum of 5 m in very adverse environments [11]. Another research was conducted to read the long-range Class-3 UHF RFID system based on harmonic backscattering. Semi-passive harmonic RFID tags were used for reading distances. Measurement results achieved a communication distance of 20 m in ideal working conditions at a frequency of 900 MHz [12].

A cost-effective and highly flexible UHF RFID system using Cat5e Ethernet cable to address remote subsystems has been demonstrated to be usable up to 150 m cable length. This indicates that this new system configuration provides high performance for long-range passive RFID applications. Today, most of the models and specifications for twisted pair cables are designed for Ethernet communication. However, communication over twisted-pair cables associated with the RFID baseband is just past its early stages. Now it is important to go further to achieve a complete cyber-physical RFID system [13].

In experimental innovation by exploiting the quantum tunneling effect of RFID backscattering in long-distance scenarios. The tag readout has a sensitivity of 81 dBm and achieves an experimental backscattering range of 1.2 km designed and tested at 5.8 GHz, where prototypes can easily be redesigned for standard UHF frequencies where higher ranges can be covered. These results, significantly reducing power requirements while enabling long communication distances, demonstrate that Tunneling Tag promises a new era for IoT wireless devices and backscattering applications [14]. In the experiment of obtaining long range RFID communication with backscatter architecture, where one or more devices (sensor nodes, WiFi access points, etc.) provide a carrier signal which is emitted by the backscatter tag and the backscatter signal is received by one or more receivers, such a scheme applies the concept of Computational Radio Frequency Identification (CRFID). The results of the experiment reached a range of over 3.4 km while operating in the 868 MHz band [15]. The results of literature review are summarized in Table 1.

Table 1. The summary of literature review related to the RFID Tag reading

No.	Publication	Proposed solution	Type & freq. RFID	Evaluation results (distance and accuracy)
1	[8]	Landmarc algorithm	Passive, 433 MHz	L = 1.5 m, 80%
2	[7]	Optimized design of the Arduino microcontroller navigation aid	Passive, 868 MHz	L = 1.6 m, 100%
3	[10]	Architecture of GS1/EPC Global	Passive, 915 MHz	L = 7 m, 100%
4	[11]	Arduino and SMS algorithm	Passive, 125 KHz	L= 9.5 m, 100%
5	[12]	Phase-Shift Keying (PSK) backscatter algorithm model	Active, 868 MHz	L = 12.7 m, 100% (antenna), L = 5.0 m, 100% (no antenna)
6	[13]	System based on harmonic backscattering	Semi Passive, 900 MHz	L = 20.0 m, 100%
7	[14]	UHF RFID system Cat5e Ethernet cable between the central controller and antenna submit on the RFID Reader	Passive, 900 MHz	L = 150 m, 100%
8	[15]	Quantum tunneling effect	Active, 5.8 GHz	L = 1.2 km, 100%
9	[16]	Concept Computational Radio Frequency Identification (CRFID)	Passive, 868 MHz	L = 3.4 km, 100%

From Table 1, analyzing the data for the literature review above, taking account of the scope of the research, namely the type of tag, work frequency, distance & accuracy, and only to determine the communication ability between reader and tag, the researcher will use the results of research from Velento and Neto [10] as the basis for further research by applying from outdoor (7 m) to be developed in outdoor locations with reading distance capabilities > 20 m.

3. **Methodology.** The methodology of this research can be described as in Figure 1. The methodology of this research begins by selecting the type of RFID tag (active, semi-active, and passive), where the use of Passive Tags is determined, taking account of cost efficiency and testing long range readings, then determining the data reading software, the next stage is testing and data collection, for further analysis and results obtained, and in the final stage conclusions and future work are drawn.

