The New Zealand RFID Pathfinder Group

The New Zealand RFID Pathfinder Group Inc.

RFID Technical Study

The Application of UHF RFID Technology for Animal Ear Tagging.

Deer, Sheep, and Cattle Farming

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Acknowledgments and Thanks

Deer Trials

The New Zealand RFID Pathfinder Group is grateful to Grant Cochrane, owner of the Totara Hills Deer Farm for making Totara Hills available for conducting tests. Pathfinder would also like to extend thanks and appreciation to Adam Whaanga, Farm Manager, for his valuable time and efforts to muster, tag and manage the animals during testing. Pathfinder is grateful too for the insight and experience of Grant, Adam and the rest of the staff at Totara Hills to help Pathfinder understand the challenges and issues faced in animal identification in the Deer industry.

Sheep and Cattle Trials

The New Zealand RFID Pathfinder Group wishes to thank Canterbury Meat Packers for kindly allowing the use of their facilities and in particular Stuart Phipps, Farm Manager, for managing the animals. Pathfinder is grateful for the guidance and expertise provided by Graeme Ward of Prattley Industries and lastly, to Mark Rance of ANZCO for facilitating and organising the trials.

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1 Executive Summary

To maintain a competitive position in global livestock markets, NZ must and is progressing track and trace initiatives through the NAIT group. A crucial decision is that of animal identification technologies – while established technologies (LF RFID) are proven, recent technology advances (UHF RFID) hold the promise of improved functionality at a lower cost.

This document is a report of a study into this new technology by the NZ Pathfinder Group that shows UHF does function in a livestock environment and has significant potential.

Low Frequency (LF) RFID has been traditionally used for Animal Identification for at least 20 years. Yet the technology shows distinct limitations when faced with use in livestock management applications that call for fast and reliable identification of multiple animals simultaneously. Such difficulties are particularly prevalent in the deer and sheep industry.

Significant advances have been made in the last 10 years with RFID technologies operating at Ultra-High Frequencies (UHF). In conjunction, internationally ratified standards have been developed due to the work of the EPCGlobal Community. UHF RFID, based on EPC standards, exhibits characteristics of high speed, the ability to read hundreds of tags per second, over much greater distances than LF systems. In addition the technology has been proven to resolve individual tag identities in dense tag populations. The technology has also been globally standardised for use in a number of market sectors predominantly in supply chain logistics and management.

Notably the cost of RFID tag technology at UHF has fallen over 10-fold in the past five years for say a paper label tag in large volumes, due to improvements in the technology, production techniques and as a consequence of standardisation efforts. Similar trends are appearing in reader products as the technology matures and is heading towards mainstream adoption. By comparison the cost of LF tags has remained relatively static.

As the technical and financial barriers to adoption for UHF systems diminish, the application of the technology for use in livestock management should be reviewed. This study shows that under conditions that exceed the current requirements of the National Animal Identification and Traceability Project (NAIT), livestock can be identified with near 100% read reliability in drafting races, where animals are not constrained to move one at a time or slowly.

Further, the study undertook to use commercially available reader equipment used in conjunction with new tags under development and commercially available tags to show the potential for an open supply and procurement process. The results showed that satisfactory performance was not restricted to one brand only.

Simulated wet conditions were made to determine if reliable performance was limited. The study shows that there was no discernable difference in read reliability between wet and dry tests but there is a recommendation that further studies are required to be undertaken in worst case (rainy) weather conditions.

Different equipment and RFID antenna configurations were investigated to identify if systems could be scaled to use minimal RFID infrastructure leading to low cost deployments. The study showed that antenna placed laterally across the race yielded optimal results and that there was little difference between 4 antenna configurations versus 2. The study recommends to further reduce the number of antennas in future studies to determine if simple low cost single antenna systems are viable.

The report concludes and recommends that the scope of studies be widened to include:

- Testing at 921-929 MHz band.
- All weather conditions.
- Larger test sample sizes.
- Reduced antenna configurations .
- And other application scenarios including real world uses such as sales yards and truck loading,

The results appear sufficiently encouraging to warrant that the technology be given serious consideration and be further investigated. Pathfinder recommends that formal research programs be put in place by industry stakeholders to undertake the recommended studies.

Part One

2 Part One - General

2.1 Introduction - The RFID Pathfinder Group

The RFID Pathfinder Group (Pathfinder) is an independent, membership based, not-for-profit incorporated society. Incorporated in 2006 under the Incorporated Societies Act, Pathfinder was established by a number of high profile New Zealand based organisations to educate, promote and increase awareness of RFID and EPC (Electronic Product Code) technologies and global standards in New Zealand. Through the utilisation of these technologies and standards, additional business value for New Zealand organisations is envisioned beyond what other technologies have been capable to date.

