Smart Factory Logistics

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Declaration

I certify that this work does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Hayden Archibald

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Executive Summery

The project looks at smart factory logistics for REDARC Electronics, a local electronics manufacturing company. REDARC has over 1000 discrete factory and warehouse locations that components and finished goods are tracked. This is requiring manual updating of database software, to reduce the labour in this process a system of automating the tracking of parts is proposed. Smart is defined as industry 4.0 and connected data driven process, factory refers to the location and logistics the flow of material. Previous research led to RFID as a preferred system for this application and REDARC supplied some equipment for validation and testing. Radio-frequency identification (RFID) is technology that uses electromagnetic fields for tracking tags without the need for line of sight and its more automated than the likes of a barcode system. Being a wireless communication system there is the opportunity for data to be lost or degrade depending on the setup and environment. The aim of this project is to perform a factory trial of a system for stock tracking suitable for the REDARC environment as a proof of concept. The project was conducted with industry partners at REDARC that have supplied some equipment from previous investigations. The project was completed over 6 months produced clear finding for REDARC to consider when creating a business case on the benefits of a complete installation. Testing evaluated multiple types of RFID tags to find the optimal equipment combinations for the proposed system. A system featuring a read portal where antennas would be positioned at a gateway and the passive tags would be read when a trolley carrying materials in tubs pass the gateway was the outcome for the most suitable system for the intended use.

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Introduction

REDARC Electronics is a manufacture of electronic products predominantly for the automotive sector. Research, design, development and manufacturing of their products is all based at the factory site in Lonsdale, South Australia. REDARC is heavily invested in industry 4.0 and advanced manufacturing having recently upgraded the facility and added more automated systems. Due to the cost of manufacturing in Australia, REDARC is progressing to a vision of a smart factory that is data driven with high levels of efficiency and optimisation, which is required to remain competitive in the market.

At REDARC, small tubs are used to move components and finished goods around the factory. An Enterprise Resource Planning (ERP) system is used to track locations of items around the factory with over 1000 discrete locations in the factory and warehouse. Currently these records are updated by manual human input, where staff input the data into the system and record the storage location. To locate products tablet computers are used to look up where items are stored and record the product and quantity moved. The current system exposes the chance for human error when handling data and the processing requires labour time for the updating.

A system that automates the tracking of parts in tubs, that would remove the labour cost of the inventory transaction has been proposed by REDARC. A system potentially would allow for a higher fidelity of information to be extracted i.e. Tracking individual serial numbers over total number of products. REDARC has also recently commissioned a pair of mobile robots for goods transportation and combining these systems will further increase the automated capability of the company, where stock can be moved without human interaction.

Previous work has found that RFID (Radio Frequency Identification) to be the preferred technology for the REDARC factory environment. This research performed static bench tests on antenna and tag combinations an provided a list of preferred tags (Nguyen and Ludbey, 2019). The next stage in this research is to conduct a larger scale trial in the REDARC factory as a proof of concept to present to REDARC for consideration. REDARC has also engaged with consulting companies that have indicated investigating an RFID system to be of value.

Radio Frequency Identification or RFID is wireless a communication system where electromagnetic fields are used to identify tags. A RFID system consists of a reader that is interfaced with a computer. Attached to the reader are antennas which are the transmitter and receiver of the system. Then tags are used to attach to objects. The tags can come in 2 forms passive and active. Active tags transmit their own signal and have a power source these are less common and more expensive. Passive tags are more common and the preferred solution of this project which are activated when energised by the signal from the antenna and then reflects signals back that is picked up. RFID systems are commonly used in many industries and have been recommended by consultants to REDARC Electronics as a way to increase capacity in their manufacturing operations.

Current literature has indicated that the accuracy and quality of RFID seems vary with the product and application and taking due diligence in testing a system will have benefits. RFID is proven to reduce labour costs in a manufacturing process and can help provide greater levels of automation. Research has mostly been conducted in controlled environments and case studies are limited, the findings of this project looking at results of a factory trial will provide some interesting results due to the noise and interference of a real-world application.

The main goal of this project is a smart factory logistics management system by developing an inventory identification and tracking system. The system is aimed to utilise RFID technology as specified by the industry partner REDARC Electronics. This system will be required to integrate into the current factory system and be adaptable to change. The main outcome for this goal is a larger scale trial inside the REDARC factory as a proof of concept for further investment by REDARC.

Goal	An inventory identification and tracking system
Specific	The project will be conducted by myself in conjunction with REDARC to develop a system for automatically measuring stock movement at the REDARC factory. The project will be run over the next 6 months with the aim to reduce labour costs and increase efficiency in the manufacturing process.
Measurable	Success will be measurable with the total number of items able to be simultaneously monitored at the end of the project and the accuracy of system in producing correct data.
Achievable	It is believed that this project is achievable with the resources provided and time frame available. Other companies have RFID systems installed that fit their needs so it is assumed a system can be developed to work with the REDARC environment.
Relevant	This project is relevant to industry 4.0 and advanced manufacturing interests of REDARC as they are an Australian manufacture and need to remain globally competitive.
Time-Bound	This project is planned to be completed within 6 months and the Gantt chart and work plan reflect this. Project risks have been accessed and this is deemed to be a realistic deadline.

A secondary goal is to validate the current equipment sourced for suitability for the REDARC Environment. The REDARC factory uses multiple types of tubs that transport a range of goods made from different materials around many pathways in the production and warehouse areas of the facility. An outcome of the project is to produce useful information from the data generated with the RFID system, with the end goal for a system would be for it to autonomously update REDARC's Enterprise Resource Planning stock management system with stock transits in conjunction with mobile robots and human movements.

The currently at REDARC all stock moves are manually entered into the Enterprise Resource Management (ERP) software, this is done by production stuff on desktop PCs at work cells and on Microsoft Surface tablets attached to trolleys that material handlers operate. There are 2 production processes that have been flagged as a starting point for an RFID system. The first system is the movement of finished goods from the production space to the warehouse. Currently a production team member has to register that the products have completed production, a material handler will collect a trolley of finished goods and move them to the storage in the warehouse where the quantities will be counted, and system updated to state the new location of the products. Products have defined storage bays that remain constant. Currently the movement of the trolleys is mixed between human and robot transport, but work is in progress to automate the transportation more with mobile robots that REDARC has purchased. Once functional the automated delivery will not have a human involved with the transportation and therefore requires automation of the ERP software updating. The other process that is listed to be experimented with is the Kanban system that REDARC has for raw material flow. The Kanban system operates on a circuit with stages and ensures that raw material is always available for the production of goods. Kanban uses pull control and tubs are refilled once emptied. The intended implementation for RFID with this system is that it could be automatically identified if tubs are moving into the warehouse or moving into the production spaces and update the needs accordingly.

An RFID system would benefit REDARC by reducing the requirement for manual updating of the ERP system of the stock movement, this would reduce labour in the manufacturing process and allow for staff to be utilised in higher value roles. The data delivered by an RFID system will be more accurate and have a higher fidelity of information than previously available which will allow from more data driven analysis and decision about the production process.

Potential risks to implementing an RFID system is it creates more steps in the material flow process and doesn't add any value. There is the opportunity that an RFID system may not to log the movement correctly this could come from various types of miss reads.

There is a gap in the knowledge about how an RFID system will operate in the environment at REDARC. REDARC produces a range of products that are made from different materials and in a range of shapes and sizes. The company wants to ensure that nothing will block a signal and cause the system not to read a tag as this could cause a major issue in the documentation of stock.

The importance of the research in this report is that it will provide confidence to the management at REDARC that and RFID system would be suitable and functional within the REDARC factory. It will provide quantifiable results about the best preforming equipment and validate any previous research and assumptions made.

The main research problem to be solved is how can RFID technology be used in the context of the REDARC environment. With an aim to confirm the RFID reader and tag combinations that investigated in previous work, select an area in a factory to preform factory trials. Within the factory trial demonstrate the functionally of an RFID system including tubs being read as the pass the reader, test multiple tub types and good types. Look at what causes missed reads on the system and best practice for reliable results.

The hypotheses of is that an RFID system will be suitable for the intended use case. This due supported by the previous research by REDARC, information provided by consultants. The system is believed that it will suitably satisfy the requirements but to confirm this before pitching for money the research and testing must be conducted.

The first phase of the project is to gain familiarity with the equipment supplied. The results from previous tests with this equipment will be validated which will allow preferred RFID tag/s to be selected.

The second phase is to move onto an expanded testing plan still within a controlled static environment. This phase will allow for simulation to occur that will form a stronger understanding on action required in a trial.

The third main stage is for a trial in the factory. This stage introduces noise and is a more dynamic environment than the control testing. By this stage it is hoped that a lot of the potential quirks in the system have been discovered allowing for a smooth and successful trial.

1.0 Equipment Validation
- 1.1 Equipment Familiarisation
- 1.2 Validation Testing
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  - 1.2.2 Test effects of tag attached to tubs of different materials on readability including anti-static tubs
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- 3.8 Investigate implementation with mobile robots
- 3.9 Investigate data output from system for Enterprise Resource Planning software
- 3.10 Review Business case

The coronavirus pandemic limited access to the company facility for a major component of the duration of this project which limited the opportunities available to complete testing on site which was the intention of the project scope. The company's production also increased during this pandemic which reduced the flexibility to make changes and tests within the facility for experimental purposes.

This report will detail the experimental procedures conducted and results gained. Starting with a review on the literature found on integrating RFID systems in to manufacturing plants, the possible integration methods, and measuring system performance. Early chapters walk through the results from equipment validation and controlled static testing. The final chapters detail the finding from factory trials the form and confirm the equipment recommendations for REDARC. Scenarios that potentially could degrade an RFID system are tested as part of the due diligence in creating a business case to minimise risk and increase understanding of a system. The results are summarised and concluded at the end of the report and outline the stages that future work would undertake.