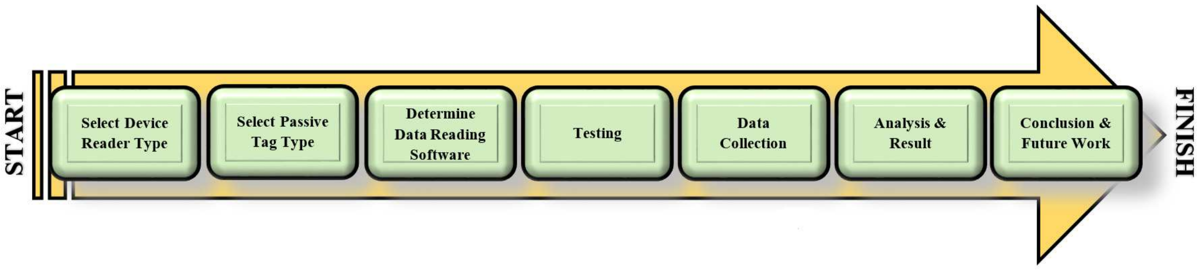

Figure 1. Research methodology

3.1. **Existing system.** Current system is still using manual labeling and QR code to identify the precast concrete products. The painted labels have to be read manually by the officer. Although the QR code can be automatically read using a smartphone, the officer must approach the products to a close proximity. Taking into account that precast concrete products require a relatively large stockyard area, relatively large types/variety and quantities, a large number of customers for similar/type products, an easy, efficient, and effective way is needed to meet the ability to read remote data accurately, as depicted in Figure 2. It shows a fairly large stockyard area with various types and product dimensions. Furthermore, Figure 3 shows the current state of marking using paint and QR code.

Figure 2. Situation map for precast concrete product stockyard

Figure 3. Types of labels on current precast concrete products

3.2. **Proposed system.** In this research, to improve the performance process of data collection, it is proposed to use the UHF RFID long range system, with the hope of reducing the activity of officers reading by approaching the product unit in question. The placement of Passive Tags as product marking is shown in Figure 4.

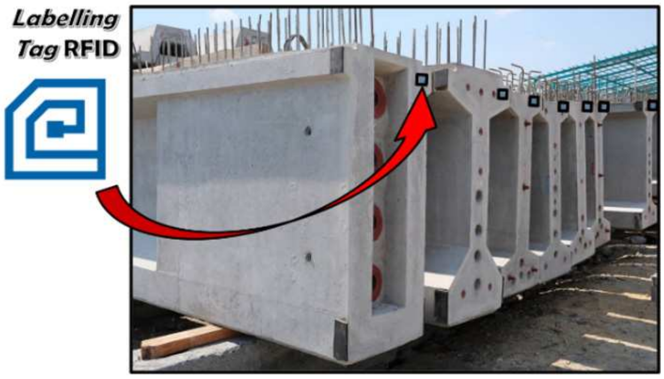

FIGURE 4. Label with UHF RFID Tag on precast concrete products

The placement of the product inventory is spread over a relatively large area (Figure 5), so it is necessary to install a UHF RFID Reader that can reach the widest possible area with good distance and accuracy, so that the optimal reading radius will be obtained from each reader (Figure 6).