Pathfinder has a specific focus on the use of RFID /EPC technologies and standards within the New Zealand supply chain and internationally and is both sector and vendor agnostic. Within the context of research, Pathfinder's charter is to take cognisance of and align with certain Government aims and objectives, namely to;

- promote trade facilitation and border security.
- enable and enhance traceability outcomes – QA & Food Safety.
- drive efficiency and productivity through technology.

Pathfinder accomplishes its research mandate through two primary channels:

- Literature searches, information collation and publishing to its website library.
- Feasibility studies, practical on-location trials and exemplars.

More information – refer: www.rfid-pathfinder.org.nz

2.2 The National Animal Identification and Tracing Project (NAIT)

In July 2006, a group of industry and Crown representatives launched the National Animal Identification and Tracing (NAIT) project. Its purpose is to develop a universal livestock identification system, supported by a core registry of data linking people, property and animals. This new system is needed to maintain commercial market access in the face of increased demand for traceability from consumers, and to improve tracing of stock in response to a disease outbreak and other on and off-farm purposes. The project is currently in the technical design phase.

NAIT will provide lifetime traceability of individual animals from initial registration before the first movement or treatment until eventual slaughter. Recording individual animals and movements on a central database will mean an infected animal can be located faster during a bio-security response. It will also help to identify animals associated with the infected animals. The faster and more effective the initial response, the quicker we will be able to limit the spread of the disease and demonstrate to trading partners that all potentially infected animals have been traced – thus limiting the impact on trade.

NAIT would want to see good levels of adoption of RFID technology before seeking approval from the Government to make its use mandatory. It is likely RFID tags will become mandatory sometime in the future (as is the case in Canada and Australia)[1]. NAIT have finalised the national animal RFID standards and confirmed the use of Low Frequency (LF) RFID technology for implementations going forward.

[1] Refer Appendix -

2.3 Scope and Objectives of the Study

The use of ultra-high frequency (UHF) RFID technologies for animal identification in international livestock is attracting increasing levels of awareness and interest as use cases emerge showing promising sector-wide utility. Global industry commentators suggest that with the improved maturation of UHF technology in recent years, specifically the overcoming of technical hurdles (e.g.: water absorption and metal reflection) and challenges such as the ability to handle dense tag environments, coupled with the emergence and acceptance of ubiquitous global standards has driven interest[2].

At the time of writing the deer industry is developing the DINZ Focus Farm project which will trial the use of Low Frequency (LF) RFID technology. DINZ have however stated that they will also investigate emerging RFID technologies.

Pathfinder considers that mandating *LF only RFID* for cattle and deer identification in New Zealand without having researched the application and potential utility of UHF technology may severely limit the performance and utility opportunities and cost economies for the New Zealand livestock community.

Specific interest surrounds how to deal with sheep that behave with a mob mentality, tending to move in a group and at speed. This provides significant challenges for low bandwidth LF technology that may be substantially overcome using a technology that has built in capability to resolve many tags at once, quickly.

Given this background, the following objectives were identified for this study:

- To investigate the use of standardized UHF RFID ear tags as an opportunity for livestock management in New Zealand.
- To raise awareness that LF technology whilst proven, may limit other RFID opportunities offered by UHF technologies within the NZ livestock sector.
- To initiate sector-wide discussion and provide a basis for investment funding for further research.

Within this context, members of the Pathfinder Group undertook two days of on-farm research at Totara Hills Deer Farm in Balclutha using a variety of combinations of UHF RFID tags and readers to determine performance characteristics and utility on deer.

Trials were also conducted at Canterbury Meat Packers near Ashburton on the 29th of May 2008. In these trials sheep and cattle were tested using a similar approach to the deer trials. The objective were refined slightly to look at the level of RFID infrastructure required to provide satisfactory (accurate) stock counts.

The research was isolated to the use of UHF RFID ear tags only, more extensive applications using UHF tags being considered out of scope.

[2] Cole 2008 – see bibliography.

2.4 Structure of this Document

Part one provides:

- Background information on the National Animal Identification and Tracing Project (NAIT)
- A brief overview of the use of RFID in Livestock tagging
- A comparison of RFID Technologies
- Applicable standards for animal tracking using RFID
- An overview of the use of UHF RFID
- International projects and mandates
- Recommendations

Part two covers tests conducted with deer:

- Details of the deer tagging tests
- Results and analysis

Part three covers tests conducted with sheep:

- Details of the sheep tagging Tests
- Results and Analysis

Part four covers tests conducted with cattle:

- Details of the Cattle tagging Tests
- Results and Analysis

The document contains a number of appendices which detail test configurations and provide some of the background of part one.

2.5 Background

2.5.1 RFID for Livestock Tagging

Many governments are encouraging or mandating the use of RFID tags to track cattle, pigs, sheep and deer to protect their food supply chain from contamination and spoilage and to provide track and trace capabilities. Some livestock producers have been using low frequency (LF) RFID tags for animal identification and weight monitoring, mainly because of the advantages RFID offers for more automated and easier data capture (less manual intervention).

