Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: Noraini Azmi *et al* 2021 *J. Phys.: Conf. Ser.* **2107** 012004

Relative Localization Method of Wet Spot of Grain using Array of Passive RFID Tags

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Abstract. Radio Frequency Identification (RFID) enables a large number of object monitoring since semi/passive tags are independent of batteries. In our previous work, the possibility of using different wireless technologies such as Wireless Sensor Network (WSN), Wireless Local Area Network (WLAN) and Radio Frequency Identification (RFID) to determine the moisture content in rice was investigated. Finding from our previous work suggest that RFID can be used to determine the moisture content of rice. While numerous research have been conducted for moisture content of grain, however, to author's knowledge, there is only a few studies conducted on the localization of grain hostpot. Therefore, this study aims to investigate if the passive RFID array can be used to localize the location of the wet spot of grain. Prior, the experiment, a suitable setting for the RFID system were determined. In addition, a simple test was conducted to select a suitable operating frequency. From the investigation, the result indicates that only frequency channels 865, 866, 867, 868 and 869 MHz can detect all 30 tags. Meanwhile, frequency channel in the range 902 to 928 MHz detects 26 to 29 unique tags. Hence, 868 MHz was selected as the operating frequency throughout the experiment. The findings indicate that the RSSI value measured by the RFID reader decreased as the moisture of the sample increased when the tags were blocked by the sample placed at the designated location during the test.

1. Introduction
Moisture content monitoring is crucial for long term duration to ensure the safety and quality of the grain [1][2][3]. Studies by [4][5][6][7] utilised electromagetic imaging (EMI) to localize the location of grain hotspots. The studies showed that EMI able to detect the location of grain hotspot. However, in this research, a simpler method utilising the RSSI from the existing wireless devices operating using the standard protocol such as IEEE802.15.4/Zigbee and Radio Frequency Identification (RFID was proposed.

Radio Frequency Identification (RFID) is used mostly in object identification. A study by [8] shows that RFID can be used to measure soil moisture content. Based on a study by [8], authors are motivated to use RFID as a measurement tool for the determination of moisture content in grains such as rice and paddy. Hence, in our previous work [9][10], the possibility of using different wireless technologies such as Wireless Sensor Network (WSN), Wireless Local Area Network (WLAN) and Radio Frequency Identification (RFID) to determine the moisture content in rice was investigated.

In our previous work, only two RFID tags were used during the test. Therefore, the main objective of this study is to investigate if the passive RFID array can be used to localize the location of the wet spot of grain. This work will be served as preliminary work to investigate the optimal setting of the RFID system before further research work on the prediction of moisture content detection measurement. This paper is arranged as follows: 2) Background information, 3) Experimental setup, 4) Result and discussion, and lastly 5) Conclusion.

2. Background Information

Several RFID settings need to be taken into consideration as shown in Figure 1 which includes reader-to-tag, tag-to-reader, and tag contention. Another important setting is the communication frequency band between tags and RFID reader.

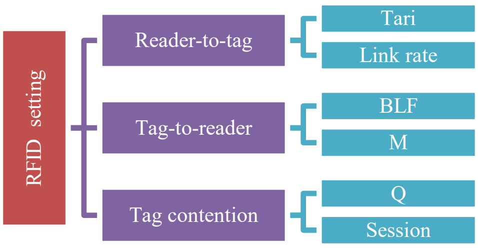


Figure 1. RFID setting

The tag communicates with the reader using either FM0 or Miller sub-carrier encoding. The RFID tags encode the backscattered data using either FM0 baseband or Miller modulation of a subcarrier at the data rate of transmission. The response back from the tag is detected and decoded at the reader ends. Miller was used to avoid interference.