Literature Review

In a previous study investigating automated tracking systems for smart factory commissioned by REDARC and conducted by students from the University of Adelaide a conclusion was derived that a passive RFID system was to be proposed to REDARC as a solution for automated stock tracking (Nguyen and Ludbey, 2019). It was highlighted that further large scale testing should be carried out prior to the implementation of the technology in to the logistics system within the factory. The concept system developed by this report proposed a system of 20 ceiling mounted readers that would cover the factory and provide positional information of where goods were in the facility. Review with the manufacturing engineering team with REDARC outlined that they would like to take a different approach to the system and setup based on a system of gates that items would pass. This was recommended to REDARC from supplier and consultant.

A basic RFID consists of the (Durick, 2013) system requirements of a tag, transceiver and interface. The systems don't require line of sight unlike a label and barcode system. An removing the new for line of sight scanning and automating the process removes the labour component (Michael and McCathie, 2005), The read and right distances are stated to be between 5 to 500mm using a high frequency system and a UHF system could read RFID tags up to several metres (Durick, 2013).

The benefits of RFID systems have been well documented in reports and case studies. (Swedberg, n.d.) found that the return on investment for its system was 33% in 12 months, and a case study from NXP semiconductors (NXP Semiconductors, 2014) found clear benefits to reducing labour with its rack system that stored components in pods that were tracked in and out. When directly compared to barcode, QR codes and external printed labels, a RFID is system is more durable as the others are susceptible to damage from environmental conditions when exposed to temperature, moisture, debris and friction. (Durick, 2013)

(Jones and LaGrega, 2014) Out lined six steps to a successful RFID asset-tracking system the steps outlined were:

Business case development and prioritization, Business process and workflow mapping, Site assessment, Architecture development and component sourcing, Installation, tuning and testing, Communication and training, For the scope of this project the first 3 stages have been partially delivered from the company and last 2 stages are beyond the project scope. (Ngai et al., 2012) also discussed that resources and support are critical to achieve expected performance, but also called for more studies to be conducted to identify the key indicators to success in a system.

RFID systems can come in many forms some examples of possible implementation are (Feng et al., 2020) case study with about using big data analysis as a component of industry 4.0. Where the RFID system was used to track movement of forklifts by having a reader on the forklift and tags on the ground, tags were also on the pallets. This allowed the knowledge of what pallet was on the forklift, the position of forklift, and the position of pallet is delivered. This study used the data from the RFID system as it had time codes to assess the efficiency's in the workflow and wasn't focused on stock tracking for inventory management. This would be another benefit to a system but not part of the intended scope for REDARC.

Another method using pallets and forklifts by (Borstell et al., 2014) implemented a system that uses a RFID gate which a forklift travels through with a pallet. The pallet is tagged and that will register with the system for identification of the pallet. This system is combined with other processes for tracking of the stock with RFID only implemented at the gate. This is more like that intended method REDARC would like to begin with starting small and not trying to track everything like (Jones and LaGrega, 2014) has also suggested with a focus on high volume initially and focus on ensuring that the system is correctly integrated with other systems. Using gates or dock system were also listed as a form of implementation the report from (Jones and LaGrega, 2014).

(Michael and McCathie, 2005) Discusses the possibility for RFID systems to be extending into smart shelf concepts where item level tracking can occur. This would allow for systems like an automated checkout in a supermarket. This concept idea was experimented with by (Huang et al., 2015) by developing a smart rack. The system looked at 2 methods of finding a position of a tag. First method used the RSSI of the signal to estimate the distance a tag was away from the antenna and the other system used multiple antennas to record the angle of arrival of the signal. Measuring RSSI assumed that RSSI will remain constant at the different positions. This study led to a result where zones could be detected but was unable to successfully detect items by shelf on the racking but did outline future work was to be done using the phase of a tags reading as part of the algorithm. (Ni et al., 2003) presents a concept of LANDMARC an indoor location-sensing prototype system that uses RFID similar to the system by (Huang et al., 2015). Using multiple readers and measuring RSSI and to get around the RSSI issue of not being constant it sends multiple power levels and then model the results, this leave to have latency in the system. This system also relied on the assumption all tag have roughly same signal strength this was found to not be the case in study by Nguyen and Ludbey but it was not tested that multiple of same model tag had any differences.

In the context of this project it shows there is potential application once RFID tags are used that a more granular approach could be implemented but not currently a suitable stable system for this style application. This would not be a starting point for the REDARC system but if the tag infrastructure is in place it allows for this expansion in the future which strengthens a business case. Item level monitoring already occurs but is a manual process and handled in software and holds the assumption that it will be updated and moved correctly. Combining these models with a dock door that could identify the item and quantity that is to be moved into the warehouse it could be assumed that they would then be placed in the correct storage location. Tracking doesn't need to occur at the storage location if item only goes into a singular location and correct processes are followed.

RFID was implemented as part of the process workflow for tracking of production (Li et al., 2010). This aligned to more like a tub method if tracking was with a trolley or tub passing the system and then the information about the items would be pulled from another source from a database. If tags aren't positioned on the product and the system, the inventory management is still handled by the software and RFID system is more the movement component and making the assumption on the other systems and information being correct.

(Gan, 2019) proposed a model to find the best placement of tags and readers with a key finding that the shortest path would deliver the strongest results being maximum reader accuracy, read count and read strength. (Ahmed et al., 2007) highlights that typical read accuracy of RFID system is around 80-90% and with high quality equipment can be as high as 95-99% but then using more than 5 tags at a time can drop as low as 70%. The report proposed a virtualised way of a software implementation to improve this system performance in recording data to minimise error. This could also have been handled in hardware with more antennas to increase a read range and have redundancy. San Francisco International Airport reported reliability at 99.5% (Michael and McCathie, 2005).

and a consultant from meta group report 3-5% error rate. The report doesn't elaborate if this is failed read or missed data and if it comes from the tags or more the system integration. (Hameed et al., 2010) discussed data loss and how it could be handled, errors include duplications, false readings, and missed readings that will inherently occur. Applying filters can help with handling of duplications, false reading could occur from detecting object that are near by but not intended to be within range.

Metal fixtures and shelfing are noted to affect RFID systems by (Jones and LaGrega, 2014) and preforming feasibility tests and tuning the system help to ensure a successful implementation. (Michael and McCathie, 2005) also mentions metal and liquid to cause issue with RFID and determining a good tag position is critical. (Jones and LaGrega, 2014) also brings up interference from other radio frequency source like wireless networks, radios, and phones this could come from other companies neighbouring. These factors cannot be controlled and also flagged in (Nguyen and Ludbey, 2019) and a strong reason to have trials in the factory which is the core of this project.

(Mercer et al., 2011) studied into materials that degrade the performance of an RFID system by simulating RFID harsh environments. Other RF noise, metal, cement, and liquid will impede the performance of a system was mentioned in other studies. Test methodology involved applying tags to a carton of bottle water. This is not an uncontrollable issue for REDARC as currently as no liquid not from part of the normal material flow, but a water bottle could be present of the trolley through if a staff member was carrying it around as they pushed a trolley. It concluded that water could be tagged but would require direct line of sight or in other terms this could mean handling the tags to face the outer edge of a trolley towards and antenna and come back to for best results when distance is minimised.

It was also found that different types of tags have different properties and some tags can be insulated and more suitable in a harsh RF application much like the findings from (Nguyen and Ludbey, 2019).

This has highlighted that RFID systems are proven to be successful in industry at reducing labour cost and improving efficiency in a manufacturing processes and provide benefits to smart factories and industry 4.0 models due to the extra data available. From the academic studies looked at there was limited research conducted in a factory environment but the case studies from industry highlighted that testing equipment has benefits to have a successful system. It was highlighted that metals and other RF signal can effect a RFID system and testing to ensure that it would not create issues at REDARC is critical to present in a business case.

Chapter 1 - Existing Equipment Validation

1.1 Experimental Procedure

The antenna was setup with distance between it and the reader and associated computer to reduce possible interference. The initial sample set of tag had 18 options. These were

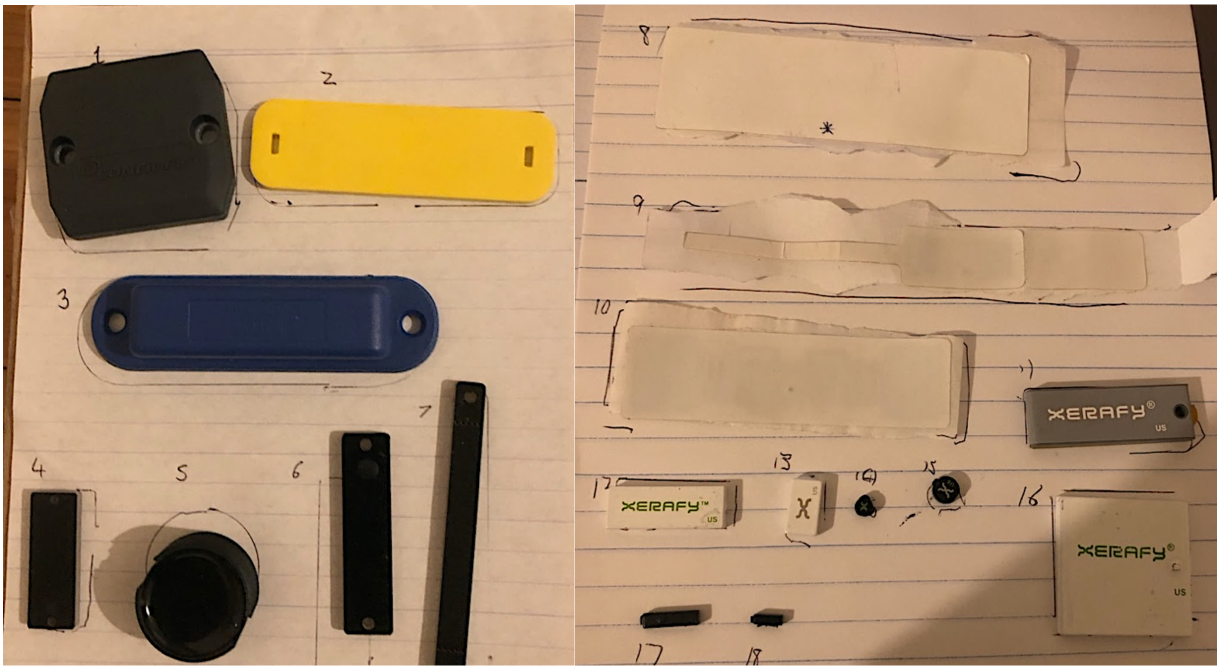


Figure 1: Initial RFID Tag sample set

numbered from 1-18 for the experiment.