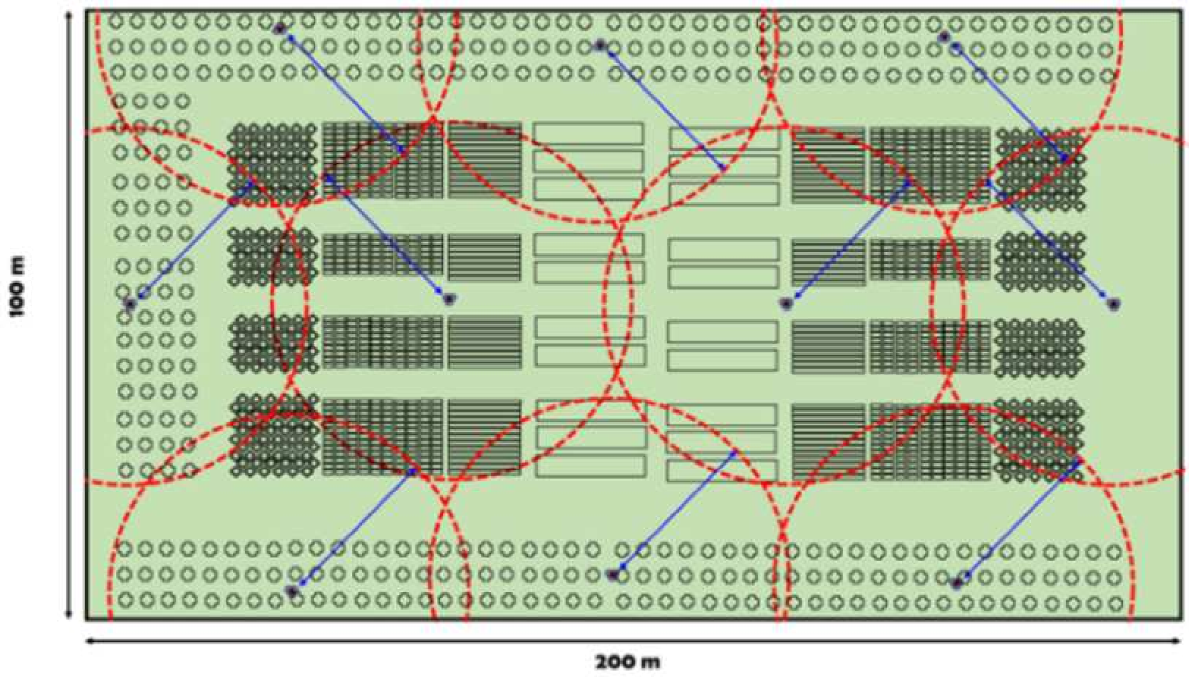

FIGURE 5. Stockyard product layout

Figure 7 shows a plan to install a UHF RFID Reader on a pole with a rotator at a height of 6 m, with the hope of reaching a stock pile up to a height of 5 m at a distance of > 20 m. Due to the need for a fairly wide coverage area and an open space, in this research it is necessary to review several things that will affect the results of the research, namely the orientation of the tag placement position, the orientation of the reader installation position, obstacles by other materials against the tag, the type of Passive Tag used. In this research, the equipment used by the manufacturer's products on the general market