Next, the Backscatter Link Frequency (BLF) was selected. BLF is the raw signalling rate. There are two options: i.e. 250 kHz and 640 kHz. The 250 kHz was selected because the application of Miller encoding forces the use of a BLF equal to 250 kHz, as higher frequencies, only support the use of FM0 encoding. Therefore, Miller was selected. The next setting is Type A Reference Interval (TARI) (ISO / IEC 18000-6-A) or also known as TARI. EPC Gen 2-compliant readers use pulse interval encoding (PIE) to code binary data. TARI is explainable through the analogy of morse code where TARI can be said to control the length of a dot (or dash). A binary '0' is indicated by a short, high-level pulse, followed by a low pulse of equal length. The length of a TARI can vary from 6.25 to 25 µs, e.g. 25 µs, 12.5 µs and 6.25 µs. The 6.25 µs TARI was selected to provide a chance for any weak energy tag to respond to the reader.

Link rate control how quickly the dots and dashes are sent. ‘M’ value modifies the way the tag communicates back to the reader and controls how many symbols are repeated. The ‘M’ value is set to 8. Q slot number assign from reader to tag. Dynamic Q is used when the number of tags is unknown otherwise Static Q is used. The Q value is set to 4. From the experimental test, the 868 MHz band was selected as the communication frequency between passive RFID tags and the RFID reader.

3. Experimental Setup

In this work, a total of 30 passive RFID tags were used where 6 tags were placed (arranged 3 by 2) on each side of the container and 6 tags were also placed on a cardboard placed inside the container, as shown in Figure 2. The RFID tags were placed vertically. The tags used in this work is UHF RFID

Alien 9662 H3 Wet Inlay EPC Rewritable. As shown in Figure 2(c), each tag was labelled with an initial character such as A, B, C, D and IN which represent Side A, Side B, Side C, Side D, and Side IN (inside the container), respectively. For example, on Side A, each tag was labelled as A11, A12, A13, A21, A22, and A23. Tags have 10 cm separation from each other horizontally and 14 cm separation vertically as shown in Figure 2(b). Meanwhile, the RFID reader is the m6e reader from ThingMagic [11] attached to a 6 dBi directional antenna. The reader is connected to a personal computer serially for data collection. The RSSI value from the tag was obtained through Universal Reader Assistant (URA) software [12] and puTTy. Some of the settings for the reader were configured as previously mentioned and a frequency selection test was conducted to select a frequency as provided in Section 3.1.

