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Enhancing IoT Network Reliability: Evaluating LoRa Module Susceptibility to Interference

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ABSTRACT

The Internet of Things (IoT) is gaining popularity, leading to the widespread use of remote communication modules (LoRa), known for their energy efficiency and wide coverage range. However, as the number of LoRa modules used in IoT networks grows, the possibility of interference from third-party devices operating at the same frequency becomes a concern. This study aimed to examine the vulnerability of LoRa modules to electromagnetic interference (EMI) when transmitting text messages and images. Radiation emission conditions were measured in the test area for evaluating LoRa module performance, and susceptibility to interference was assessed under non-line-of-sight (NLOS) conditions. The study's outcomes reveal that interference with LoRa transmitters has no noticeable effect on the range within a distance of up to 50 meters. In contrast, the interference power required to disrupt the LoRa receiver decreases with increasing distance. Additionally, interference from frequencies outside the designated LoRa working frequency (915 MHz) has no discernible impact on module performance. Introducing a delivery delay check demonstrates consistent performance even in interference. These findings deepen our understanding of the susceptibility of LoRa modules to tampering, emphasizing the importance of implementing effective disruption management strategies in IoT deployments. By considering the potential impact of electromagnetic interference (EMI) on LoRa modules, developers can design more robust IoT networks, ensuring reliable communication and improved system performance. Overall, the research focuses on the interference characteristics of LoRa modules, providing insights for developing resilient and interference-resistant IoT solutions. It underscores the necessity of addressing interference issues to ensure the reliable operation of IoT devices across diverse environments.

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1. INTRODUCTION

The Internet of Things (IoT) is a network paradigm that enables communication among diverse devices [1]. Considerations for IoT deployments encompass numerous factors, including node cost, network cost, battery life, data rate (throughput), latency, mobility, range, and deployment model [1]–[7]. Long Range (LoRa) communication modules are widely used in the Internet of Things (IoT) field [8]. The LoRa module can be applied as a data transmission module for the Wireless Sensor Network (WSN) [9]. One of the reasons LoRa modules are widely used today is their energy efficiency and wide range [10]–[15].

Every electronic device emits electromagnetic interference, and the LoRa module is no exception. The increasingly widespread use of LoRa modules does not rule out the possibility of interference between LoRa modules. Research has been conducted to propose a method for estimating network congestion caused by many self-managed LoRa network deployments [16]. However, research on the ability of LoRa communication modules to withstand electromagnetic interference (EMI) when transmitting information is not widely known [17]. Factors that affect EMI can be categorized as the nature of electronic equipment that emits noise, the distance between electronic equipment, and the equipment's susceptibility to electromagnetic waves [18].

Previous research has focused on the performance of LoRa modules in the presence of interference from other LoRa modules operating on the same frequency. The LoRa module is installed in a building, so it is known that the LoRa signal coverage covers most of the building locations. The LoRa signal is difficult to receive at the center of the building due to interference [19]. In addition, research has been carried out on the performance of LoRa against interference in densely populated areas, where there are many signals transmitting devices with different frequencies. This test revealed a frequency shift in the LoRa system due to interference caused by non-directional reception on LoRa [20].

However, in these studies, no research has been carried out to determine the level of interference that can interfere with the performance of the LoRa module from third-party devices with the same working frequency as the LoRa module. The researcher needs to determine how many EMI levels can affect the performance of the LoRa communication module when sending text and image messages. In this study, the authors conducted a study to determine the vulnerability of the LoRa communication module to interference. The author focuses on testing the LoRa communication module connected to a Smartphone on the transmitter and receiver sides when sending text and image messages. Then, the LoRa module susceptibility testing is carried out against interference by alternating interference on the transmitter and receiver sides. The LoRa module used in this study is the TTGO ESP32 LoRa, with a working frequency of 915 MHz.