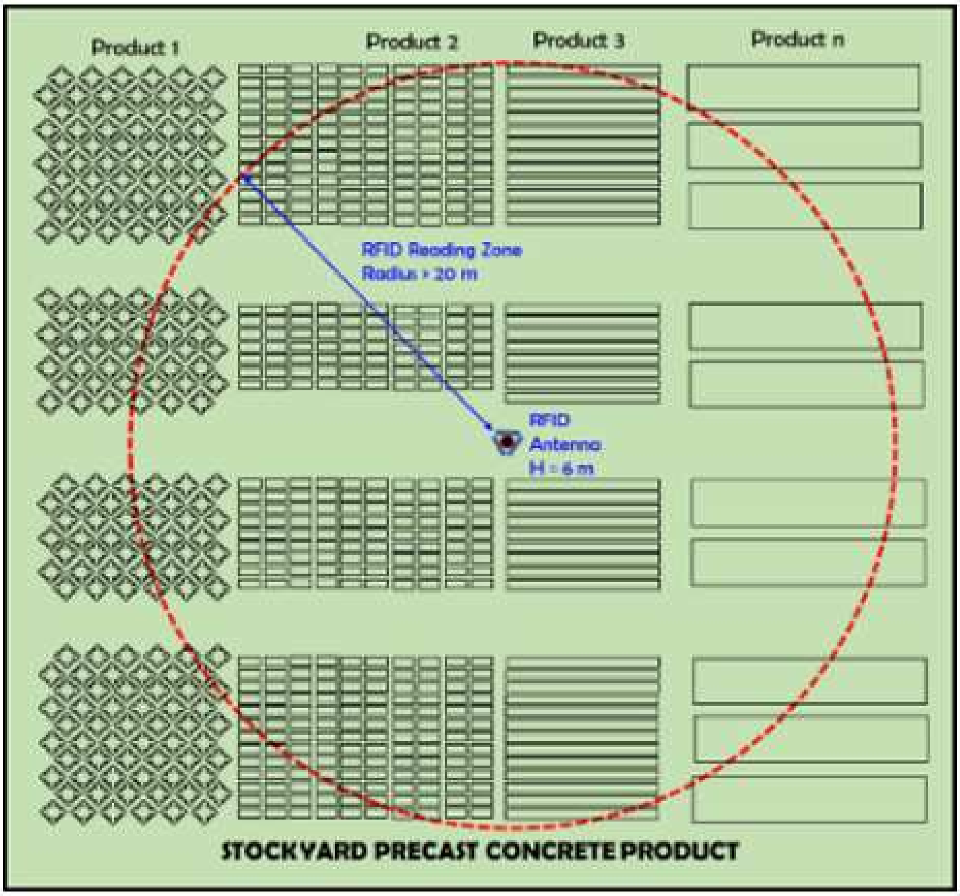

FIGURE 6. Stockyard layout top view RFID product reading zone

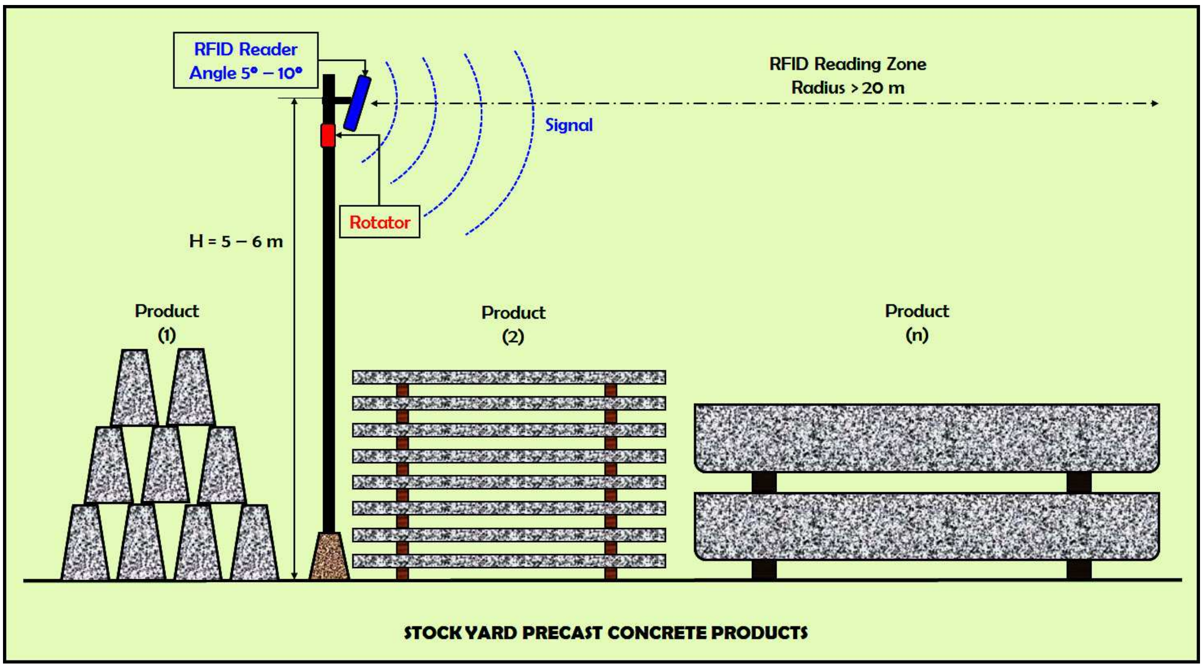

FIGURE 7. Stockyard side view RFID product reading zone layout

is Reader, Electron HW-VY12K [17], Passive Tag WZ-G16 [18], Passive Tag Electron EL-U8-9662-C2 [19], and Electron HW-VY Series Demo Software for RFID Tag data reading [20].

The problem with RFID distance estimation with Passive RFID Tags is that the system has a high inherent error because the signal reading value can easily change by environmental conditions, depending on some physical position in the monitoring area, and Passive RFID Tags do not behave the same, even though the tag comes from the same manufacturer and model. Due to the variation between Passive Tags, there is a high estimation error, so to improve the accuracy of estimation, we recommend using 1 tag per type to reduce variations in tag performance [20].

As for environmental factors that can affect the reading of RFID data, it can be classified as follows:

1) The orientation of the tag placement position, as the basis of testing parameters, as shown in Figure 8;

FIGURE 8. Orientation of tag position

2) Orientation of the reader installation position, as shown in Figure 9;

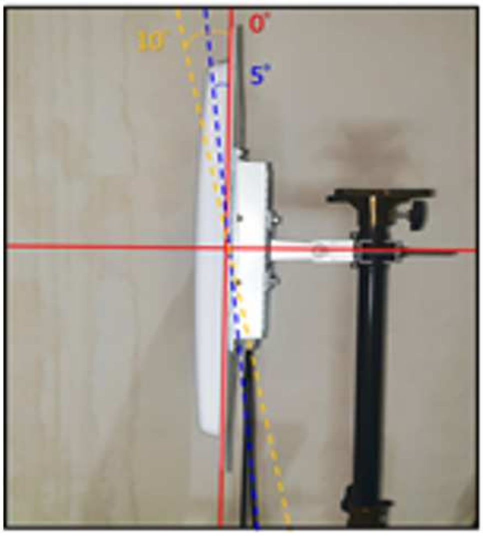

FIGURE 9. Orientation of reader position

3) Barriers by other materials to the tag, the type/variety of Passive Tag used, in this research the obstacles are non-metallic materials, namely concrete plates and metal materials in the form of 3 mm steel plates.