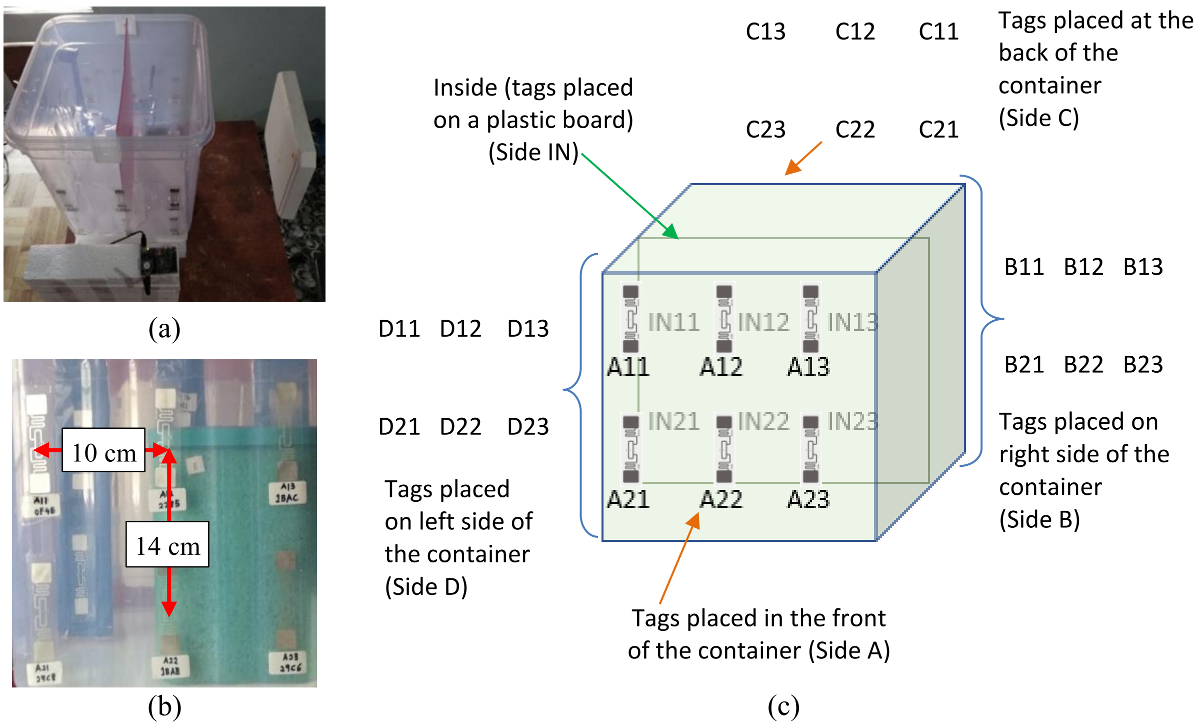


Figure 2. (a) Actual setup of the experiment, (b) separation distance between RFID tag on the same side, and (c) RFID tags position of each RFID tags attached to the container.

3.1. Frequency Selection

Test using a frequency in the range from 865 until 928 MHz was run one after another. A total number of 30 passive tags were used and the number of unique EPC were recorded as plotted in Figure 3.

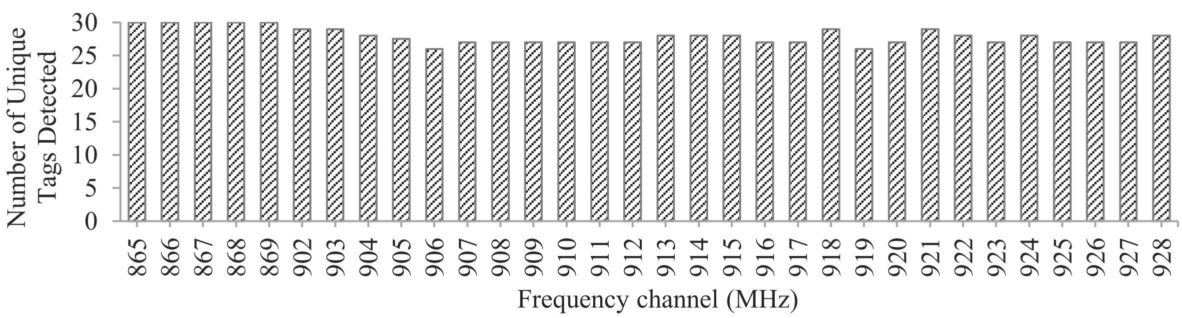
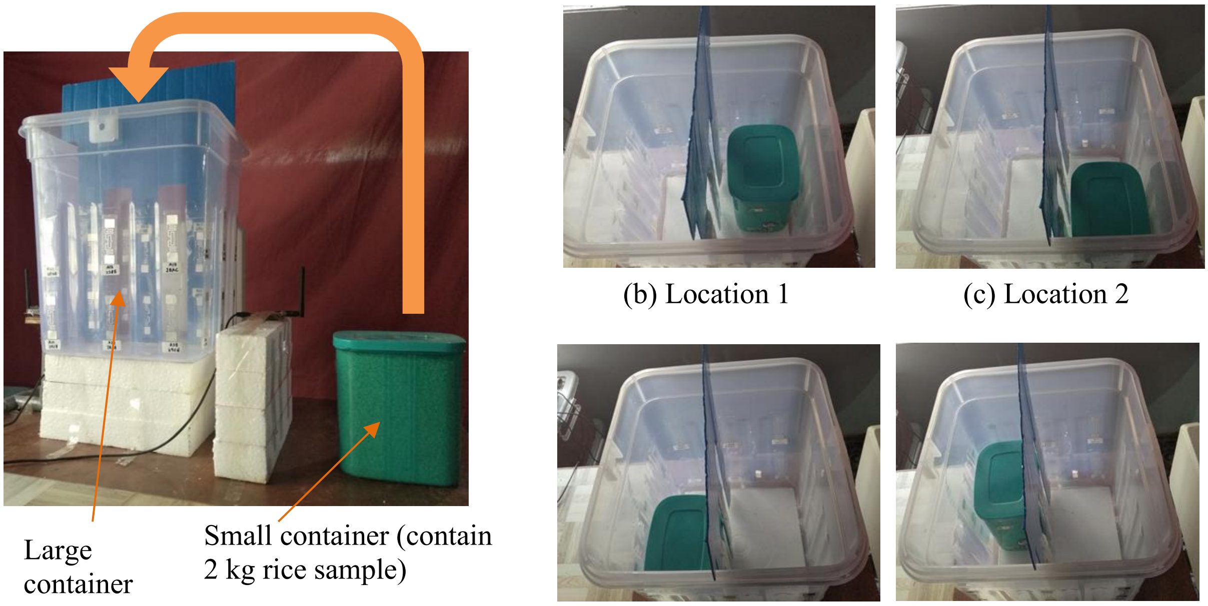