2. METHOD

The research process involves several stages. Figure 1 illustrates the research flowchart. The study was conducted under Non-Line of Sight (NLOS) conditions. It was divided into two stages: measuring radiation emission conditions in the test area, the Transmission Media Laboratory of Politeknik Caltex Riau, and testing the vulnerability of the LoRa module to interference. The flow chart for testing the susceptibility of the LoRa module to interference can be seen in Figure 2.

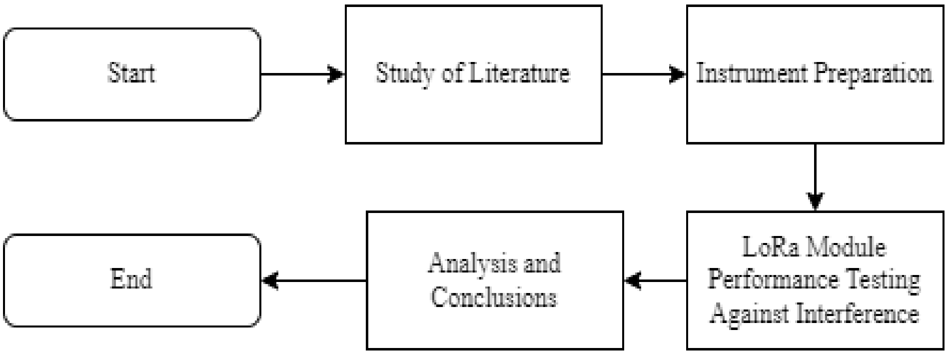


Figure 1. Research Flow

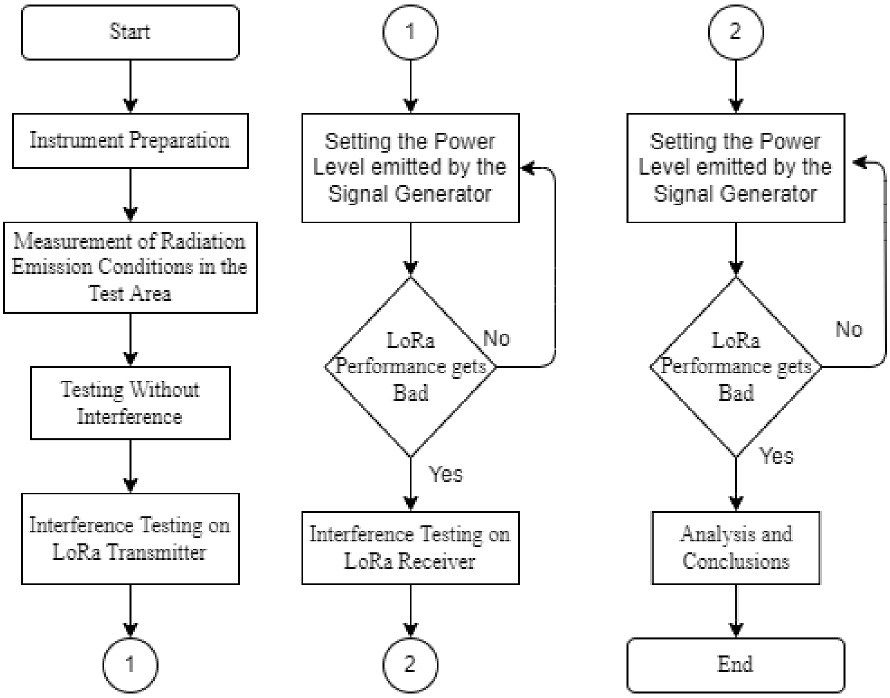


Figure 2. Test Flow

2.1. Measurement of Radiation Emission Conditions in the LoRa Module Performance Test Area in Non-Line of Sight Conditions

Measurement of radiation emission conditions in the LoRa module performance test area is carried out at the test site to know the signal level conditions around the LoRa device to be tested so that the analysis process can be carried out accurately. Measurements were made using the Aaronia Antenna and Spectrum Analyzer. Antena Aaronia is connected to Spectrum Analyzer using SMA to N cable. Then, the antenna is directed in all directions and takes data in the direction of the highest voltage level on the Spectrum Analyzer designation.