The test method for each of the test parameters mentioned above can be illustrated in Figure 10. This test begins with setting the software on a computer that is connected to the reader, to calibrate the system used as a background measurement by reading the no

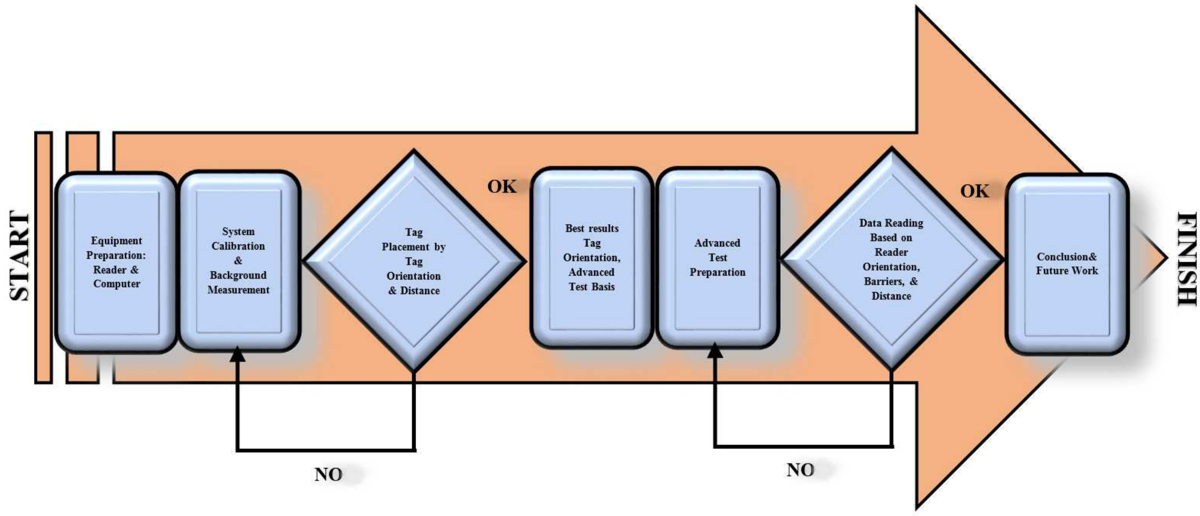

FIGURE 10. Analysis process of reading RFID data

barriers tag, which is placed based on the orientation (angle) and distance. If there is a discrepancy in the parameters, the recalibration will be carried out. If the parameters are appropriate, the reading will be recorded. The same steps are performed for the testing with concrete barriers and metal barriers. From the results of this test, conclusion & future work will be obtained.

4. **Result and Discussion.** The process of reading the RFID Tag data is performed using Electron HW-VY Series Demo Software as shown in Figure 11. While the software settings for reading RFID Tag data is shown in Figure 12. In this experiment, the software settings include connection with USB, reading power of 26 dBm, working frequency of