Figure 3. The number of unique tags detected per frequency channel.

The result plotted and shown in Figure 3 indicates that only frequency channels 865, 866, 867, 868 and 869 MHz can detect all 30 unique EPC or tags. Meanwhile, frequency channels in the range 902 to 928 MHz are unable to detect all 30 unique EPC or tags. Hence, channel 868 MHz will be used for the rest of the test.

3.2. Moisture Detection

The method to prepare the rice sample for the test was used from our previous studies [10][9]. The rice sample from henceforth will be referred to as the sample. 2 kg rice was moistened to the moisture content of 25%, 40% and 45%. Meanwhile, for the 0% test, the container was left empty. For 12% moisture content, the rice was taken from the packaging directly without the moistening process. Hence, there are 5 moisture condition levels tested which are 0 (empty container), 12% (original moisture content without moistening process), 25%, 40%, and 45%. The moisture content range value selected for testing is large because this is a preliminary test in which the authors aim to investigate the possibility of using the RFID arrays to detect the moisture content and location of the sample. Figure 4 and Figure 5 show the four different locations of the rice sample in the actual setting and graphical representation, respectively.



(a) Test setup
(b) Location 1
(c) Location 2
(d) Location 3
(e) Location 4

Figure 4. Sample location inside the large container. (a) Actual test setup, and location of the sample (b) Location 1, (c) Location 2, (d) Location 3, and (e) Location 4.

4. Result and Discussion

In this research, a total number of 30 passive tags were used. Figure 5 shows the illustration of the test setup from the top view. From the illustration, some tags are predicted will be affected by the wet rice. To support the hypothesis, the average of the RSSI value measured for each tag when the sample was placed at four different locations were plotted as shown in Figure 6. Both Figure 5 and Figure 6 show that tags on Side C are not affected by the changes of moisture in rice because they are directly facing the antenna. However, some tags on Side A, Side B, Side D and Side IN (tag placed on a board that later was placed inside the container) are affected due to the sample location.