2.2. Lora Module Performance Testing Against Interference in Non-Line of Sight Conditions

LoRa module susceptibility testing against interference is carried out by emitting interference signals when the LoRa module receives and sends messages. Devices used in transmitting interference are a Signal Generator and an Aaronia Antenna. There is an obstacle between the transmitter and receiver module and given a certain distance, namely 25 m to 100 m. The power level of the interference signal emitted from the Signal Generator is started based on the amount of transmit power of the LoRa module, obtained from the measurement of the radiation emission produced by the LoRa module at a frequency of 915 MHz. Then, the power level of the interference signal is increased or decreased based on the response of the LoRa module when a signal is emitted from the Signal Generator so that the actual power level is known that can interfere with the performance of the TTGO ESP32 LoRa module.

LiveChat Application sends text messages using the Serial USB Terminal Application.

The frequency used in this test is 868 MHz to 925 MHz with details, namely:

a. 915 MHz is the working frequency of the LoRa module used.
b. 868 MHz is the working frequency of the LoRa module, which is close to the working frequency of the TTGO ESP32 LoRa module.
c. 900 MHz is the working frequency of GSM [21].
d. 914 MHz and 916 MHz are frequency channels adjacent to the working frequency of the TTGO ESP32 LoRa module.
e. 923-925 MHz is the LoRa planning frequency in Indonesia [22].

The block diagram for testing the LoRa module susceptibility to interference can be seen in Figure 3 and Figure 4.

3. RESULTS AND DISCUSSIONS

3.1 Pulse Measurement of Radiation Emission Conditions in the LoRa Module Performance Test Area in Non-Line of Sight Conditions

The measurement begins with measuring the radiation emission conditions around the test location; the measurement results are indicated in **Error! Reference source not found.**. The value of the frequency with a high power level in the radiated emission measurement of the NLOS test area is the frequency of the 2G (945 MHz), 3G (2.115 GHz), and 4G (1.825 GHz) networks [23]–[25]. This frequency does not affect the performance when testing the LoRa module's performance of the LoRa module against interference during NLOS conditions.

3.2 Lora Module Performance Testing Against Interference in Non-Line of Sight Conditions

Testing the performance of the LoRa module against interference in Non-Line of Sight (LOS) conditions is carried out at a distance of 25-100 m. The test was carried out under three conditions: when there was no interference, interference at the LoRa transmitter, and interference at the LoRa receiver.

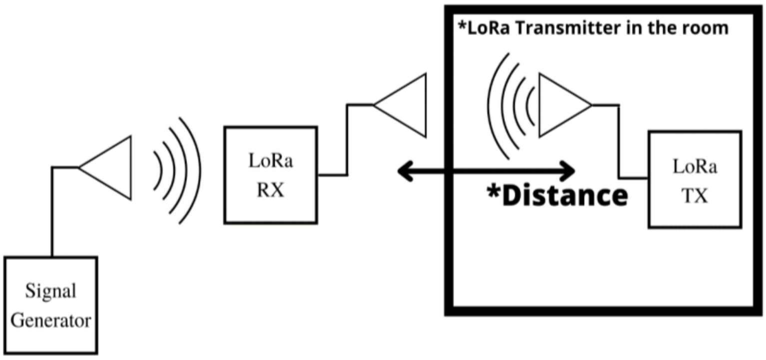


Figure 3. Block Diagram of LoRa Receiver Module Susceptibility Testing Circuit to Interference