At REDARC electronics there is multiple types of tubs that are identified by the colours and commonly are Red, White, Blue, Grey. All these colours are normal tubs of different defined sizes. There are also black tubs which are ESD tubs and the purpose of these tubs are they are conductive and will dissipate charge to prevent build-up of static and causing a shock to a circuit board which could damage components.

In most cases products are moved around the factory in plastic tubs but for bulkier goods the raw material could remain in the supplied packing usually cardboard box or special items that are supplied in a corflute tray. Items leave the production line normally also in trays and once again the bulkier goods will leave in shipper boxes.

The no contact test is for a base line so that the all the unique cases can somewhat be accounted for. It also will show if the normal tubs have an effect on the system to degrade the signal or if its just an effect of the signal being partially blocked.

Nguyen and Ludbey in their premilitary study tested with the tags contacting a metal sheet this was now replicated as deemed not to be applicable to the use case application described by REDARC.

The previous research of the equipment, (Nguyen and Ludbey, 2019) indicated that using the RFID tags in conjunction with ESD plastic tubs would have a negative impact on the distance that a tag could be read.

All movement within the room, furnishings, position of equipment, mounting point of antenna were controlled. The distance was measured with a tape measure on the ground starting at the antenna and ending at the wall. A ruler was used to ensure height from the ground remained constant as the tag was gradually moved back from the antenna until it was out of range. To ensure only one tag was being picked and that it was the correct tag all other tags were removed from the testing environment shielding used a mobile phone and container to hold down and block the tags from the system.

1.2 Results

Results showed in Figure 2 indicate that Tag 1,2,3,8,10 had the strongest signal strength when measuring the range that it could be detected in a controlled environment.

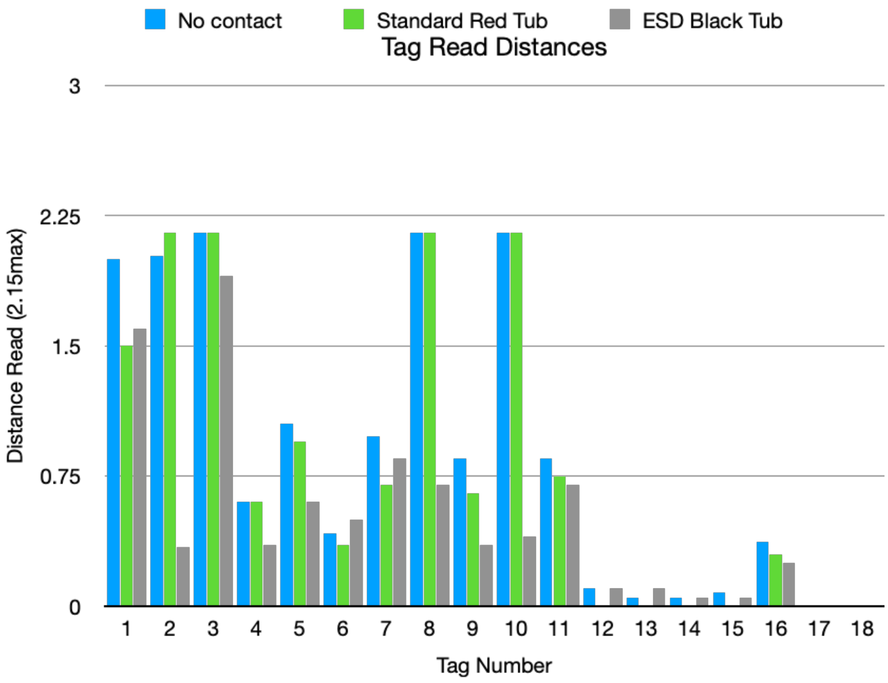


Figure 2: Maximum Read Distance of RFID tags

The tags that had the shortest read range in this test were 12, 13, 14, and 15. This is expected based on the intended use of these tags as they were more for close range application.

These tags that only had a small range will not be suitable for the application REDARC is planning for a RFID system.

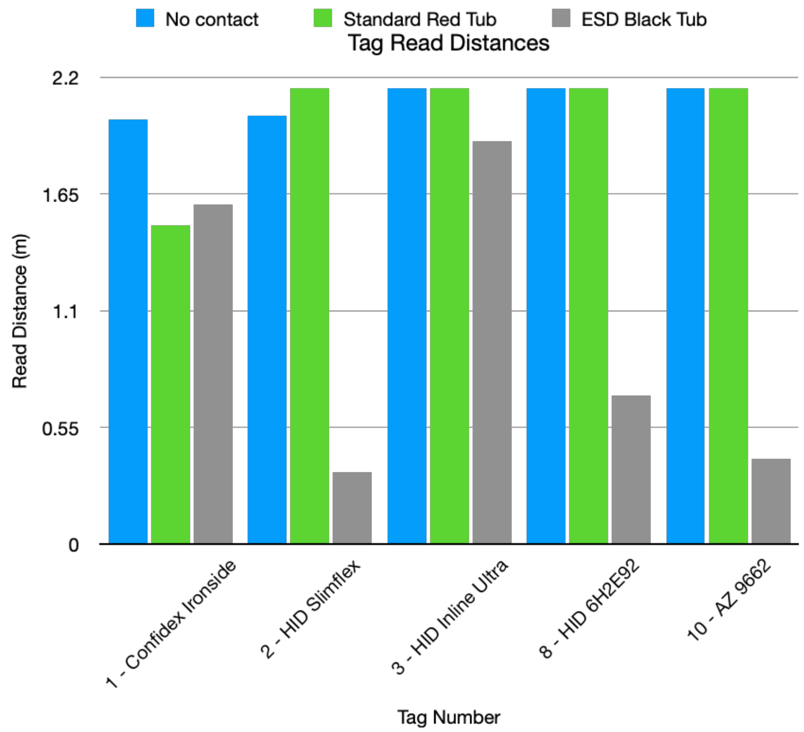


Figure 3: Maximum Read Distance of RFID tags Top 5

Figure 3 highlights the 5 tags that had the strongest readings leading to the furthest distances. The maximum distance that could be read was 2.15m but this was more than far enough for a real-world application. Tag 1 and 3 didn't suffer a strong lost when attached to the ESD tub this is because these models of tags are insulated all-purpose tags when compared to tag 2, 8, and 10 which are adhesive inlay tags. The other difference between these two types of tags is the insulated tags cost over $2 a tag and others are as low as $0.50 a tag. With over 1000 tags desired for a final system the cost difference is large. These findings are what was expected as it had been documented in previous research by REDARC and this reconfirmed and validated the results. REDARC in discussion decided that in the initial installation ESD tubs would not be used as the flow that requires these tubs is not part of the simple cases to implement.

The second test was to compare the antenna types with the tags to measure the effects if any. The same environmental conditions were controlled. The supplied test equipment kit came with 4 variations of antenna that could be used. each antenna was intended for a different use case. The list of antennas are as followed:

Ant1 Close Range – Times 7 A1001 NF

Ant2 Door Frame – Times 7 A8060

Ant3 Large Range – FEIG ISC.ANT.U270-FCC

Ant4 Control – Times 7 Slimline A5020

Due to space limitations the maximum distance that could be measured with the experimental setup was 2.15m. This was suitable from the results to still be valid as the intended use case for the system was for a doorway that's width would not exceed this distance.

1.2.1 Antenna 1

This was intended for close range application and the results show that tags need to be touching the antenna or very close range (within 10 cm) for data to be read. This tag would not be suitable for the use case intended at REDARC. Where this antenna could become useful is when registering tag to a system as due to the close read range of this tag it would be simple to isolate other tags from being read. This then would allow a single tag to be read and the serial number of tag recorded and the tag registering with the system.

1.2.2 Antenna 2

This antenna is intended for mounting on a door frame for an application where a tag is read as it passes through a door. The intended use for this antenna is suitable for the system goal at REDARC and in theory would be the best option. The read distance average from the 5 tags tested is 1.54m. This is with the normal default setting and no changes made to the system. The widest trolley used for goods transportation is the trolley used with the mobile robot system and is 0.88m wide. Current minimum doorway width on the route that tags take from warehouse section to production section is 1.2m, this is within the read distance of this antenna within these conditions.

1.2.3 Antenna 3

For all the tags tested in this experiment the maximum distance physically possible in the room the system was still able to read the tag without issue. With the normal configuration of this antenna being on a roof and reading up to 5m this result is expected. This antenna is not likely to be most suited for the application for the first use cases proposed due to is large read range is likely to detect tags when they are not passing through a doorway. This would cause issues with the system and could lead to a major data issue if incorrect passing data is processed. A strong antenna like this could be used where appropriate shielding is achieved with a structure like a faraday cage.

1.2.4 Antenna 4

This antenna produced stronger results than the door frame antenna but not as strong as antenna 3. This was the antenna used in the previous step as a control antenna. It was also the antenna used in the previous work for the same testing.

