Test 1: Packaging effects on the RFID tag

Objective

Evaluate whether common packaging materials measurably affect RFID signal strength (RSSI) and read performance.

Experimental Conditions

Four packaging conditions were tested:

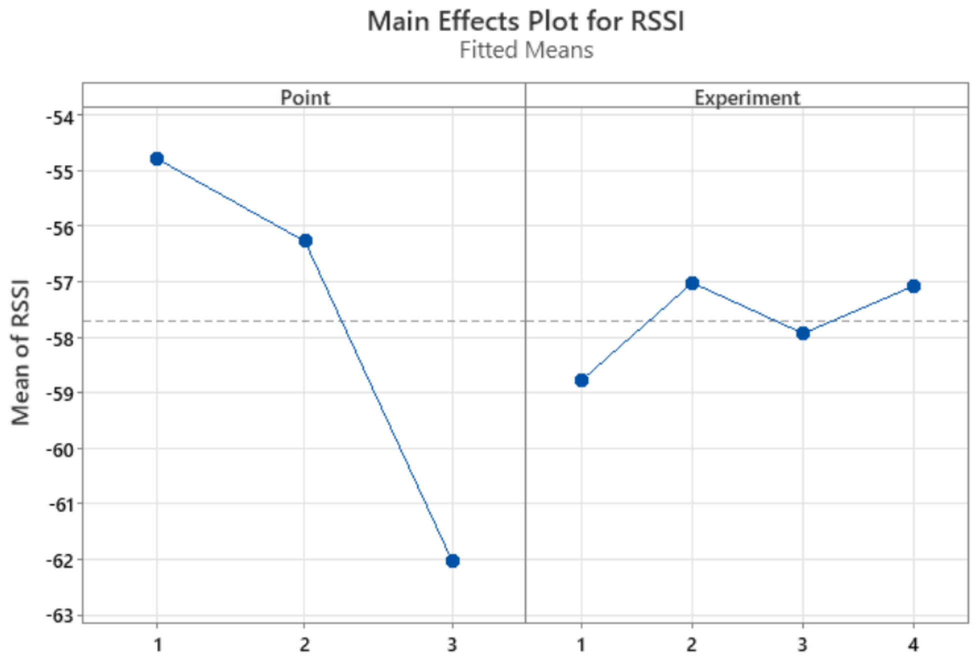
1. **Baseline:** RFID tag only (no packaging)
   Cardboard box: Tag placed in a cardboard box
2. **Plastic bag:** Tag placed in a plastic bag
3. **Cardboard + plastic:** Tag placed in a cardboard box and inside a plastic bag

RFID Tag [FC73]	Cardboard Box	Plastic Bag	Cardboard and Plastic Bag
			

Experimental Factor and Levels

Packaging was treated as a categorical factor with four levels:

- 1 = Baseline: RFID tag only (no packaging)
- 2 = Cardboard: Tag placed in a cardboard box
- 3 = Plastic: Tag placed in a plastic bag
- 4 = Plastic + Cardboard: Tag placed in a plastic bag and then placed in a cardboard box



Main Effects (RSSI)

Based on the Main Effects Plot for the RSSI experiment, the signal slightly improved under the packaging conditions compared to the baseline. However, packaging does not appear to be a significant factor affecting RSSI overall, except for Antenna 2, which showed a more noticeable change in RSSI across packaging levels.

Key Findings

- Packaging produced minor changes in RSSI, with a small improvement trend relative to baseline.
- The effect was not consistent or large enough to treat packaging as a primary driver of RSSI variation.
- Antenna 2 was the only antenna showing a clearer sensitivity to packaging compared to the others.

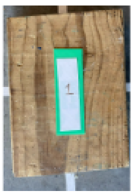
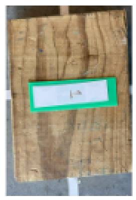
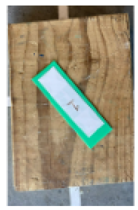
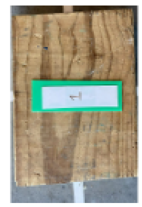
Conclusion

For the tested setup and packaging materials, packaging has a limited impact on RFID RSSI and is unlikely to meaningfully affect localization performance or model results in most cases. Packaging can be treated as a secondary factor, with the exception that Antenna 2 may require closer attention in future testing or analysis.

Test 2: Orientation of the RFID Tag

Objective

The purpose of this test was to determine whether tag orientation (angle) impacts RFID performance, specifically read counts and RSSI.

0°	45°	90°	135°	180°	225°	270°	315°
							

Analysis Method

An ANOVA was conducted for Antenna 1 and Antenna 2 to evaluate the effect of angle on the measured outcomes.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Point	8	710353	88794	11.66	0.000
Angle	7	1127753	161108	21.16	0.000
Error	56	426281	7612		
Total	71	2264387			

Read Count Antenna 1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Point	8	245115	30639	1.13	0.358
Angle	7	932206	133172	4.91	0.000
Error	56	1518301	27113		
Total	71	2695621			

Read Count Antenna 2

Results (ANOVA)

For read counts, the ANOVA results show that angle is a statistically significant factor for both antennas:

- Antenna 1: p-value for angle = 0.000
- Antenna 2: p-value for angle = 0.000

This indicates that orientation significantly affects read counts.

In contrast, orientation does not meaningfully affect RSSI under the tested setup (i.e., RSSI remains relatively stable across angles compared to the changes observed in read counts).

Key Findings

- Orientation affects read counts: Tag angle significantly changes how often the tag is successfully read (Antenna 1 and 2 both show strong statistical significance).
- Orientation does not affect RSSI: RSSI is not substantially driven by orientation in this experiment, even though read reliability changes.