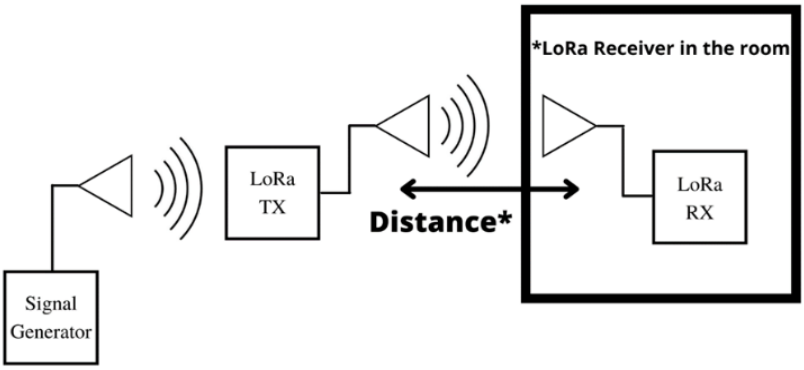


Figure 4. Block Diagram of LoRa Transmitter Module Susceptibility Testing Circuit to Interference

3.2.1 Testing Without Interference

LoRa module performance testing is performed at 25-100 m without interference. Sending messages can be done well. The LoRa receiver can receive each character of the message the LoRa transmitter sends. The image sent by the LoRa module can also be converted properly by the LoRaChat application on the Smartphone connected to the LoRa receiver. Whereas at 75 m to 100 m, the receiver module cannot receive text messages and images the transmitter sends. At this distance, there is a building obstacle so that the signal emitted by the LoRa transmitter is reflected and does not reach the LoRa receiver.

3.2.2 Interference Testing on LoRa Transmitter

Based on Table 1, the interference on the LoRa transmitter during NLOS conditions does not affect the distance range of the LoRa module from 25 m to 50 m. Even though the distance is getting further, the LoRa module is still disturbed at the same interference signal level, which is -46.78 dBm. So, it can be concluded that the farther the distance from the LoRa transmitter module to the LoRa receiver does not affect the interference value that can interfere with the performance of the LoRa transmitter module.

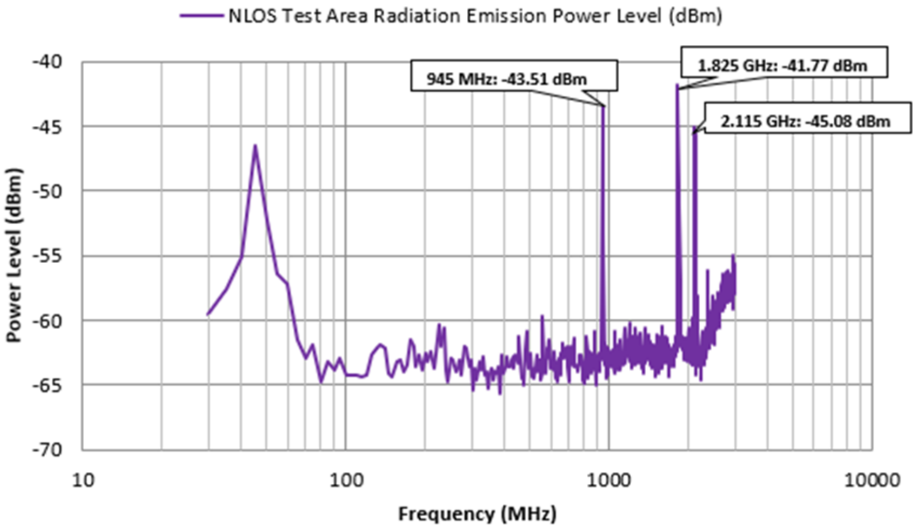


Figure 5. Graph of Measurement of Radiation Emission Conditions in the LoRa Module Performance Testing Area in Non-Line of Sight Conditions

Table 1. Effect of Interference on LoRa Transmitter on Distance

Distance Tx and Rx (m)	SSG Power Level (dBm)	Power Levels Readable by Spectrum Analyzer (dBm)	Status
25	≤ -3	≤ -47.37	Succeed
	-4 to 2	-46.78 to -39.91	Annoyed
	≥ 3	≥ -39.46	Fail
50	≤ -3	≤ -47.37	Succeed
	-4 to 2	-46.78 to -39.91	Annoyed
	≥ 3	≥ -39.46	Fail