Using RFID for the tagging of livestock is far from a new idea. As early as 1989, Texas Instruments was asked to develop a chip suitable for a cattle-tracking trial in Holland. An estimated 30 million head of cattle have been tagged worldwide over the past 15 years. But that number pales when one considers that there are about 1 billion head of cattle worldwide.

RFID tags for animals come in 3 varieties:

1. glass tags that can be injected under the skin of the animal – typically more suitable for smaller animals
2. ceramic bolus tags that can be inserted in the reticulum – a compartment in the cow's stomach with a special tool
3. tags attached to the ear of the animal - these tags can be rugged and can withstand water and animal-generated damage,

Concern over the entry of tags into the food chain if not removed at the slaughterhouse has made the ear tag by far the most common way to tag livestock.

Skin tags (15 mm)

Bolus tag (20 x 70 mm)

Ear tags (30 mm diameter)

Figure 2-1

The tags typically hold a unique ID number and nothing else. Information associated with the animal is stored in a database. Fixed readers can be placed at the opening of a livestock restraining shoot, so animals can be identified as they leave a corral or enter an abattoir. Farmers can also use handheld readers.

2.5.2 Different RFID Technologies

A number of frequencies are used for passive RFID: low frequency (LF), high frequency (HF) and ultra-high frequency (UHF). Each of these frequencies has different features and operating characteristics.

LF - Low Frequency (125 and 134 kHz):

- Good penetration of water and body tissue
- Affected by attenuation by metallic materials
- Reading range from a few centimetres to a few tens of centimetres (depending on transponder size and reader used)
- Transponders (tags) are typically more expensive (starting from around NZ$0.80 for a paper stock label, a low cost encapsulation of the inlay). (See note below on pricing).
- Low data transfer rates (the lower the frequency, the slower the communication)
- Most LF systems can only read one tag at a time and do not support simultaneous reading of multiple tags
- 125 and 134.2 kHz are globally accepted frequencies – no restrictions

HF - High Frequency (13.56 MHz):

- Good penetration of water and body tissue
- Affected by attenuation by metallic materials
- Reading range from a few centimetres up to about 1 metre
- Transponders (tags) are less expensive than LF (starting from around NZ$0.80 for a paper stock label, a low cost encapsulation of the inlay). HF tags are comparable in price to LF tags, but may be cheaper when bought in larger quantities.. (See note below on pricing).
- Higher data transfer rates
- Readers can identify multiple tags simultaneously (typically tens of tags per second)
- Frequency 13.56 MHz is recognized and used globally (no restrictions)

UHF – Ultra High Frequency (between 860 and 960 MHz):

- Poor performance around water-based liquids (incl. body tissue)
- Affected by reflections from metallic materials
- Excellent read distances (up to 5 metres)
- Tags are relatively cheaper (starting around NZ$0.20 for a paper stock label, a low cost encapsulation of the inlay). (See note below on pricing).
- Very high data transfer rates.
- Readers can identify many tags simultaneously (typically hundreds of tags per second). High end systems can read thousands of tags.
- No single frequency across the globe; different regions have allocated different frequency bands in the 860–960 MHz band; region-specific restrictions with respect to maximum power level and communication protocol (frequency-hopping, LBT).

It is difficult to generalise about tag costs. It must be stressed that tag prices are influenced by a wide variety of factors including but not limited to encapsulation costs, production costs, chipsets, antenna design, tag performance specifications, standards compliance, vendor competitive practices, purchase order quantities, data management overheads etc. Nevertheless it should be borne in mind that UHF tags are designed specifically with high volume, low cost practices in mind, consistent with large scale item level management applications.

2.5.3 Applicable Standards for Animal Tracking Using RFID

The International Organization for Standardization (ISO) has established international standards for animal tracking using RFID – these standards apply to transponders that operate at low frequency (125 or 134.2 kHz).

- **ISO 11784** specifies the structure of the identification code. The first 3 digits of the ID are the manufacturer code.
- **ISO 11785** specifies how a transponder is activated and how the stored information is transferred to a transceiver (the characteristics of the transmission protocols between transponder and transceiver). There are 2 protocols in use to communicate between tag and reader: Full-Duplex (FDX or FDX-B) and Half-Duplex (HDX).

A number of issues with the ISO 11784/11785 standards have been identified:

1. Inability to ensure unique ID codes.
2. Lack of manufacturers' accountability.
3. No minimum transponder performance is stipulated.

These standards are updated and expanded in ISO 14223/1 which regulates "advanced" transponders for animals, in an attempt to address the issues mentioned above (e.g. ID duplication).

2.5.4 The Use of UHF Technology for Livestock

The use of LF technology has a number of restrictions, mainly due to the limited read range and the inability to identify multiple tags simultaneously and difficulties in reading tags when animals are moving at high speed. This typically results in narrow read portals where animals need to be passed through one-at-a-time. Also, many breeders have voiced concerns over the costs of the tags and related other LF hardware.