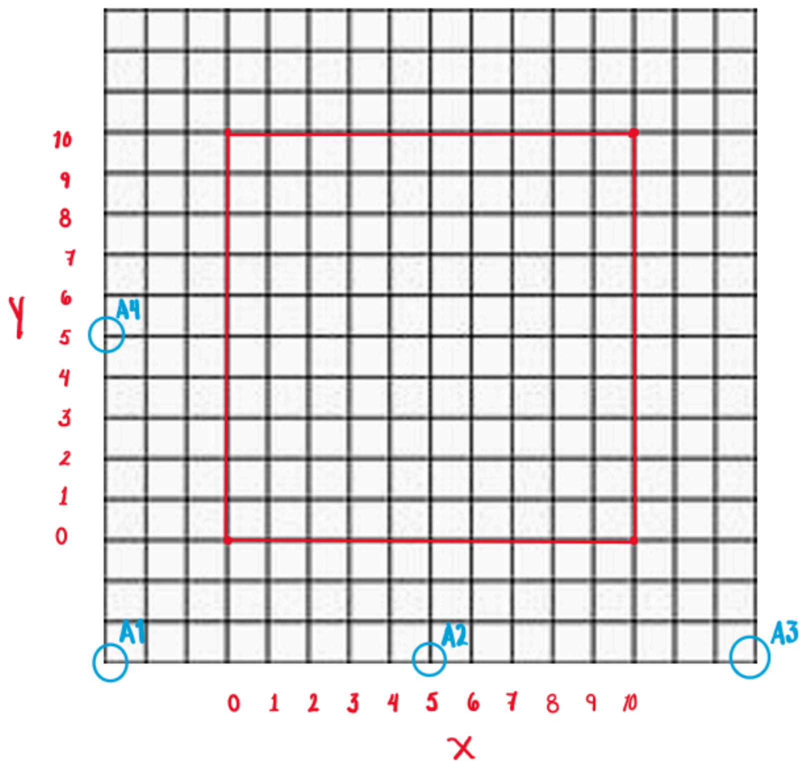
Conclusion / Practical Implication

Because tag angle significantly impacts read counts, orientation must be controlled during data collection. As long as the tag angle is kept constant and the resulting read counts meet acceptable thresholds, the collected data can be considered reliable for analysis and modeling.

Test 3: Recreation of the Final Dataset (Capstone 2022–2023, 11×11 Grid)

Objective

The purpose of this test was to recreate the final 11×11 RFID dataset from the 2022–2023 capstone project and verify whether the RSSI measurements were consistent with the prior year's dataset.

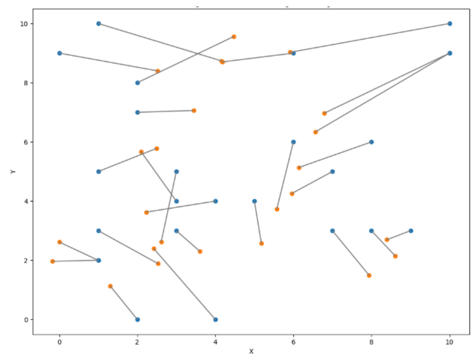


Approach

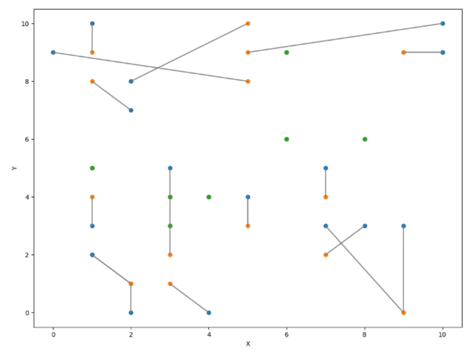
We replicated the prior-year data collection as closely as possible using the available information, which primarily included the approximate antenna locations used in the original setup.

Results

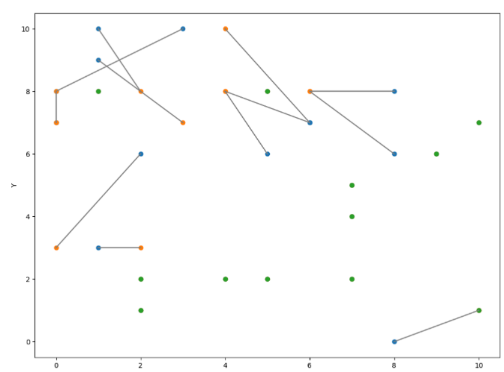
- RSSI consistency: The recreated dataset did not produce RSSI measurements that matched the prior-year dataset. The RSSI patterns across the 11×11 grid were different from the 2022–2023 results.
- ML prediction performance: Despite the RSSI mismatch, the ML model produced acceptable localization predictions on the recreated dataset, indicating that the recreated data still contained learnable signal patterns for prediction.



Linear Regression



Decision Tree



K-Nearest Neighbor

Interpretation

The difference in RSSI relative to the 2022–2023 dataset is expected because the prior setup could not be reproduced precisely. Beyond approximate antenna placement, the following key variables were not recorded and therefore could not be controlled:

- Antenna height
- Antenna tilt (up/down)
- Antenna alignment/orientation (left/right pointing direction)

RSSI is highly sensitive to these geometric factors; even small deviations can shift signal strength distributions across the grid. However, the ML results suggest that internal consistency within the recreated dataset was sufficient for the model to learn the mapping between RSSI features and grid locations, even if the absolute RSSI values differed from last year.

Conclusion

Although the recreated setup did not replicate the prior-year RSSI distribution, the dataset still supported usable ML-based localization. For future reproducibility and year-to-year comparability, the antenna configuration should be documented with measurable parameters (height, tilt angles, and alignment references), not just approximate location.