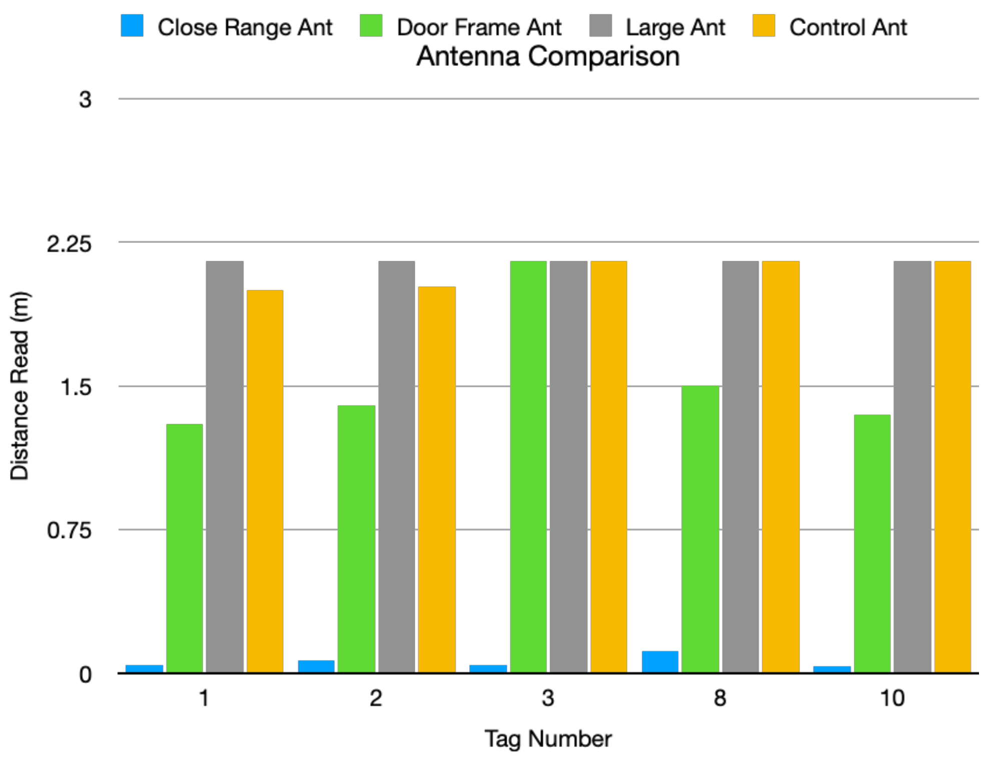


Figure 4: Comparison of Antenna

The cost of the tags needs to be compared to the performance and consisted. The system has set thresholds required to perform and maximising signal strength and read distance isn't critical to the job. As long as the tag is read every time the strength that it is read it may not have any impact on the system. Read distance also needs to be controlled to area desired to minimise false reads, if the system picks up tags outside of the intended read range it could lead to issues. Having a large exclusion zone for storage of goods near the antenna could waste valuable space in the factory. Testing in factory could scale results better or worse, so recommending at tag and antenna combination that is only read between 0.5m and 1.5m isn't the correct process.

The software package used had very basic functionally and limited how data could be record. The software was provided with the reader and intend for demonstration purposes. Alternative software packages are available but associated costs were not viable to investigate during the project. Ultimately in an end final product a software package would be required and associated licencing fees to be factored into the total expense of the system as well as the programming and linking software for the RFID system to communicate with the resource management planner ERP system that REDARC has.

Chapter 2 - Position of Tag on Tub

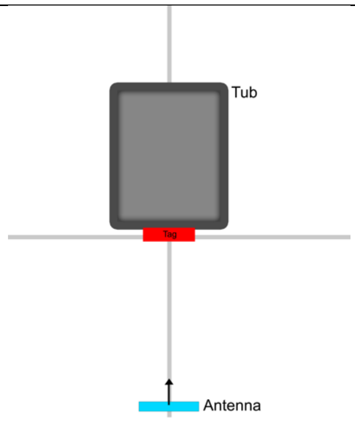
2.1 Purpose of Test

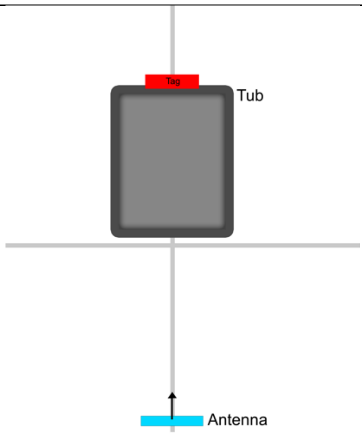
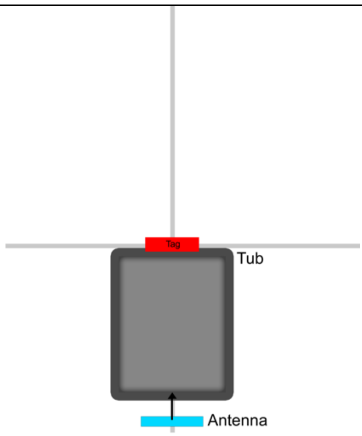
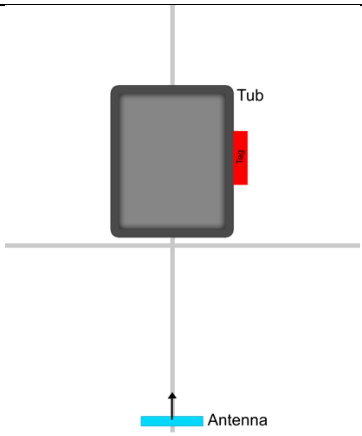
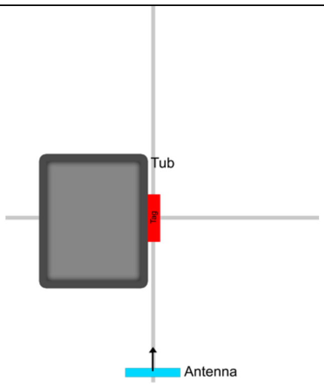
The purpose of this test was to determine the location of tub where a tag would return the strongest reading. The test would also identify if any locations on the tub posed to be an issue for the system and should not be used.

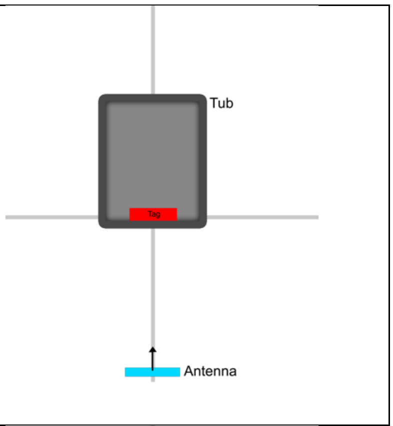
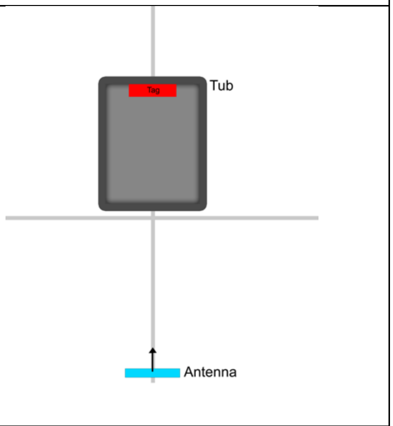
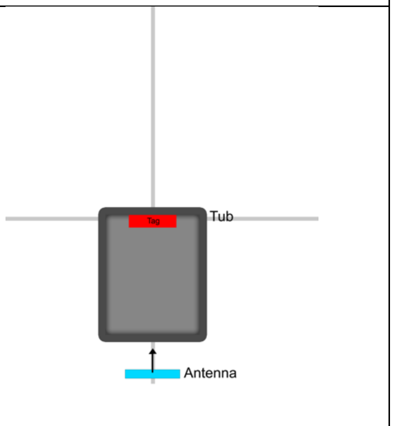
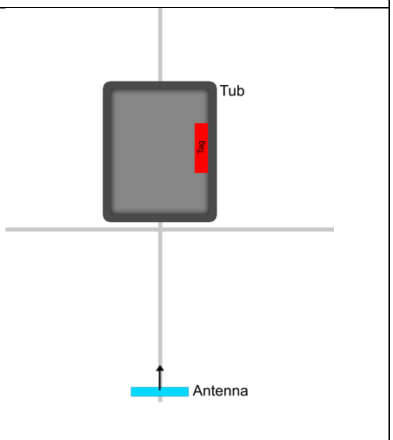
In the real world application tags are likely to be in more than one origination on the trolley as it might not be practical for all the tags to be on the edge of the trolley facing the antenna due to the size of the tubs and shelfs allowing grid patterns of tubs placed on them.

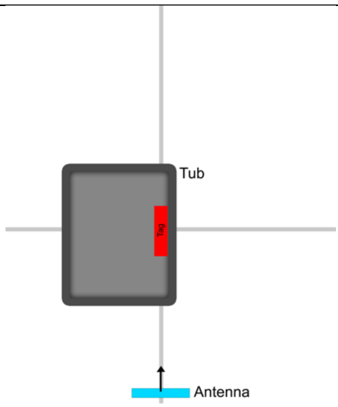
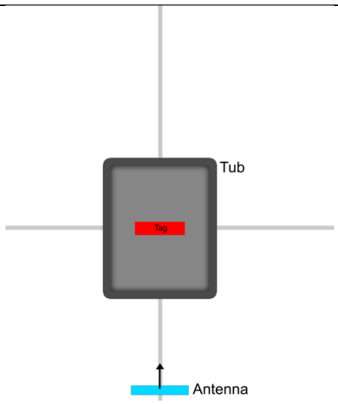
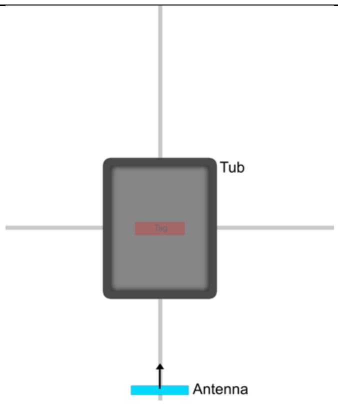
The reasoning for doing this testing it to identify if the equipment delivers poor readings and only leave 1 position that is suitable. This then would require engineering controls to be in place with human interaction to ensure that the tags are in the correct position. The alternative to this is having good equipment that doesn’t require prefect positing.