Research undertaken by the University of Adelaide's Auto-ID lab has been evaluating the use of EPC UHF RFID in recent years using pigs. With increasing global standardisation of UHF technologies, the Auto-ID Labs investigated whether the use of UHF would allow production of low cost animal ID tags that would provide satisfactory performance. Satisfactory performance was defined as the ability to read tags and identify specific animals in a suitably confined area.

The Auto-ID researchers reported very favourable performance within the terms of their definition on the use of UHF ear tags on pigs. In summary, the report documented high confidence in the use of UHF on pigs for the future use in the livestock industry and commented that this is good news because the tags were easy and economical to construct. Since EPC Generation 2 chips are abundantly available, if RFID vendors manufacture tags based on the UHF prototype and standards, livestock producers should find it more economical to RFID-tag animals.

2.5.5 Benefits of UHF RFID:

The Benefits of RFID technology operating at UHF over LF include:

- Enables higher speed of animal movement.
- Increased maximum reliable read range.
- Increased maximum reliable read rate.
- Identification of multiple animals simultaneously with standardized protocols.

This means that the use of UHF can reduce the complexity and/or the cost of existing read points (e.g. less antennas required to cover a wider area), but it can also enable new use cases for example the potential to use RFID across additional paddock gates for mustering in the field.

ISO18000 standardized (EPC GEN2) UHF protocols also employ advanced modulation schemes and symbol encoding protocols to provide a robust communication protocol capable of operating reliably in electrically noisy environments by being able to extract and recover signals from the noise.

2.5.6 Benefits of EPC RFID Tag data standards and unique identifiers.

Supply chain information and equipment interoperability among all trading partners or supply chain stakeholders is an area of national and global opportunity – driving towards a collaborative information platform. Information sharing using standardised data and unique identifiers will become the basis for further enhanced supply chain solutions, like demand-driven ordering, 'actionable' supply chain visibility and importantly for the livestock sector - traceability. Understanding how harnessing collaborative technologies, data sets and identifiers can deliver better value to customers and industry alike and should be of vital importance to any industry and form the basis of trading at any level in the age of eCommerce.

2.6 Recommendations

The study results documented in parts 2, 3 and 4 of this document indicate that under certain conditions 100% readability of animal tags can be achieved. However the tests undertaken represent a single isolated trial of each animal type. Pathfinder makes the following recommendations:

1. That the Deer, Sheep and Cattle industries seriously consider the use of EPC UHF RFID technology as an alternative to LF for its use in the management of livestock.
2. That interested parties undertaking research activities for said Industries conduct independent trials to corroborate the findings and implement the recommendations made herein.
3. That the scope of tests be expanded to include tags operating in both RFID spectra allocated for use in New Zealand, viz. 864-868 MHz and 921-929 MHz.
4. Further development of the tags is recommended to create a suitably robust design for larger scale tests and if livestock shipping applications are to be considered then design of a “wide-band” tag is desirable for use in other regions or countries.
5. Antennae configurations for animals may require additional engineering or component selection to optimise conditions for good readability. Pathfinder recommends that further studies include development of specifications or criteria for antenna selection.
6. That further tests be conducted in all-weather conditions.
7. That application scenarios such as: Meat processing, Sheds, Sale yards, Loading and unloading be investigated.
8. That new application scenarios (such as field musters across wide paddock gates) be tested to broaden the scope of utility of the technology on the farm.
9. That further tests be performed to identify the minimum level of RFID infrastructure required to implement a reliable drafting and sorting system, to facilitate cost benefit calculations.
10. That interested parties investigate the data mapping requirements to provide a migration path for current ISO Standards for Animal identification for provision in UHF based systems.

Part Two
Deer Trials

3 Part Two – Deer Trials

3.1 Test Methodology

The results presented in this section are those of tests conducted at the Totara Hills Deer Farm (near Balclutha) on 14th and 15th April 2008. The tests were carried out indoors, inside the shed which is used for sorting the deer. The research sample consisted of 10 animals[3]. The test group was randomly selected by the farm manager.

3.1.1 Tagging the Animals

Two different ear-tags (both EPC GEN2 UHF) were tested – referred to as tags A and B. Every animal in the test group was fitted out with two tags, one of each type in each ear.

Tag A: button tag, narrow spectrum (866 MHz)

Tag B: "hang tag", broad-spectrum (860-960 MHz)

Both tags are applied to each animal in the test group

Figure 3-1

Irrespective of the test results, it is clear that the size and shape of tag A is more fit for purpose; tags of type B ("hang tags") being much more likely to get caught behind barbed wire, ripped off etc, therefore are not compliant with NAIT retention requirements.

After tagging the animals, the animals were tested in a "controlled run" environment to ensure tag operability. Testing consisted of presenting each animal - one at a time – in front of the reader and waiting until both tags were correctly identified (less than 5 seconds per animal). The control run validated that the 20 test tags (10 type A, and 10 type B) were not damaged during the application process.