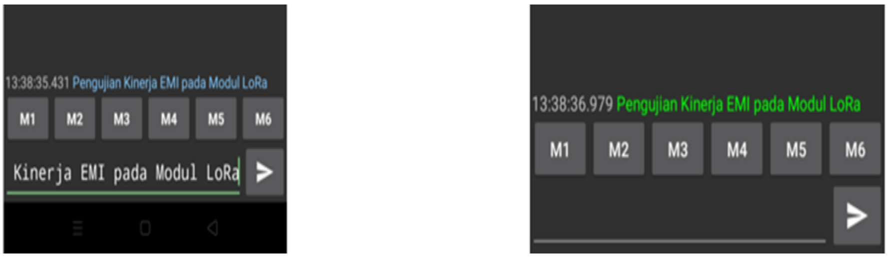
3.2.3 Interference Testing on LoRa Receiver

In Table 2, it can be seen how the condition of the message sent after interference is given to the LoRa receiver module along with the power level that can interfere with the performance of the LoRa module in Non-Line of Sight conditions. The farther the distance between the LoRa transmitter and receiver, the lower the power level required to interfere with the performance of the LoRa module. This susceptibility to interference is due to the decreased signal strength received by the LoRa receiver from the transmitter when positioned at greater distances.

Table 2. Effects of Interference on LoRa Receivers on Distance

Distance Tx and Rx (m)	SSG Power Level (dBm)	Power Levels Readable by Spectrum Analyzer (dBm)	Status
25	≤ -35	≤ -73.88	Succeed
	-34 to -28	-72.95 to -67.37	Annoyed
	≥ -27	≥ -66.44	Fail
50	≤ -38	≤ -76.67	Succeed
	-37 to -33	-75.74 to -72.02	Annoyed
	≥ -32	≥ -71.09	Fail

Examples of successful message sending are shown in Figure and Figure 7.. Examples of interrupted message sending are shown in Figure and Figure . An example of sending a failed message is shown in Figure and Figure 1. Figures 9 and 11 were obtained using the homemade LoRaChat App, while Figure 10 was obtained using the "Serial USB Terminal" application.