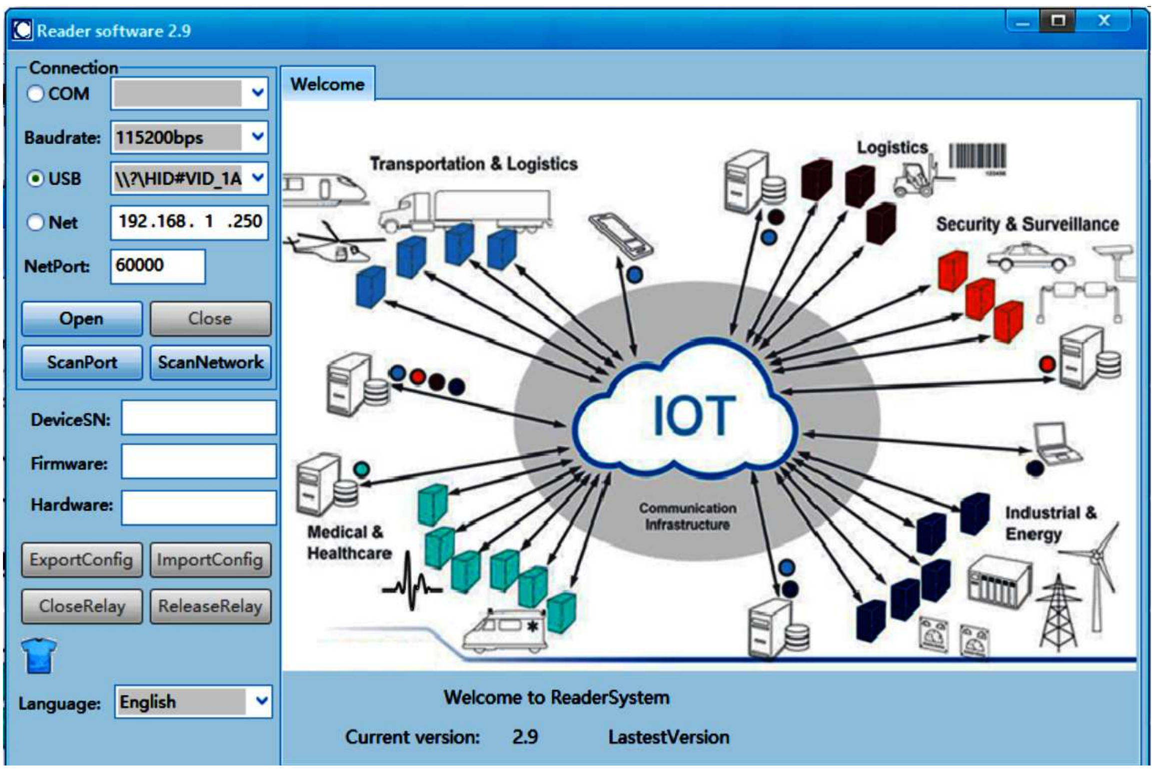

FIGURE 11. RFID Tag data reading software

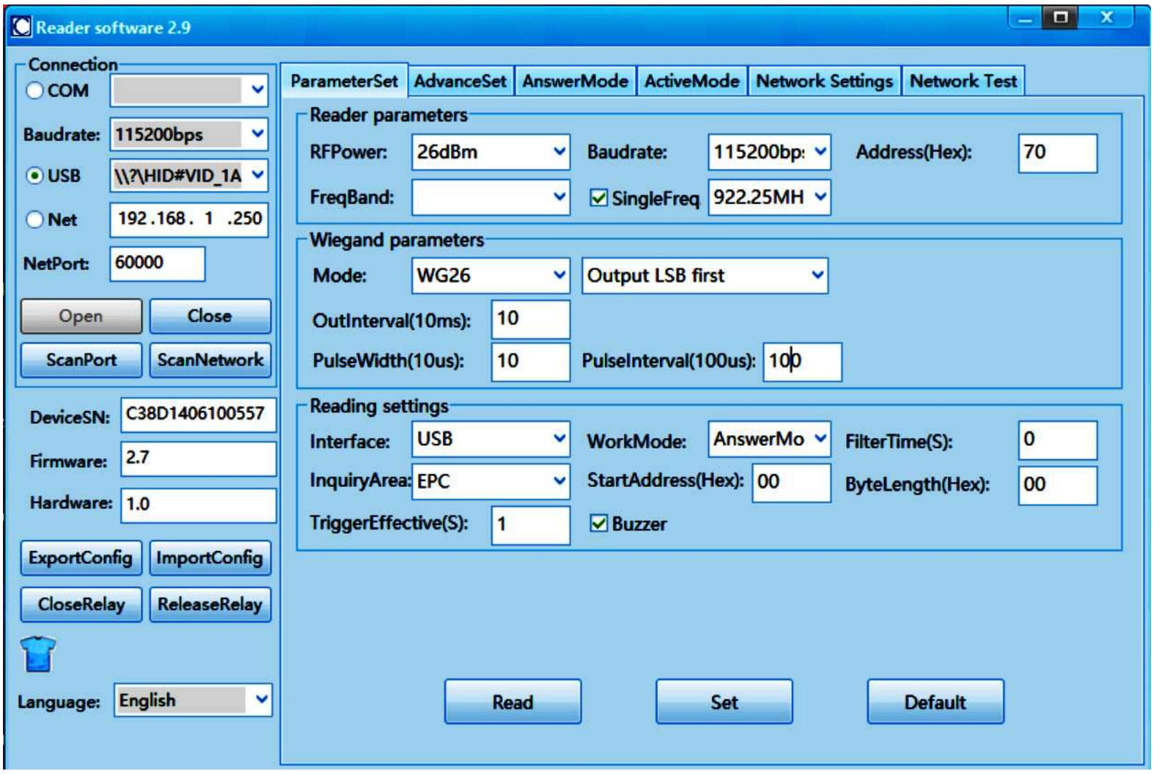

Figure 12. Software settings for reading RFID Tag data

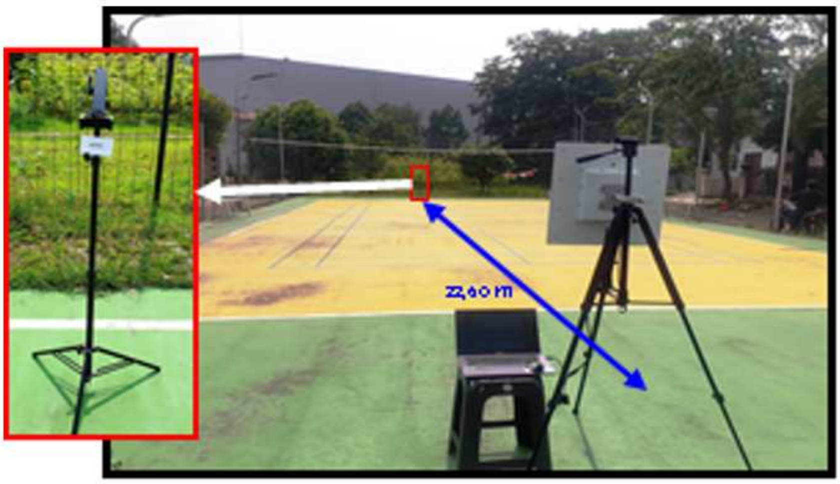

Figure 13. Field testing process

922.25 MHz, read card setting on EPC, and working mode of 40 ms answer interval and filter.

The testing process for reading RFID data can be described as in Figure 13 and with the readings as shown in Figure 14, where if the identity on the tag can be read by the reader, it will appear in the report.

From the implementation of the testing process in the field with the existing parameters, the results of reading RFID data are obtained as shown in Table 2. Based on the reading results, the best tag orientation for Passive Tag Electron EL-U8-9662-C2 is at an angle of 90°. On the other hand, the Passive Tag WZ-G16 can still be read by the reader at various tag orientations of 0°, 45°, and 90° angles. The results of further testing of data reading based on reader orientation can be seen in Table 3.