The positions tested were as followed:

Number	Position	Description	Graphic
1	Front External	Tag placed on the external side on the tub on the front ie facing the antenna	

2	Back External – Offset	Tag placed on the external side of the tub on the back ie far side away from antenna. Tag is at greater distance from antenna due to offset. Tub position hasn’t moved.	
3	Back External – Aligned	Same as above tub been moved closer to antenna to distance from tag reader is same as front extrenal.	
4	Side External – Offset	Tag placed on external side of the tub on the side, line of sight from antenna to tag had a very low surface area as tag was perpendicular to antenna. Offset being tub in normal centred position and tag placed on tub.	
5	Side External – Aligned	Same as above but with tub moved so tag was centred and perpendicular to the antenna.	

6	Front Internal	Tag inside the tub on the front face	
7	Back Internal – Offset	Tag inside the tub on back face offset by the tubs size	
8	Back Internal – Aligned	Same as before with tag moved to be equal distance as baseline	
9	Side Internal – Offset	On the side inside the tub offset by width	

10	Side Internal – Aligned	Inside tub on the side aligned at reference	
11	Base of Tub – Internal	Inside the tub on the base, tag flat.	
12	Base of Tub – External	Tag under the tub on the base.	

2.2 Results

The results show that the worse performing position was having the tag under the tub. It was also noted that when tag was on the side and aligned it was read. This is hypothesis due the tag being perpendicular to the antenna with minimum surface area it didn’t reflect back a response when it was move slightly either side it was read indicating it is just a black spot. This isn’t an issue as the tags will pass the antenna and at some point in the passing it would be read.

Tag Positions of Tub

Position	RSSI [dBm] (Lower is Better)
Front External	-76
Back External (Offset by Tub)	-66
Back External (Tag at Reference)	-58
Side External (Offset by Tub)	-70
Side External (Tag at Reference)	Didn't Read
Front Internal	-58
Back Internal (Offset by Tub)	-75
Back Internal (Tag at reference)	-66
Side Internal (Offset)	-69
Side Internal (Tag at Reference)	-59
Base of Tub (Internal)	-75
Under Tub (External)	-80

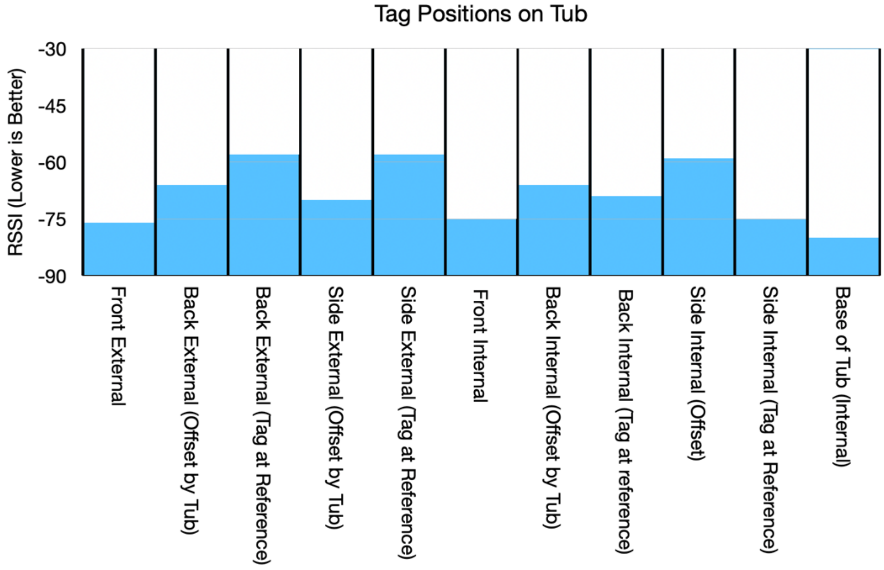


Figure 5: RSSI across positions of a tub

Offsetting the tag with the width of the tub decreased the signal strength, this is assumed as the distance the tag is away from the antenna is increased. Having plastic tub between the tag and the reader didn't have a negative effect on the system, meaning that unobstructed direct line of site was not required.

Results were inconclusive on prefect position for a tag to be placed as multiple positions were with a suitable threshold to a system. This is positive for the factory environment as the positioning of the tubs orientation is seen to be not critical.

Although assumed to have no major effect on the system but the origination of the test tag was tested to see if having it horizontal or vertical to the antenna had any measurable effect.

Having the tag vertical gave a reading of -52 dBm, this compared to the tag being horizontal where the reading was -47 dBm. While there was a difference in these reading both were well within the threshold to be suitable for a full application and compared to other changes in the system was minimal in the variables to control. With a tag of this footprint the space on the tub for a clear mounting surface would be more critical than what the orientation is.

Not that it should happen, but this gives a level of confidence if there was an instance that a tub was on it's side that the RFID system would still log data as expected and record what actually happened with the movement of goods. Smaller Kanban tubs this could be applicable for as they can be stacked within tubs of different sizes and potentially some on the side.

Chapter 3 - Second Sample Set of Tags

3.1 New Tags

Results were discussed with REDARC Electronics and a supplier Comware this led to a recommendation to trial a new sample set of tags closer to what had been discovered to preform best. Also included in the new sample set was 2 plastic cards much like a credit card that had RFID chips embedded. These cards could be printed on and are an option of use with the Kanban system of tubs. The other tags only 1 was available of each this new sample set came with multiple examples of the same tag models.

A new sample set of tags was received and required baseline testing. The new tags were numbered from 1 -10. The experimental setup was the door frame antenna. This was connected to the FEIG RFID reader and connected to a PC. The antenna was mounted to clamp and arm at set distance above the ground. The tags were handled using a plastic clothes peg that was clipped to an electrical tape tag as seen in Figure 6.

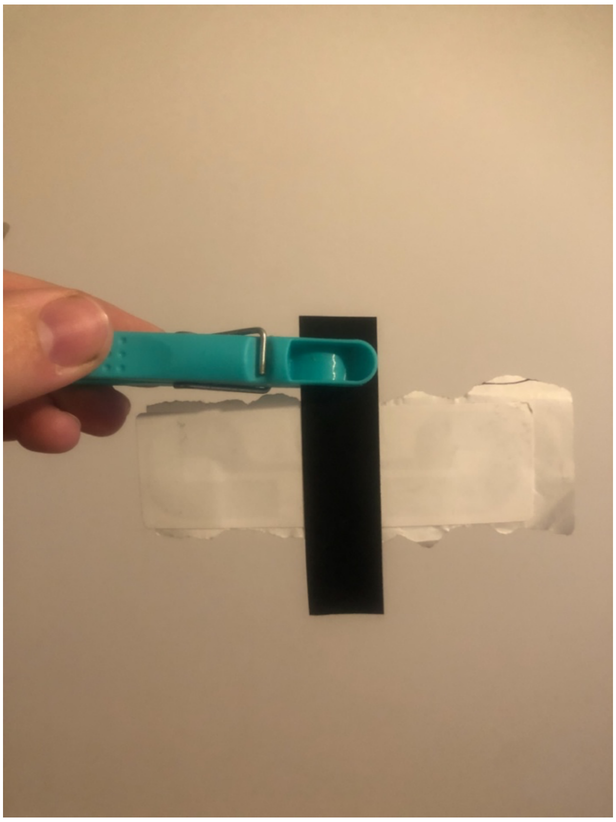


Figure 6: Tag Handling Method

3.2 Data Collection

The received signal strength indicator (RSSI) was measured at 3 set distances as well as the maximum range that the tag could be read. The first distance was when the tag was touching the antenna, next distance was 60cm away from the antenna and third distance was 120cm. 60cm is approximately the minimum distance require that could be practically possible to have all tags within during a real world application if all tags were positioned optimally on a trolley to be read. 120cm is approximately the width of the current doorway that is used when transporting goods between the production and storage area in the REDARC factory. The maximum read distance was also recorded as another baseline to the strength of a tag, due to the space available a maximum distance of 2.4 could be achieve. This distance is far greater than any intended application.

The purpose of this test was to evaluate the tags that had be ordered and supplied for their performance with the test equipment and to identify the preferred tags for a factory trial. The expectation is that the tags most suitable will have a RSSI greater than -80 dBm meaning a suitable strength for the system.

Normal RSSI Ranges are:

-30 dBm strongest likely to be seen

-50 dBm exceptional reading

-60 dBm strong reading

-80 dBm minimum required strength

-90 dBm read but not useable

-100 dBm out of range

In addition to the 10 new tags sourced, a HID 6H2E92 that was used as tag 8 in previous tests that lead to the adhesive inlay tags being preferred was used as a control and comparison point.