[3] Note: during the second day of testing, one of the animals got away; subsequent test used only 9 animals.

3.1.2 Test Configurations and Layouts

Two different read portal configurations were examined during the tests:

- a narrow portal (1.1m wide) – the weighing station (scale)
- a wide portal (2.1m wide) – the various gates / boxes inside the shed

Narrow portal

Wide portal

Figure 3-2

The weigh scales used for the narrow portal tested is not an industry standard size. It does correspond, however, to the width of a drafting race, as well as a ramp for loading animals onto a truck. As such, the dimension of the portal provides a valuable test baseline as the same read rates can be expected for those similar size portals.

The second portal was used to evaluate the tag / reader performance across a wider pathway. The ability to use wider portals allows additional applications with wider sorting and mustering gates.

For each portal, a number of different antenna configurations were evaluated. The details of the antenna layouts, as well as the exact dimensions of each of the portals, can be found in the Appendix: Test Configurations and Layouts – Deer.

Figure 3-3

3.1.3 Test Scenarios

The same testing scenario was used for all tests conducted. The entire test group (10 animals) passed through the read portal unimpeded (i.e.: without slowing the animals down.) In most cases, this resulted in the animals running (and even jumping) through the portal in an average time of 3-5 seconds for the entire group. This applied to both the narrow and the wide portals.

On the second day of testing, the research team modified the test scenario where the animals were sprayed with water before being led through the portal. This was done to emulate a wet environment in order to investigate the possible effects of wet conditions (rain) on the read rates and read reliability.

Every test conducted (i.e. the combination of a read portal, antenna configuration and test scenario) was repeated three (3) times in order to provide for a more statistically robust analysis.

Figure 3-4

3.2 Test Results

3.2.1 Tag Sensitivity

As outlined, each tag was individually checked in the control run to ensure that it was readable by the readers. Tag A was tuned to 866MHz. Tag B complied with the EPC UHF Gen 2 global standard i.e.: 860-960 MHz. The incidence of each tag being read was recorded for each run and the results indicated that some tags appeared to be more 'deaf' than others - especially Tag B. The cause of deafness was not investigated but further analysis and research is recommended to monitor and understand the affects of tag orientation, occlusion by the ear, tag antenna geometry and possibly polarisation. All these factors may contribute to tag performance degradation.

Figure 3-5 below shows the distribution of tag responses based on how often individual tags were observed during all the tests.

- Type A tags had a fairly narrow distribution skewed towards 100% meaning that this tag was consistently seen by a reader, more frequently; a good indicator given that the ideal outcome would be 100% readability of all tags on every read. For example, Figure 3-5 shows that 6 of the Type A tags were seen 80 to 90% of the time in the course of all tests.

- Type B tags tended to have a much poorer response and a wider spread indicating that tighter read conditions (read range, tag orientation, position relative to the ear, length of time in the read zone etc.) might be needed in order to achieve a high degree of readbility with this tag type. Interestingly, Figure 3-5 shows that 2 of the type B tags were observed between 90 and 100% of the time, indicating almost perfect readability of those individual tags.

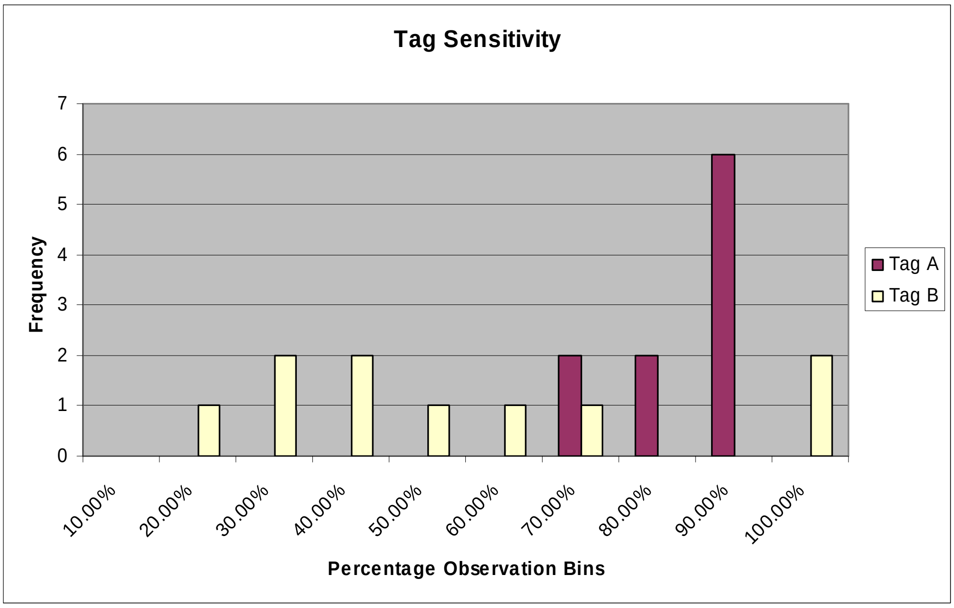


Figure 3-5

3.2.2 Overall Readability

Test runs were conducted varying both the reader type, antenna layout arrangement and portal configuration. This was done to determine if one or more of any of the configurations could read the tags on all the animals thereby satisfying a system design goal: i.e. to accurately count and identify animals in a range of use cases. The results shown in Figure 3-6 indicate that of the 13 test runs executed (excluding the control run) three (namely runs 3, 5 and 12) resulted in a 100% read rate (of Tag A). Figure 3-6 illustrates that tag responses varied according to portal width and layout.