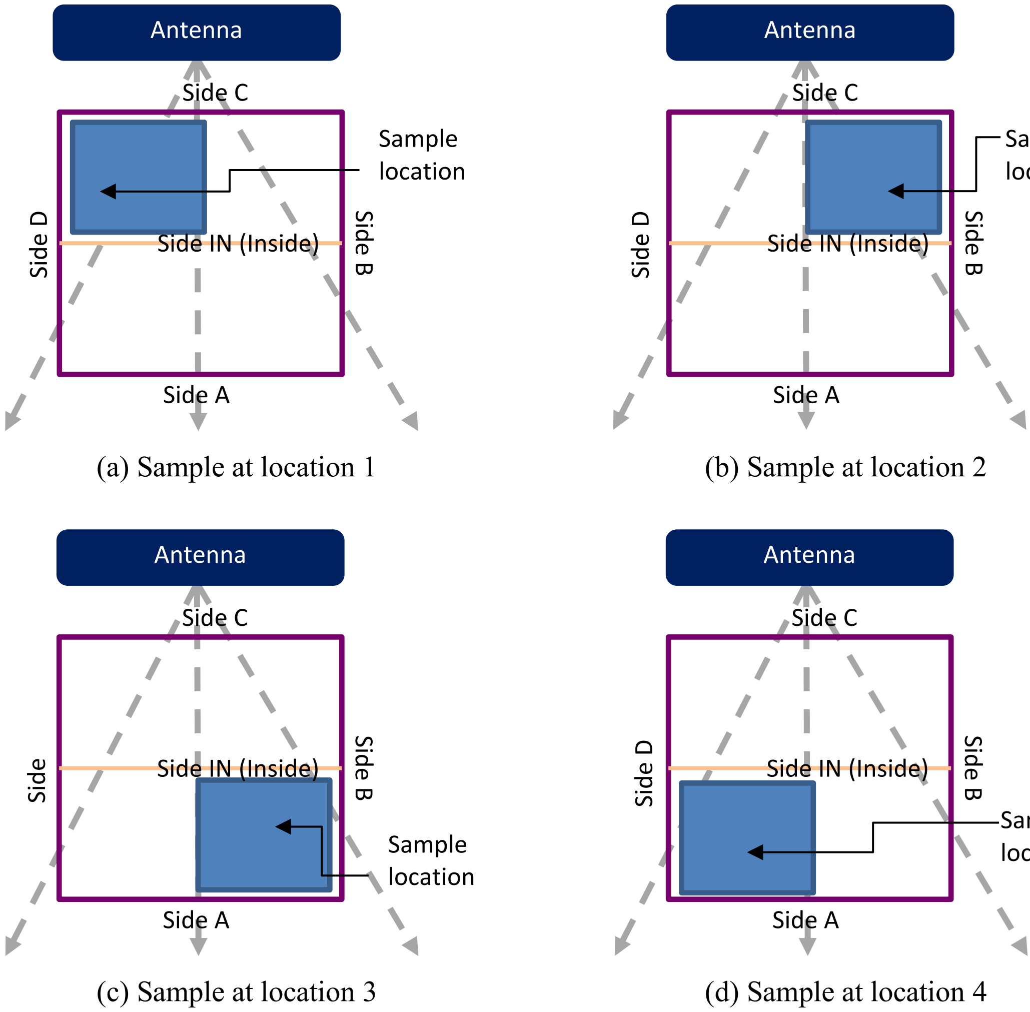
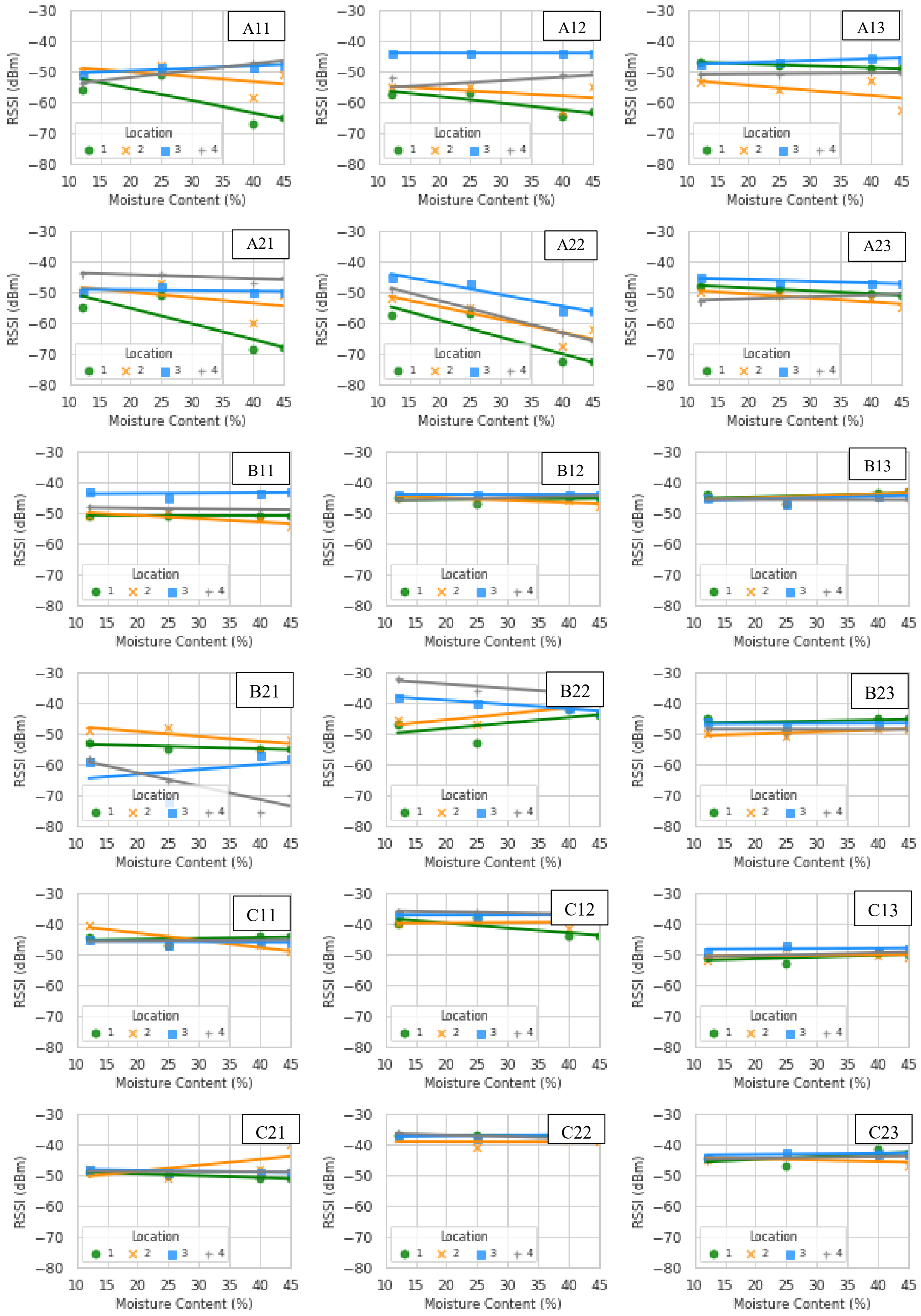