3.3 Analysis

Table 1: Strength of Tags at distances

Tag	RSSI touching	RSSI @ 60cm	RSSI @ 120cm	Max Read Dist
1	-45	-66	-75	2.4
2	-51	-72	-76	1.8
3	-48	**-100**	**-100**	0.4
4	-60	-80	**-100**	0.2
5	-40	**-100**	**-100**	0.3
6	-50	-66	-70	2.4
7	-52	-64	-69	2.4
8	-66	**-100**	**-100**	0.05
9	-38	-60	-64	2.4
10	-66	**-100**	**-100**	0.5
Control	-34	-61	-70	2.4

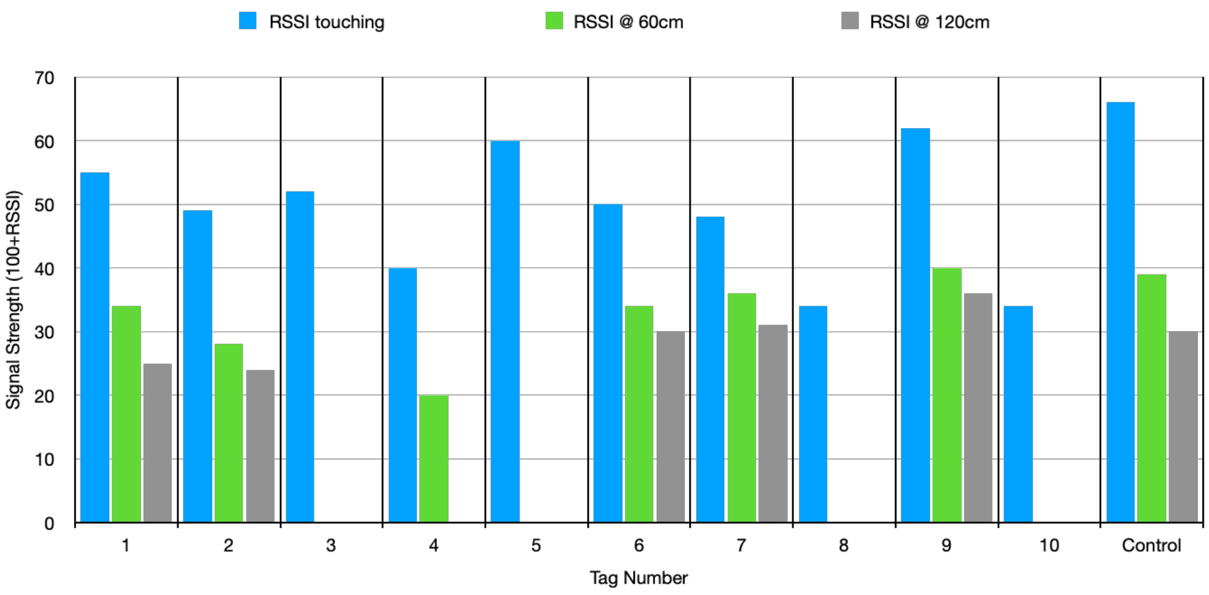


Figure 7: Strength of Tag at set distances

The plot created a formula to display the results in a more visual way as using dBm being a negative value is inherently hard to interpret. This formula used the RSSI value and added 100 to it to invert the graph and display that as higher is better. Results show that all tags were able to be read when touching the antenna, with the RSSI ranging from -34 dBm to -66 dBm all within a suitable strength at this range. At 60cm some tags were out of range and not picked up by the reader. Of the tags that were read the strongest reading was -60 dBm and weakest read -80 dBm. When at 120 cm one more tag couldn't be detected but of the 5 remaining tag and the control the range of RSSI was between -64 and -76 dBm and hence within a strength that would be suitable to proceed with future trials.

Tag 1 and 2 both being varieties of plastic card with embed chips had very similar results with tag 1 being measured slightly stronger. Tag 1 average across the 3 distances of -62 dBm and Tag 2 – 66 dBm but of note that tag 2 had a shorter maximum read distance.

Tag 9 has the highest recorded RSSI at 120 cm and highest other than the control at 60cm and when touching, while also being able to be read at the maximum distance available of 2.4m.

After testing more information on each tag was sort out as it was assumed all tags would be similar as it had be request of the supplier to provide a sample of similar tags to the highest preforming from the previous tests. Findings when looking into the types of tags are that some of the tags were intended to be attached to a metal object and hence would explain while in the test conditions they didn't produce a strong reading. In the intended real world use case no tags would be directly in contact with a metal object so these tags are not the best fit.

Table 2: List of Tag and Cost

NUM	PART NUMBER	DESCRIPTION	COST (AUD)
1	IDC-CR80-UHF-4QT	ISO Card, UHF, Monza 4QT chip	2.2
2	IDC-CR80-UHF-H3	ISO Card, UHF, Alien Higgs 3 chip	3.3
3	9-9900-200-9	UHD RFID Tag, IQ 400	4.07
4	9-9720-011-0	Label UHF Metal Skin Platinum, Thermal Transfer, 58 x 19 x 0.8 mm each	2.64
5	9-9891-620-8	Metal Skin Dry Inlay, 90x30x0.66mm (RFI-U500-M3-D) ea	1.98
6	9-9740-682-2	Alien Wonder Dog, White Wet Inlay, Higgs-4, Each	0.44
7	9-9741-542-3	Alien G, White Wet Inlay, Higgs-3, Each	0.44
8	9-9720-003-2	Label UHF Metal Skin Titanium, Thermal Transfer, 45 x 5.6 x 0.86 mm ea	2.53
9	9-9740-405-2	Alien Squiggle, Clear Wet Inlay, Higgs-4, Each	0.33
10	9-9740-102-3	Alien Squig, White Wet Inlay, Higgs-4, Each	0.33

3.4 Conclusion

This data can conclude that some of the tags in this control environment show that at the distances expected in the use case they are suitable for the application. The difference if results can be related to the tag size as one of the factors in the results, this is because a large tag can contain a larger antenna and hence stronger response. Preferred tags for the system are tag 1,2,6,7,9 and the other tag are unsuitable for the application.

Chapter 4 - Initial Factory Trial with a Single Card

4.1 Factory Trial Arrangement

Testing RSSI of single tag in a controlled position within the factory was the aim of the first factory trials, testing in the factory introduced other variables that hadn't previously been looked at. 2 types of trolleys one a plastic catering trolley, and the other a metal scissor lift trolley were used. A selection of sizes of plastic tubs filled with metal, plastic and empty were trailed. The positing of the tub with attached tag was adjusted. Other factors like the shelf were also looked at.

The antenna was set up using a Manfrotto Magic Arm and super clamps to hold the antenna. The computer and reader set up away from the antenna and connected to the power. Cable was run and securely taped down to ensure it didn't move the system what caused a safety risk in the test environment. Care was taken to ensure the speed the trolley was pushed past the antenna remained constant during the tests. Each test started with the tag out of range and then it was pushed until the tag was picked up by the system at which point the user of the computer inform the person pushing the trolley the tag was in range the trolley was then pushed past the antenna until it was out of range again. This was to observe the stability of the system. To measure the strength of the tag in the test scenario a constant position was marked with type on the floor and on the trolley to ensure that consistency occurred with the position the tag as it was held stationary in front of the antenna and signal strength measured. Ideally the maximum strength from a pass could be logged but the software was limiting this functionally and the manufacture was unable to provide any APIs or SDK's for its system.

The two card type RFID tags were to be compared to identify any differences in performance. These cards would be implemented into the Kanban system and use a smaller plastic tub with has a slot to hold the cards in place. 3 tubs were used in the test one filled with metal screws, the second filled with plastic washers, and third empty.

4 orientations of the tub were examined, 1) facing the direction of travel, hence facing the front of the trolley. 2) facing away from the direction of travel and hence the back of the trolley 180 degrees rotated from first. 3) facing the antenna, so the to the side at the

antenna was on. 4) facing away from antenna, tag on the far side of with the tub and goods between the tag and the antenna.

Both types of card were run through all orientations and goods tests on a plastic and metal trolley. The RSSI was recorded in a consistent position with marking on the ground to line the trolley up with on each test and tub was positioned in same position on the trolley shelf. The RSSI was also monitored on the computer screen as the trolley was pushed at a constant rate, this was recorded with a pass/fail criteria with duration and stability of the signal looked at. Walking all tests that could be read has a period of time/distance that could be read. Tests with no read didn't pickup at any point walking or what stationary.

Error issues were also looked at like a tag falling into tub or placed on a trolley. This stemmed from REDARC wanting to know what would happen in all possible scenarios to understand the risks of a system.

4.2 Results

Table 3: Data Set from Plastic Trolley with Kanban Tub

Goods	Orientation of Tag	Tag Type	RSSI
Metal	Facing Direction of Travel	Card Type 1	-69 dBm
Metal	Facing away from Direction of Travel	Card Type 1	-64 dBm
Metal	**Facing Antenna**	Card Type 1	**-66 dBm**
Metal	Facing away from Antenna	Card Type 1	-72 dBm
Empty	Facing Direction of Travel	Card Type 1	-70 dBm
Empty	Facing away from Direction of Travel	Card Type 1	-72 dBm
Empty	**Facing Antenna**	Card Type 1	**-62 dBm**
Empty	Facing away from Antenna	Card Type 1	-70 dBm
Plastic	Facing Direction of Travel	Card Type 1	-71 dBm
Plastic	Facing away from Direction of Travel	Card Type 1	-70 dBm
Plastic	**Facing Antenna**	Card Type 1	**-70 dBm**
Plastic	Facing away from Antenna	Card Type 1	-70 dBm

Results clearly shows that in each test having the tag facing the antenna produced the strongest reading in all tests. This is demonstrated in the subset of data presents above and the analyst bellow.

Table 4: Position of Card on Plastic Trolley with variable goods and card types

	CARD Type	Facing Direction of Travel (dBm)	Facing away from Direction of Travel (dBm)	**Facing Antenna** (dBm)	Facing away from Antenna (dBm)
Metal	**1**	-69	-64	**-66**	-72
Empty	**1**	-70	-72	**-62**	-70
Plastic	**1**	-71	-70	**-70**	-70
Metal	**2**	-80	-76	**-70**	-76
Empty	**2**	-78	-74	**-69**	-78
Plastic	**2**	-82	-82	**-64**	-76
Median		-74.5	-73	-67.5	-74
Min (Weakest)		-82	-82	-70	-78
Max (Strongest)		-69	-64	-62	-70

When presented as a percentage of signal strength it is clearly show facing the antenna yields the strongest reading and least variation from the data.