Runs 7 to 11 were conducted using a wider portal. In Figure 3-6, readability data shows a tag read performance range of 30 -75% compared to the narrower portal read range (50 -100%). The results reflect a drop in readability which is likely attributable to *RF path loss*, because the power required to energise the tag falls away in proportion to the distance to the tag.

Notwithstanding, Tag A showed promising results in the 2.1m portal configuration. The researchers expected that with a low frequency operation there would be a readability performance decrease towards zero (0) beyond the 0.5-1 m range. For a more robust analysis, side by side tests using low frequency reader equipment would provide a better comparison.

Another contributing factor to readbility is the *speed* at which the tag UID can be read by the reader. Typically, the bandwidth of a UHF system is about 100 Kbit/s compared to the fastest LF systems operating at around 1-10 Kbit/s. In essence, this means that animals can be in the read zone for a relatively shorter time using UHF readers.

In many of the trials, animals were often bunched together and travelled at an estimated 2.5 animals/second past the readers (or approximately 3 -5 m/s average speed for the entire herd). The high readability performance recorded in runs 1,3,4,5,12 and 13, indicate that with UHF technology, we were able to capture fast moving animals readily or conversely, the time taken to record the 'inventory' is significantly shorter than would be possible for LF applications. This may have useful applications within an on-farm environment.

Reliable readability is exacerbated by having to resolve multiple tag IDs simultaneously if there is more than one animal in the read zone. It was observed in the trial that in some tests there was estimated to be up to 16 tags in the field of the antennas simultaneously[4].

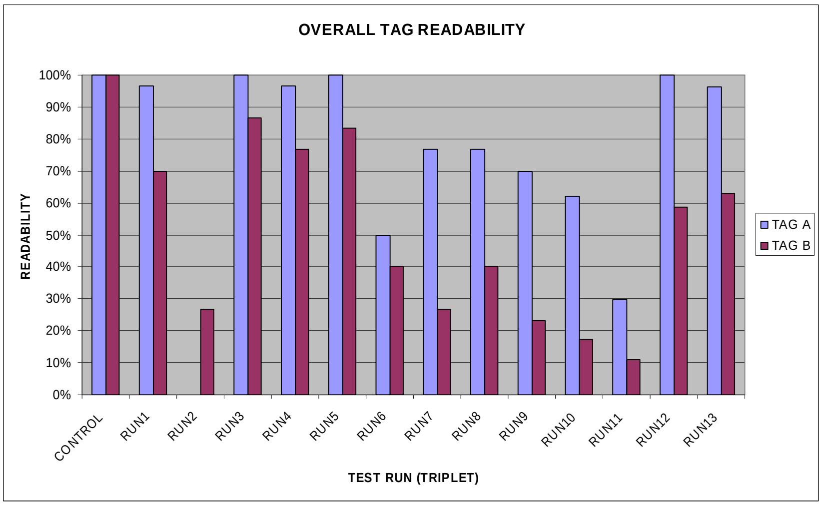


Figure 3-6

[4] Note – Test Run 2 was conducted with reader Z. This reader was only able to be configured for 915 MHz band and could not read type A tags, as the were tuned to respond only to transmissions at 866 MHz, hence a zero response.

3.2.3 Tag Readability by Layout

Consideration was given to the antenna arrangement/ configuration with respect to both the portals and animals. In total, seven different antenna configurations were used[5]. Where lateral arrangements were employed, (layouts 1, 3, 4, 5, 6 and 7) the antennas were mounted approximately in line with the head of the animal. If multiple antenna pairs were used (layouts 1, 3, 6, 7 and in some instances 2) then antennas were separated so that the beams were unlikely to interfere with one another. In some configurations, mono-static arrangements were used. In this design, the antenna acts as both transmitter and receiver (layouts 2, 6). In other cases bi-static antennas were employed, however the pairing relationship of transmitter/receiver pair was varied to arrange pairings either side by side (layouts 1, 5) or across the width of the portal (layouts 3, 4, 7)[6].

For each test run, tag reads were recorded against the layout and Figure 3-7 and Figure 3-8 indicate the average readability for both tag types (A and B). The error bars indicate the range of reads for each layout. For example, for layout 1, Tag A recorded an average readability of 87% compared to 48% for tag B. Tag A performance ranged from 70% to 100% readbility for the various test runs conducted using this specific layout. This compares to a much wider spread of 20-80% for Tag B.