13:38:35.431 Pengujian Kinerja EMI pada Modul LoRa

Kinerja EMI pada Modul LoRa

13:38:36.979 Pengujian Kinerja EMI pada Modul LoRa

Figure 6. Text Message Sending Successful

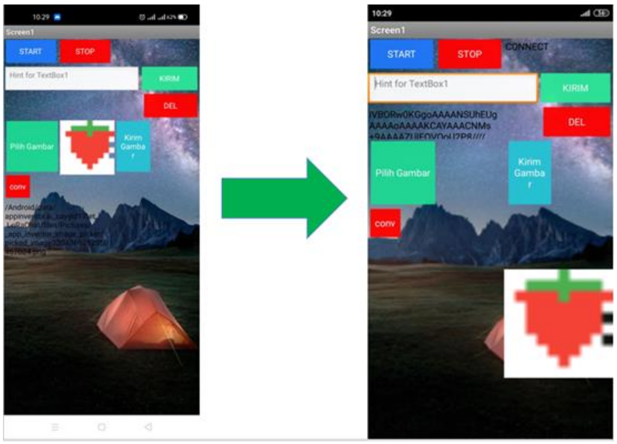

iVBORw0KGgoAAAANSUhEUg
AAAAoAAAAKCAYAAACNMs

Figure 7. Image Message Sending Successful


13:40:39.807 Pengujian Kinerja EMI pada Modul LoRa

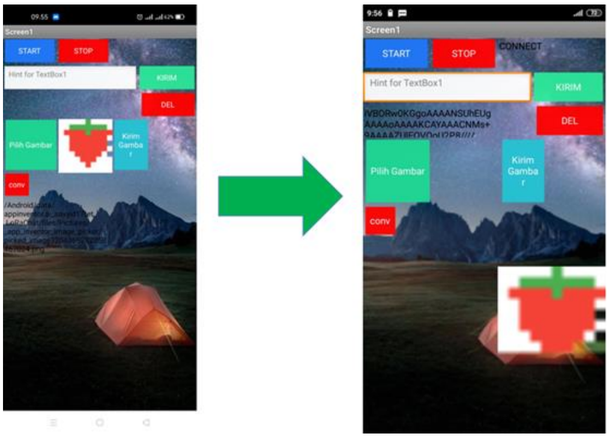
Kinerja EMI pada Modul LoRa

13:40:41.356 Pegujan Kinerja Elpda Mod oa

Figure 8. Interrupted Text Message Delivery

3.2.4 Comparison of LoRa Module Performance when Exposed and Not Exposed to Interference

Based on Table 3, interference does not affect the delay in sending messages and images; the delay value obtained is the same for each delivery. At 25-50 m, the LoRa module can transmit information well despite being exposed to interference at the transmitter and receiver. However, if the interference power level displayed on the LoRa module reaches a specific number, the performance of the LoRa module will be disrupted. Lora transmitter performance will be disrupted if the interference power reaches -46.78 dBm while the LoRa receiver is disturbed at different interference signal power levels at each distance. The farther the receiver is from the transmitter, the lower the interference power level. The comparison of the power level of the interference signal that affects the performance of the LoRa transmitter and receiver module is shown in Figure 2.



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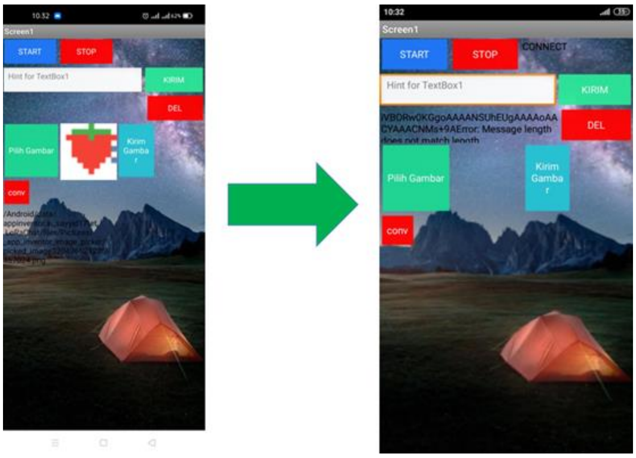
VBORw0KGgoAAAANSUhEUg
AAAAoAAAAKCAYAAACNMs+
```

Figure 9. Interrupted Image Message Delivery

```
13:41:01.620 Pengujian Kinerja EMI pada Modul LoRa
Kinerja EMI pada Modul LoRa
```

```
13:41:03.230 hError: Recipient address does not match l
ocal address
13:41:03.471 Error: Message length does not match lengt
h
13:41:03.518 Error: Message length does not match lengt
h
13:41:03.639 ^HError: Message length does not match le
ngth
```

Figure 10. Text Message Sending Failed