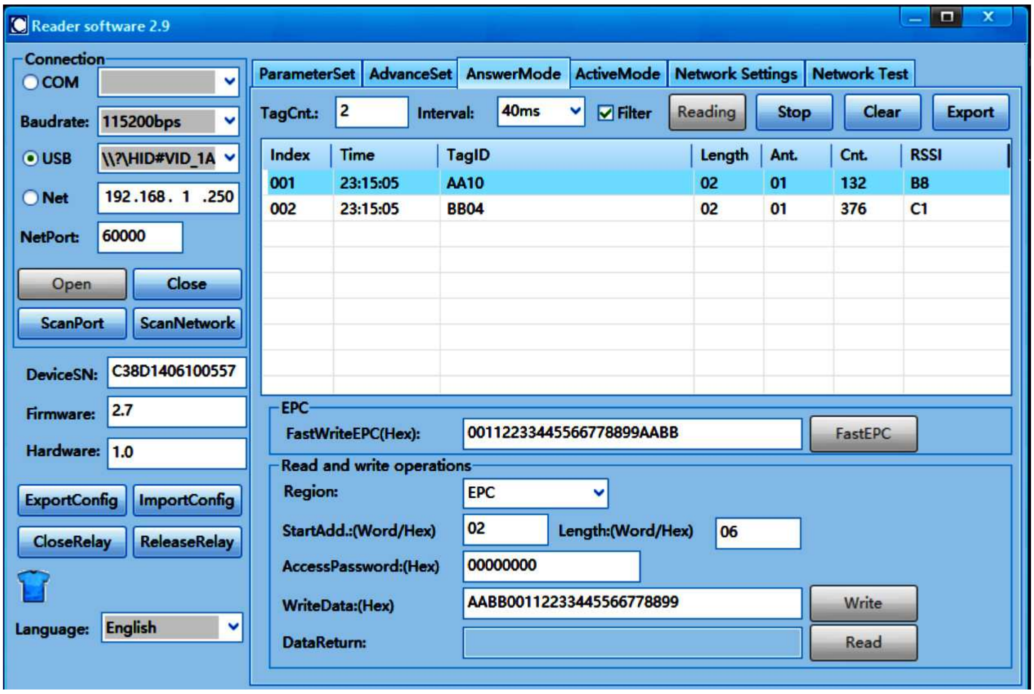

FIGURE 14. Results of data reading on software

TABLE 2. RFID Tag reading results based on tag orientation

Distance (m)	Angle (degree)	Sensitivity	
		Passive Tag EL-U8-9662-C2 (No Barriers)	Passive Tag WZ-G16 (No Barriers)
0	0	read	read
3.65	0	unread	read
5	0	unread	read
7.50	0	unread	read
10	0	unread	read
15	0	unread	read
20	0	unread	read
22.60	0	unread	read
25	0	unread	unread
0	45	read	read
3.65	45	read	read
5	45	read	read
7.50	45	unread	read
10	45	unread	read
15	45	unread	read
20	45	unread	read
22.60	45	unread	read
25	45	unread	unread
0	90	read	read
3.65	90	read	read
5	90	read	read
7.50	90	read	read
10	90	read	read
15	90	read	read
20	90	read	read
22.60	90	read	read
25	90	unread	unread

Table 3. RFID Tag reading results based on reader orientation

Distance (m)	Angle (degree)	Sensitivity					
		Passive Tag EL-U8-9662-C2			Passive Tag WZ-G16		
		No Barriers	Concrete Barriers	Metal Barriers	No Barriers	Concrete Barriers	Metal Barriers
0	0	read	read	read	read	read	read
3.65	0	read	read	read	read	read	read
5	0	read	read	unread	read	read	read
7.50	0	read	read	unread	read	read	read
10	0	read	read	unread	read	read	unread
15	0	read	read	unread	read	read	unread
20	0	read	read	unread	read	read	unread
22.60	0	read	read	unread	read	read	unread
25	0	unread	unread	unread	unread	unread	unread
0	5	read	read	read	read	read	read
3.65	5	read	read	read	read	read	read
5	5	read	read	unread	read	read	read
7.50	5	read	read	unread	read	read	read
10	5	read	read	unread	read	read	unread
15	5	read	read	unread	read	read	unread
20	5	read	read	unread	read	read	unread
22.60	5	read	read	unread	read	read	unread
25	5	unread	unread	unread	unread	unread	unread
0	10	read	read	read	read	read	read
3.65	10	read	read	read	read	read	read
5	10	read	read	unread	read	read	read
7.50	10	read	read	unread	read	read	read
10	10	read	read	unread	read	read	unread
15	10	read	read	unread	read	read	unread
20	10	read	read	unread	read	read	unread
22.60	10	read	read	unread	read	read	unread
25	10	unread	unread	unread	unread	unread	unread

Based on the data in Table 3, it can be analyzed for the best reading of RFID data to occur as follows:

- Reader orientation position does not significantly affect the reading of Passive Tag WZ-G16 data and Passive Tag Electron EL-U8-9662-C2;
- Reading data with unobstructed environmental conditions, the results are the same between Passive Tag WZ-G16 and Passive Tag Electron EL-U8-9662-C2, which is at a distance of 22.60 meters with 100% accuracy read by the reader;
- Reading of data with environmental conditions with a concrete slab barrier, as well as the same result between Passive Tag WZ-G16 and Passive Tag Electron EL-U8-9662-C2, which is at a distance of 22.60 meters with 100% accuracy read by the reader;
- Reading data with environmental conditions with a steel plate barrier, giving the results that the Passive Tag WZ-G16 can be read by the reader at the furthest distance of 7.50 meters with 100% legibility accuracy. Meanwhile, the Passive Tag Electron EL-U8-9662-C2 can be read by the reader at the furthest distance of 3.65 meters with 100% legibility accuracy.

5. **Conclusion and Future Work.** Based on the tests and analyses that have been carried out in this research, it can be concluded that RFID technology can be used as a

monitoring tool for precast concrete finished product inventories that support industry 4.0, where this conclusion is based on as following:

- Scanning processes can be performed in batches simultaneously, thereby increasing time efficiency.
- The scanning process can be carried out at a considerable distance, > 20 m, so that scanning can be carried out remotely which is suitable for storage areas with a large enough area.
- To minimize barriers by other materials on the tag, the placement of the tag can be managed by using a stick to place the tag, so that the tag in the free position can be read by the reader.

For future work, experiments can be carried out on materials such as using a reader with 3 units for one point, without a rotator, using an omnidirectional antenna, developing a tag coordinates determination, using the grid and GPS methods.

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