- The combined highest readabilities were achieved with layouts 3, 4, 5, and 6 using layout 2 appearing to be the worst performer.
- Layout 5 provided the single best results in terms of average readability and range of readings and offered the bonus of using a minimal number of antennas. Additional data is required to form a sufficiently large statistical sample to determine if there is a strong correlation between individual layouts and readability.
- High average readings for layouts 1,3, 4 and 5 for Tag A indicate that further tests should concentrate on establishing if there is a difference between having 2 and 4 antennas.

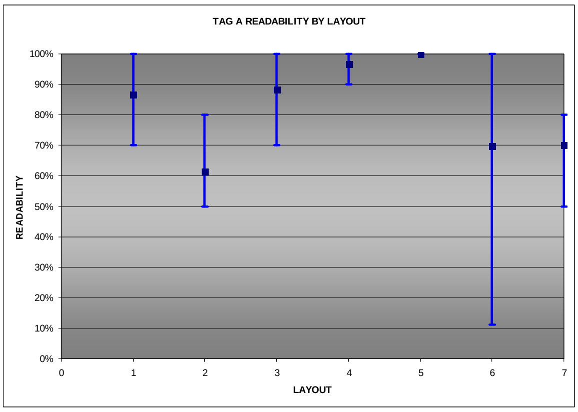


Figure 3-7

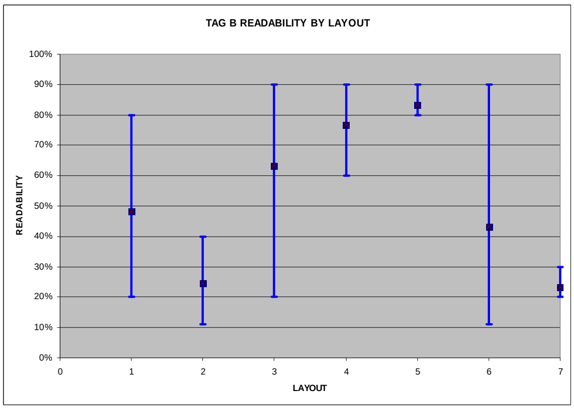


Figure 3-8

Antenna Configurations Tested

The following antenna configurations were utilised during the testing regimes.

- **Layout 1**: 4 Antennas Paired Side by Side
- **Layout 2**: 1 to 4 Antennas mounted overhead
- **Layout 3**: 4 Antennas Paired Across
- **Layout 4**: 2 Antennas Paired Across
- **Layout 5**: 2 Antennas Paired Side by Side
- **Layout 6**: 4 Antennas Side by Side
- **Layout 7**: 4 Antennas above and below paired across

[5] See Appendix – Antenna Layouts
[6] See Appendix – Antenna Layouts

3.2.4 Comparative Reader Performance

Figure 3-9 reveals that both Readers X and Y performed with similar performance. This indicates that in general, the affects of variability of individual reader performance can be ignored when evaluating the performance of tags and antenna layouts. A third reader (Reader Z) was used to conduct some tests but because it could not be configured to read Tag A, its utility was limited to evaluating just one layout configuration thereby rendering it inappropriate for comparison purposes in this analysis.

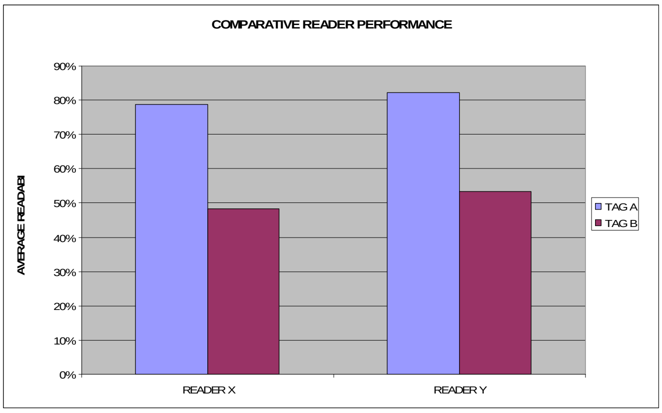


Figure 3-9

3.2.5 Side by Side vs. Cross Paired Antennas

The send/receive pairing for bi-static antenna layouts was analysed using a Chi Squared test to determine if there was any statistically significant difference in overall tag readability based on antennas being paired in a side-by-side configuration or in a cross paired configuration across the portal. Using a null hypothesis that there is no significant difference between the two configurations, the following contingency tables were produced for both tags.

Applying the test, it yielded probability factors of 0.24 and 0.63 for tags A and B, respectively, which is not considered statistically significant. Therefore, our initial conclusion is that the pairing arrangement of antennas has no impact on the readability of tags.