Figure 5. Top view of the container with four different locations of sample

Figure 6 shows the plot of each RFID tag. Each plot is the average data of RSSI value measured for each tag for different moisture content and sample location. The circle marker (green) represents the average RSSI data for location 1, the star marker (yellow) represents the average RSSI data for location 2, the box marker (blue) represents the average RSSI data for location 3, and the plus marker (grey) represents the average RSSI data for the location 4.

Based on Figure 6 (plot labelled A11, A12, A21 and A22), the data at location 1 shows a decreasing pattern as the moisture of the sample increased. This is because the sample partially blocks the energy radiated from the antenna to the tags. Hence, the reduction of the RSSI value is caused by the reflection of the antenna by the tags. Meanwhile, the tag at positions A13 and A23 is not affected since there is a clear path between the antenna and those tags.

Tags located on Side C, as previously deducted, are not affected by either the increasing moisture content or sample location because the tags are located directly facing the antenna, hence, no obstruction between the antenna and the tags on Side C. Meanwhile, some tags on Side B and Side D are affected by the location of the sample, since the RSSI value decreased as the moisture content increased. For example, tag B21 is affected when the sample located at locations 4, D12, D13, D22 and D23 are affected when the sample at location 1. It also can be observed that the tags located at Side A and Side IN are mostly affected by the location of the sample.