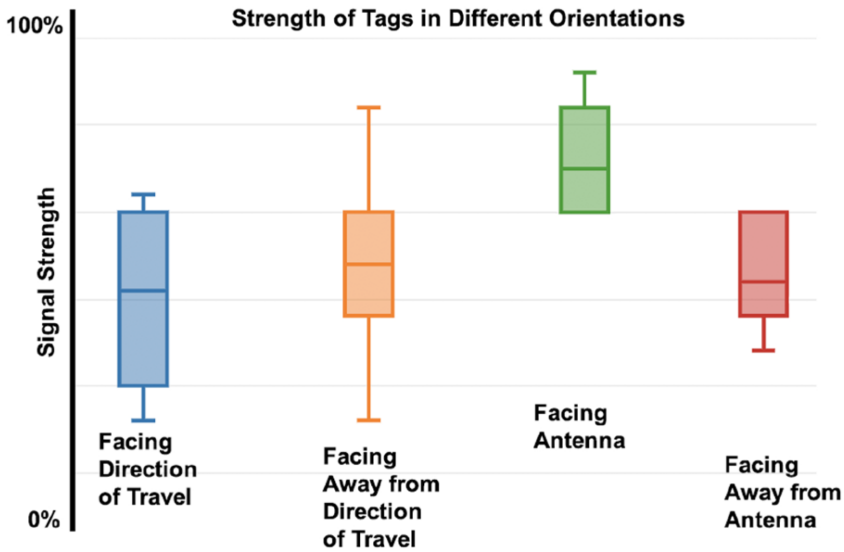


Figure 8: Strength of Tags in Different Orientations

4.3 Analysis

Card 1 is reporting to be stronger than card 2 in the factory trials this is inline with the finding in the controlled testing. The average RSSI recorded across all positions with all goods types on both metal and plastic trolleys was -71 dBm for card 1 and -77dBm for card 2.

Assuming an optimal orientation of facing the antenna the preferred trolley was looked at finding that the plastic trolley readings ranged from -62dBm to -70 dBm in these optimal conditions and the metal trolley was from -69dBm to -76dBm. Both were within a suitable threshold but indicates the metal trolley weakens the signal and as a preference the plastic trolley should be used.

While the data set gained allows for an analyst of signal strength differences with different good types this is not a beneficial comparison to make as the system must work with metal goods and that variable cannot be eliminated. The report from the testing is that having metal goods in a tub with an RFID system does not stop the tags from being read and hence confirmed the working of the system in this scenario. While the metal goods can't be controlled the metal trolley can and hence why that was compared. The position is another variable that can be controlled, and the recommendation is to have the tags facing the antenna where possible.

When relaying the results to REDARC and Comware a suggestion came to have an antenna of both sides of the door way increasing the read range but also allow a tag to face the antenna in either side of the trolley removing the need for position to be monitored. Comware detailed a method of a read portal where a tunnel is constructed that is lined with multiple antennas at different heights and on both sides and from above this will ensure that the tags are read but requires software handling and the costs were outside of the scope of this project as it was estimated to be approximately $25, 000. This was the recommendation moving forward once RFID and its benefits are understood.

A requirement of the Kanban system would be to have the direction the tags travels through the door this can be handled in two ways the first being having multiple antennas on the transit path and identifying which one detected the tag first and hence when direction can be determined from the order of which antennas receive the signal. This fits in with the read portal concept of more antennas, but the budget is available to test this. The alternate method to having a complex system of more antenna is to make the assumption put the next direction it's always the opposite the one that just occurred. Knowing the initial case then it can constantly switch between the two directions to identify which way the tag is heading. This comes with limitations as if a tag did not go through the reader then the system or get picked up on the system would be creating an error that would continually propagate until it was manually discovered and resolved but could create a major error in the systems and hold up production, therefore, the first method with the extra level of automation it's far preferred as it limits the chance of having an error in the system.

The testing conducted concludes that card 1 and 2 on the metal and plastic trolley are suitable for a normal use case and demonstrated to not have any issues with misread where run as intended.

Other testing was conducted as it was found a normal use case presented no issues to the system, these tests involved using finished products as they have been completed in the factory and moved to the warehouse. The adhesive tag 9 that was the highest preforming in the controlled test was used for its previous results and that it had the greatest supply of 20 sample tags available. Tags were placed on a tub with 16 finished products. The product tested has an individual shipping size of 150mm x 120mm x 37 mm and weight of 0.68 kg and has a high amount of metal in the product. Finished products were in packaging ready for shipping. No miss reads were noted and a maximum RSSI was -56 dBm was record when facing the antenna on the middle shelf of plastic trolley. This is well within the desired threshold of acceptable results.

The plastic trolley used had 3 shelfs, antenna was not optimised for a shelf height but lined about centred to middle shelf, hence why the middle shelf gave the strongest readings. It was noted that with the current antenna the signal was stronger on 2 shelfs over 3 and in this case middle was best. If the trolley was stacked high on the top shelf there would be a chance that items could become out of range. Having multiple antennas at different heights would help overcome this issue or processes may need to be created in the height range to stack trolley so all tags are read.

Being an electronics company one material used is solder. Although low quantity it is still part of the material flow. It is not expected to cause any issue as it is just like the other metal components tests that are conductive and isn't an active product. Testing has found to not cause any issues to the system unless that tag was touching the solder, and which point the tag would not be read. This is a simple thing to control with process to ensure tags are only on tubs.

Another test which is critical to control is when the tag was directly touching the surface of the metal trolley the signal was completely blocked and not read. This could lead to a serious issue with the final system if not controlled.

4.4 Possible Miss Reads

While conducting the testing a couple of possible scenarios were thought of that could happen. These related to if a card was to fall into the Kanban tub and was left touching the goods. As it was known that when touching a metal object, the signal would be degraded it was hypnotised that this could create a miss read and was valuable information to provide REDARC about possible risks in the system. Tests were conducted for a card fallen into the tub of metal screws and touching but not covered, this would the most likely scenario. The second was that it was placed into the tub pushed to the side so that it was still upright but inside the tub touching the goods. This would potentially happen if communication wasn't clear with the staff about placement of cards. The third was a card submerged in the screws, so it was completely covered.

Figure 9: Card Falling into Kanban Tub

Figure 10: Card Placed in Kanban Tub

Figure 11: Normal Use of Card and Kanban tub

These 3 scenarios were tested for both card 1 and 2. It was found as expected with card 1 that if any part of the card was touching the metal the signal would be blocked and not read. For card 2 interestingly it could still be read when touching the metal and when full submerged results showed a stronger signal that note. The stability in the signal was reduced but the peak strengths were unaffected or improved in the submerged case. This was noted to be retested to confirm the results.

High volume products are packed into a shipper box that contains multiple units. These large cardboard boxes are moved and stacked onto a pallet for storage and shipping. Handing of these finished goods could occur in 2 ways with each individual unit being tagged with an RFID label or just the shipper being tagged. Currently each product is label with the serial number on the box and then the order in barcoded with order labels placed on the larger shipping box. The benefit to tracking each individual unit could be limited as that is not currently how the data is logged on the system. The replicate the current system of labelling a RFID tag was placed on the shipper where the barcodes go and on the low line trolley for manoeuvring those larger items the product was tested with the reader.

Tag 9 was used for this test and once again the 4 orientations were tested. Results showed that in this configuration the system worked as expected and tag we able to be read in all orientations without issue. The trolley being used was made from metal and the was a chance that the shipper box could be pushed against the back support and in that case the tag could become in direct contact with the metal of the trolley. In this case of the tag contacting the trolley the signal was very intermittent and had week signal that was not suitable for a system.

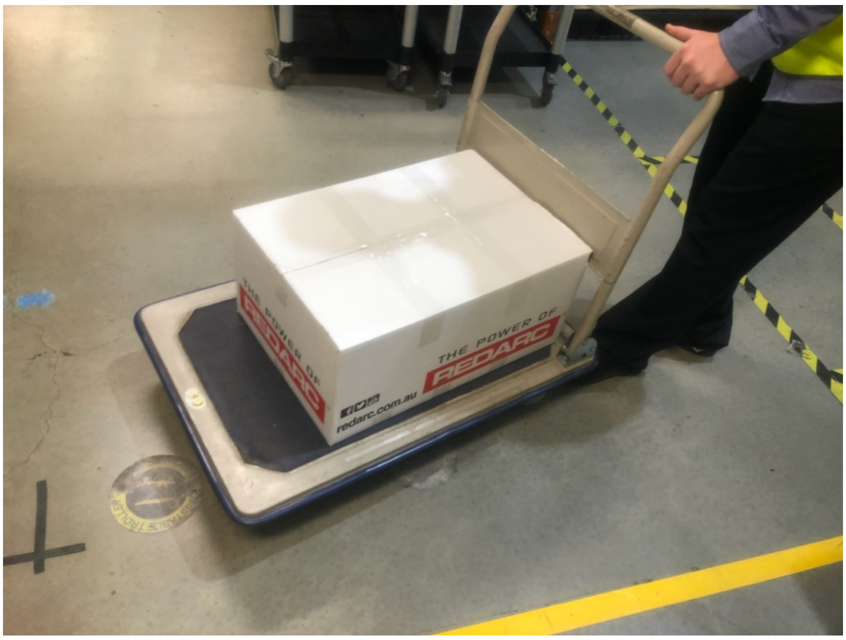


Figure 12: Low Metal Trolley for Finished Goods

A solution to this potential issue was found to have some insulation between the metal where the tag could touch, this reduced the effects and improved the performance. This highlighted that the system wasn't entirely full proof and careful management would be required to ensure that miss reads don't occur. All of the management control discovered were reasonable processes to be implemented and monitored.

Other possible points of interference that are inherent when testing in the factory are that the factory is fitted with Wi-Fi routers positioned in multiple locations on the ceiling. The location that the factory testing took place what positioned in near proximity to one of these routers.it was also closely located to an electronic sliding door that is frequently used for access between the two areas of the factory.