```
VBORw0KGgoAAAANSUhEUgAAAAoAA
CYAAACNMs+9AError: Message length
does not match length
```

Figure 1. Picture Message Sending Failed

Table 3. Comparison of LoRa Module Performance when Exposed and Not Exposed to Interference

No.	Condition	Distance (m)	Message Delay (s)	Picture Delay (s)	Status
1	No Interference	50	1.55	7.23	Succeed
2	Interference in Tx	50	1.55	7.23	Distracted at -46.78 dBm
3	Interference in Rx	50	1.55	7.23	The farther Rx is from Tx, it will be interrupted at lower power levels.

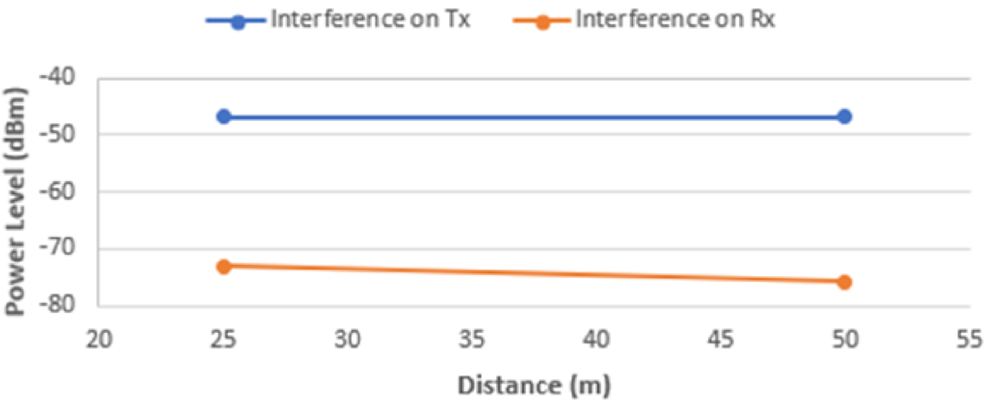


Figure 2. Graph of the Effect of Interference on the Performance of LoRa Transmitters and Receivers in Non-Line of Sight Conditions

3.2.5 Interference Testing from Frequency Other Than 915 MHz

The test results of transmitting signals at 868 MHz, 900 MHz, 914 MHz, 916 MHz, and 923-925 MHz (other than the LoRa working frequency) demonstrate that LoRa modules can function effectively. The test was also carried out by emitting the maximum power that the Signal Generator could emit, which was 13 dBm, but the LoRa module could still work well.

3.2.6 Delivery Delay

A comparison of the delay in sending text messages and images can be found in Table 4. The delivery delay of the LoRa module before and after the information is provided remains consistent. This consistency is attributed to the fact that the text and images tested are identical (Text: Pengujian Kinerja EMI pada Modul LoRa, Image: Cherry Fruit Pixel). The delay in sending the LoRa module is influenced by the size of the packet (number of characters) sent; the more characters sent, the greater the delay in sending, and vice versa. If the interference signal is not too strong, then the interference signal does not affect the transmission delay.

Table 4. Delivery Delay

Distance (m)	No Interference (s)		With interference (s)	
	Message Delay	Picture Delay	Message Delay	Picture Delay
25	1.55	7.23	1.55	7.23
50	1.55	7.23	1.55	7.23
75	-	-	-	-
100	-	-	-	-

4. CONCLUSION

LoRa modules exhibit remarkable resilience against interference, with no significant impact on communication distances within the first 50 meters. This robustness assures consistent and reliable data transmission in shorter-range IoT applications. Nevertheless, as the communication distance extends beyond 50 meters, the power level of interference required to disrupt the LoRa receiver decreases. This distance-dependent susceptibility underscores the importance of interference management strategies, particularly in scenarios involving extended communication ranges. LoRa modules have proven their ability to withstand interference from frequencies other than their working frequency (915 MHz). They remain functional and maintain reliable communication, even in the presence of various frequency sources. Notably, the examination of delivery delay reveals consistent module performance despite interference, highlighting the robustness of LoRa technology. This research contributes valuable insights to the field of IoT and LoRa technology. It highlights the pressing need for proactive interference management strategies in IoT deployments, especially when extended communication distances are involved. By addressing interference challenges, developers can design IoT networks that are resilient, interference-resistant, and capable of delivering superior system performance in diverse environmental conditions. The findings of this study underscore the critical role of interference management in ensuring the reliable operation of IoT devices across many scenarios. In turn, they pave the way for developing more robust and dependable IoT solutions, reinforcing the IoT's potential to transform industries and enhance our daily lives.

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