A11
A12
A13
A21
A22
A23
B11
B12
B13
B21
B22
B23
C11
C12
C13
C21
C22
C23
RSSI (dBm)
Moisture Content (%)
Location
1
2
3
4
−30
−40
−50
−60
−70
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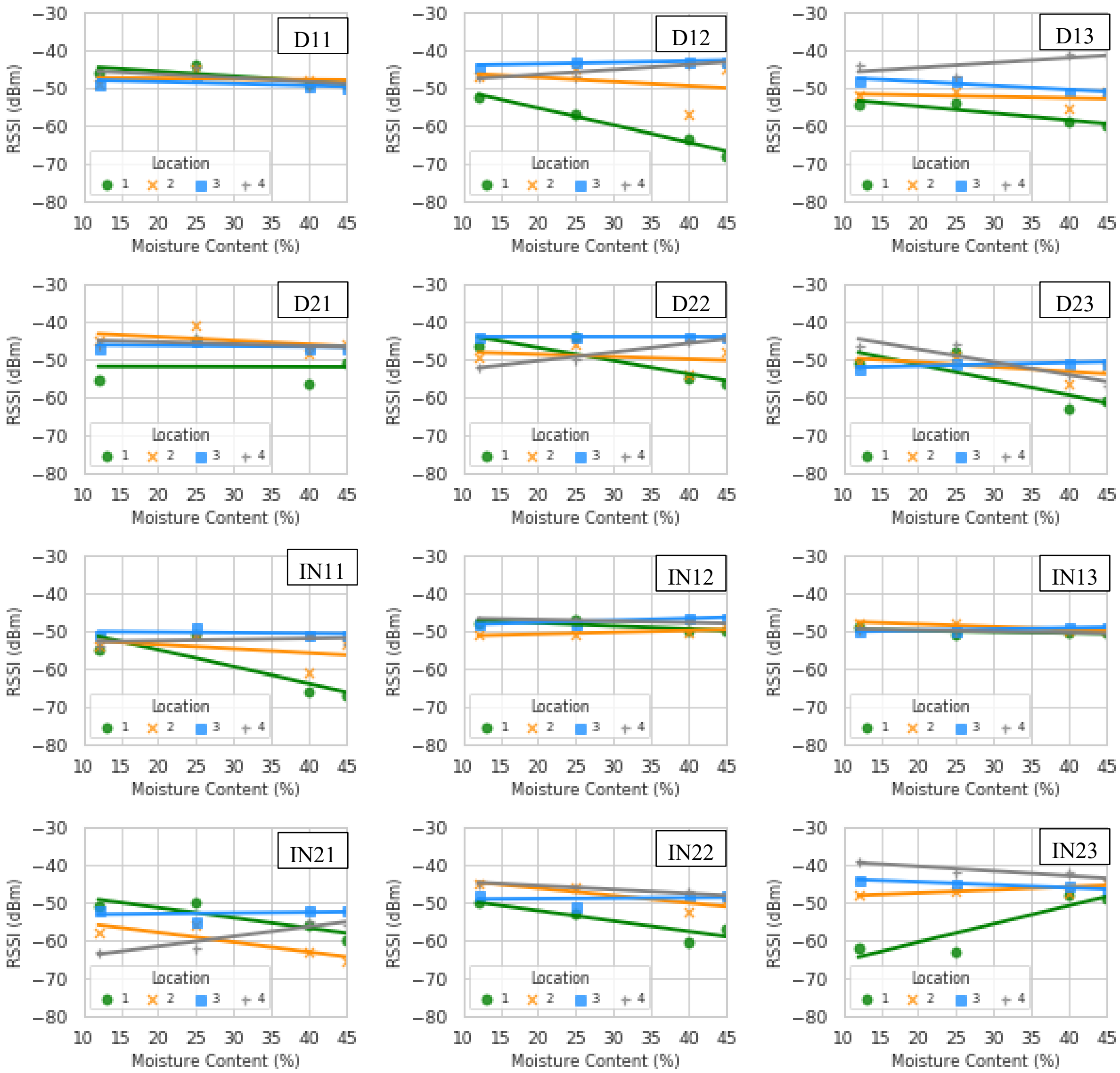

Figure 6. RSSI value of each RFID tag (30 passive tags) versus moisture content of rice sample at four different locations of sample.

5. Conclusion

The tags on Side C are not affected by the changes in the moisture content of rice because they are directly facing the antenna. Besides that, only some tags on Side A, Side B, Side D and Side IN (tag placed on a board that later was placed inside the container) is affected due to the sample location.