REDARC electronics uses RFID security systems for access to doors and rooms. the key fob tags that employees carry on person were tested and found not pick up on the system. RFID tags found in common access cards that would be held in a wallet and then an entire wallet in front of the system none of which were found to produce a writing that was picked up with the equipment available.

Chapter 5 - Continued Factory Trial

5.1 Experiment Outline

Due to the low variation in the difference between card 1 and card 2 strengths in the first factory trial the results were revisited. This confirmed the finding that Card type 1 produced a stronger signal based on the maximum RSSI recorded when passing the antenna within the factory. Both of the card type tags would be suitable for a system do recommendation is that both would be suitable card 1 would be preferred if cost and availability where not a factor. Also, reviewed was the scenario that a card had falling in to a tub of raw materials with a high metal content, like the first test it was seen that card 2 was the only card that was constantly being read when it had falling into the tub.

The mobile robots move stock around the factory using a custom trolley designed inhouse to work with the chosen robot platform. The robots have plate with pins that is lifted using electronic lifting actuators that moves this 100mm up. The plate will lift from under the trolley and pins locating in holes under the bottom shelf. The trolleys are manufactured from aluminium extrusion with high density polyethylene (HDPE) shelfs. This platform is inheritably different to the other trolleys used in the factor. Results have shown that the tags read higher on the plastic trolleys when compared to the metal trolley but the metal trolleys still all for the RFID tags to be detected. The robot trolleys are also a larger size than the other trolleys tests and send in below figure.

Figure 13: Mobile Robot and Trolley at REDARC

The robot was unable to be used with testing, so the trolley was manually pushed pass the simulated doorway where the antenna was setup. This was due to issue with the robots that led to them being offline for a large periods and supplier support being stuck interstate with border restrictions. Previous experience with the mobile robots has indicated that due to the large stainless steel lifting structure fitted to the robots that REDARC Electronics has purchased all internal radio frequency interference has been masked or blocked.

5.1 Results

Due to the size of the trolley the single antenna was not providing signal that covered the entre trolley. The results were noted that the signal had be weakened and a procedure that looked at the positioning on the robot trolley was to be constructed.

Peer review of potential issues with RFID system and things the wider manufacturing engineering team wanted tested before investment lead to testing a box of magnets, and a product that is shipped with batteries installed. Both the finished product in a shipping box with battery's and the magnets show no negative impact on the system. This was testing across the 2 card type RFID tags and a selection of the highest preforming adhesive inlay tags. The RSSI measured for each tag was all very similar across the different types of tags and all within a suitable threshold for the application.

To compare the adhesive inlay tags sourced the system was tested using the top shelf of the robot trolley and finished goods. The testing all had the tag facing the antenna. 3 Types of product were tested, the one containing batteries, a box of magnets densely packed and an empty cardboard box as a baseline.

Table 5: Adhesive inlay tags factory results

Tag	**Goods 1**	**Goods 2**	**Goods 3 (Empty)**
Tag 9	-51 dBm	-51 dBm	-46 dBm
Tag 6	-50 dBm	-50 dBm	-50 dBm
Tag 7	-52 dBm	-51 dBm	-48 dBm

There was no major variation in these 3 models of tags and all would be suitable for a large system. Tag 6 and 7 were quoted at 44c a tag and 9 was 33c so assuming equal availability tag 9 would be recommended as there is no measurable performance indicators seen.

Chapter 6 - Multiple tag trial at factory

6.1 Previous Findings

As noted in the first testing of this robot trolley its size and material were causing a greater weaking of the RSSI when compared to the other trolleys. This was widely unexplained in the data the reasoning so further testing was conducted to quantify what was happening.

It was found that when having the trolley in a fixed position to the antenna and then moving the tags between 6 positions being close edge, far edge and middle of the top and bottom shelf that for strongest results the middle on the bottom shelf was best and close on the top. There was a drop in the readings at the top in the middle. This was not the case with the bottom where it showed a gain in RSSI. This was done this the antenna centred to the top shelf. The rail support structure was initial thought to be the issue as the shelf bracing is made from 40x40mm aluminium extrusion.

Table 6: Positions on Robot Trolley

Position	RSSI
Top Close	-52 dBm
Top Mid	-65 dBm
Top Far	-59 dBm
Bottom Close	-74 dBm
Bottom Mid	-64 dBm
Bottom Far	-72 dBm

6.2 Positions on Trolley

To test multiple tags a single tub was used with a card type on 1 end and an adhesive type on the other. One would be facing the antenna and other on the far side. This would then be reversed once all positions were tested. The positions to be tested were close, mid and far on the bottom and top shelfs of the robot trolley.

The results from the test showed that all reading were withing the suitable range for a system and provided confidence that with multiple tags of different styles the system would still meet the needs of the company. This was assumed to be the case but having the evidence strengthens the business case for pitching the technology to management.

This test still showed that there isn't a consistent drop off in signal strength as distance from antenna is increase and that there can be some dead spots in the system. As the trolley will be in motion as it pass the reader the tags would be across the whole spread of the antenna and these areas of lower reading wont be of issue.

Table 7: RSSI of multiple tag test

Orientation	Tag Type	Position	RSSI
Card Facing Front, Tag on back	Card Type 1, Tag 7	Top Close	-52 Card, -76 Tag
		Top Mid	-83 card flashing, -70 tag
		Top Far	-62 card, -76 tag flashing
		Bottom Close	-49 card -64 tag
		Bottom Mid	-52 card, -70 tag
		Bottom Far	-55 card - 69 tag
Tag Facing, Card Back	Card Type 1, Tag 7	Top Close	-55 tag -76 card
		Top Mid	-60 tag -68 card
		Top Far	-73 tag -78 card
		Bottom Close	-52 tag -64 card
		Bottom Mid	-60 tag -76 card
		Bottom Far	-60 tag -70 card

6.3 Multiple Tags

The RFID system will be required to handle multiple tags on items within the one tub for finished good items. A box full of one of REDARC best selling products was used. This product is PCB within a plastic housing and is about the size of a mobile phone. In the finished good configuration, the products are stacked in their packaging side by side and can be in groups of up to 40 items.

3 tags were place in the group of items one on the centre item and 2 on the far ends. The RSSI was recorded for each tag 3 times, each time the trolley was moved as the antenna was centred on each tag for a test. Results show that when the antenna was aligned with a tag at the end the other ends tag wouldn't be in a stable range. When the antenna was centred on the middle tag all 3 tags produced reading that were stable and suitable for a system.

The number of tags was increased by 2 to 5 tags in total. The theory developed in the 3 tag test remained valid that the tags closest to the antenna would have the strongest RSSI and as the trolley is moved pass the antenna the tags strength will increase as approaching the antenna and then peak and decrease as they pass. This is in line with all other observations seen during testing and is assumed to be the response of the system.

The number of tags was then increased to 11 being the number of items across that were packed in the box. The same response as in the previous test was observed. When watching the program read out the number of tags in view by the reader that was connected to the antenna it could be visually seen that the number of tags would increase from 0 to at least 9 before coming back down and returning to zero. Not in all cases all 11 tags could be read at once it was achieved but normally 9 or 10 could be picked up. This was not because of the system had a limit of the number of tags was just to the distance range that the tags were spread out and when the position was changed all tags would be read at some point during the passing.

The RSSI of the tags that were in place for the tests before 11 didn't see any significant drop in strength as more tags were placed on the products within the same area.

This test proved the basic functionality of the intended use case for RFID stock tracking of finished goods within the REDARC factory. A tub or box of multiple items each with tags could be placed anywhere on a trolley and pushed past a door way that had RFID antenna and a system would record and log the movement of these tags and hence be able to update and track the movement of the tubs, products or raw material.

Conclusion

The results from this study found that an RFID system would be suitable for use inside the REDARC factory for the application of automating part of the movement of finished goods and raw material. Testing found that in normal use the current equipment delivers results within the desired threshold of strength and tags can be read when passing an antenna. The finds showed that proper processes must still be followed as if tags are touching directly to a metal the confidence in the data being correct is lowered.

It is recommended that REDARC initially implements at system that records the movement between the production and warehouse areas in the factory. An initial commissioning to take place on the Kanban circuit due to once tags are setup the system integration will remain the constant. REDARC has already taken this recommendation and engaged stakeholders to purchase RFID card for this purpose as part of a wider upgrade of Kanban labelling and handling.

The proposed system would be to have a read portal custom designed by Comware with multiple antennas to ensure quality and consistent data and remove the need for extra processes around positioning of goods on a trolley. This will also reduce the human error in the system. If budget dictated the requirement for a smaller system for initial implementation, then the current antenna would be suitable with controls in place. These controls would include goods being placed with the tags facing the antenna and on designated shelfs to make sure the tags are as close as possible to the antenna.

The recommend equipment from results obtained would be that the read portal at a door way uses Times 7 A8060 Antennas, and then any selection of HID6H2E92 or Alien Squiggle Adhesive inlay tags and Monza 4QT or alien Higgs 3 chipped ISO Cards. These were the highest performing tags but if availability or cost was a major factor than other options could still be considered especially when proposed antenna system would be more powerful than what was tested.

While highlighted in literature as a potential the other RF sources and metal racking in the factory were not found to be problematic with the system. The results from previous studies commissioned by REDARC were supported with the same recommend equipment and results replicated. The findings around tags on the use on ESD plastics and metal surfaces were critical in determining suitable equipment and explaining findings from factory trials.

Future work on this project is to invest in hiring Comware to consult and quote on equipment for commissioning and then presenting the project to stakeholders in management for consideration. While it wasn’t possible during the timeframes this project was completed in testing a system with the mobile robots that REDARC has would be important to ensure no unforeseen issues. REDARC plans to invest in equipment for a system to run within the factory and has secured funds for the project. The initial commissioning of the project would run on the closed loop Kanban system where plastic style cards with RFID chips will automatically update the ERP system about stock levels on the production floor. The company requires time to get the other aspects of the system organised before the RFID automation component can be introduced.

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