Based on the results presented in Figure 6, the result suggests that arrays of the RFID tag can be used to localize the location of the wet rice. However, further works need to be conducted by filling up the large container with rice. Besides that, a smaller range of moisture levels of the sample needs to be used (e.g., 10%, 14%, 20%, 25%, and 30%). Moreover, deep learning also can be used to further improve the measurement of the moisture content of rice.

Acknowledgments

This research work was funded by the Ministry of Higher Education (MOHE) Malaysia under grant Transdisciplinary Research Grant Scheme (Grant No.: TRGS/1/2018/UNIMAP/02/4/1) titled

"Determination and Characterization of Radio Frequency Signal for Moisture Sensing in Rice Grain Silos".

References

[1] M. S. M. Abdullah, M. H. F. Rahiman, A. Zakaria, L. M. Kamarudin, and L. Mohamed, "A review on moisture measurement technique in agricultural silos," in *IOP Conference Series: Materials Science and Engineering*, 2019, vol. 705, no. 1, doi: 10.1088/1757-899X/705/1/012001.
[2] A. A. Almaleeh *et al.*, "A Review on the efficiency and accuracy of localization of moisture distributions sensing in agricultural silos A Review on the efficiency and accuracy of localization of moisture distributions sensing in agricultural silos," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 705, no. 2019, 2019, doi: 10.1088/1757-899X/705/1/012054.
[3] N. A. M. A. M. Ramli, M. H. F. H. F. Rahiman, L. M. M. Kamarudin, A. Zakaria, and L. Mohamed, "A review on frequency selection in grain moisture content detection," in *IOP Conference Series: Materials Science and Engineering*, 2019, vol. 705, no. 1, doi: 10.1088/1757-899X/705/1/012002.
[4] M. Asefi, I. Jeffrey, J. LoVetri, C. Gilmore, P. Card, and J. Paliwal, "Grain bin monitoring via electromagnetic imaging," *Comput. Electron. Agric.*, vol. 119, pp. 133–141, 2015, doi: 10.1016/j.compag.2015.10.016.
[5] C. Gilmore, M. Asefi, K. Nemez, J. Paliwal, and J. LoVetri, "Three dimensional radio-frequency electromagnetic imaging of an in-bin grain conditioning process," *Comput. Electron. Agric.*, vol. 167, no. October, 2019, doi: 10.1016/j.compag.2019.105059.
[6] C. Gilmore, M. Asefi, J. Paliwal, and J. LoVetri, "Industrial scale electromagnetic grain bin monitoring," *Comput. Electron. Agric.*, vol. 136, pp. 210–220, 2017, doi: 10.1016/j.compag.2017.03.005.
[7] M. Asefi, C. Gilmore, I. Jeffrey, J. LoVetri, and J. Paliwal, "Detection and continuous monitoring of localised high-moisture regions in a full-scale grain storage bin using electromagnetic imaging," *Biosyst. Eng.*, vol. 163, no. 2017, pp. 37–49, 2017, doi: 10.1016/j.biosystemseng.2017.08.015.
[8] R. Berkley, "Measuring soil moisture with radio-waves," The Ohio State University, 2016.
[9] N. Azmi, L. Munirah, L. Mohamed, N. A. Abdul Latiff, A. Zakaria, and M. H. Fazalul Rahiman, "Influence of Moisture Content in Rice on Radio Signal Strength Indicator Readings at 2.4 GHz," in *2019 IEEE International Conference on Sensors and Nanotechnology*, 2019, pp. 1–4, doi: 10.1109/SENSORSNANO44414.2019.8940086.
[10] N. Azmi *et al.*, "RF-based moisture content determination in rice using machine learning techniques," *Sensors*, vol. 21, no. 1875, Mar. 2021, doi: 10.3390/s21051875.
[11] JADAK, "ThingMagic UHF RFID Modules Development Kit," *ThingMagic RFID*, 2020. https://www.jadaktech.com/products/thingmagic-rfid/thingmagic-uhf-rfid-modules-development-kit/.
[12] S. Hardware, "Universal Reader Assistant User Guide."