TAG A	DETECTED	NOT DETECTED	TOTAL
SIDE PAIRED	82	8	90
CROSS PAIRED	103	17	120
TOTAL	185	25	210
CHI SQ VALUE	1.3659		
DEGREES FREEDOM	1		
P	0.2425		

TAG B	DETECTED	NOT DETECTED	TOTAL
SIDE PAIRED	54	36	90
CROSS PAIRED	68	52	120
TOTAL	122	88	210
CHI SQ VALUE	0.2347		
DEGREES FREEDOM	1		
P	0.6281		

Table 3-1

3.2.6 Comparison of Lateral vs. Overhead Antenna Location

Tests were undertaken with antennas placed laterally (adjacent to the animals head) and overhead (above the animals head pointing downward) in order to determine if there was a preferable location to suit a variety of drafting, loading/unloading or race constructions.

Tests results indicated that tags were significantly more readable when the lateral reader antenna arrangements were used. This may be attributed to the geometry of the tags and tag orientation in the ear (orientation with respect to the illuminating r.f. beam). For example, antennas placed adjacent to Tag B (i.e. the hang tag) in general presented the face of the tag antenna to the reader antenna whereas an overhead reader the tag is more likely to be orthogonal to the beam.

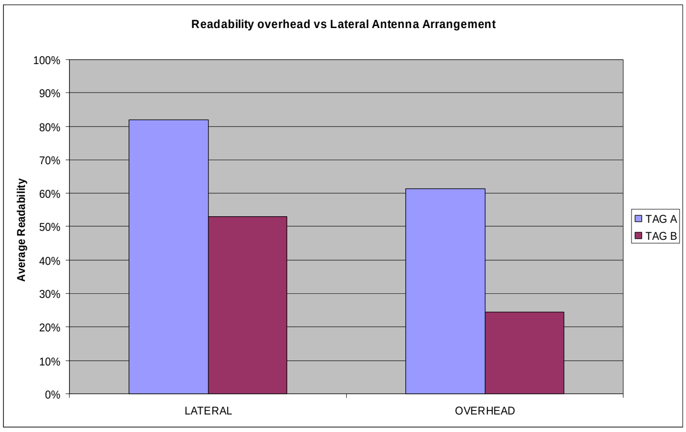


Figure 3-10

3.2.7 Comparison of Wet and Dry Conditions

Two test runs were performed using the same antenna and reader configurations as outlined above in order to identify the susceptibility and potential performance degradation of UHF tags in wet conditions. In general, UHF tag performance is known to be affected by water through the absorption of r.f. signals by moisture. On this basis, the research team tested the tags in a simulated 'wet' environment. The animals and tags were hosed with water. Comparative readings were taken using a Layout 6 and narrow portal combination.

The results indicate that there was little discernable difference in tag readability with both tag types performing relatively the same.

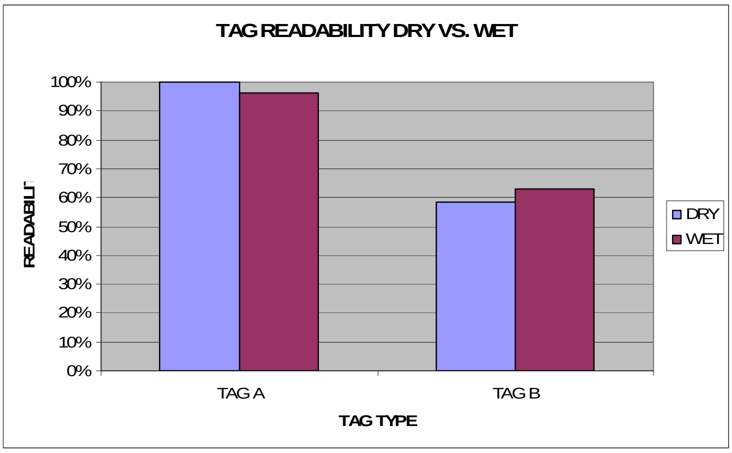


Figure 3-11

Part Three
Sheep Trials

4 Part Three – Sheep Trials

4.1 Test Methodology

The results presented in this section are based on tests conducted at the stock holding sheds of Canterbury Meat Packers (CMP) processing plant in Ashburton. The tests were conducted both outdoors and inside the shed with a sample group of 20 animals. The animals were tagged with a single tag in the right hand ear then herded past a reader and antenna system. Multiple reader systems were utilised and various antenna configurations tested.

Tests were conducted both indoors and outdoors to eliminate the potential interfering effects of metallic and other obstacles.

4.1.1 Assumptions

On analysis of the results of the deer trials, a number of test scenarios were omitted from these trials given that any repetition would serve no useful purpose. These 'redundant' tests included the following:

- Wet/dry tests were not repeated because a separate more comprehensive all weather test is warranted and no performance issues were identified in the previous, limited test.
- Overhead antenna testing was eliminated because they were unlikely to be implemented in practice.
- Multiple antenna systems with phasing relationships. This was eliminated because of the desire to minimise infrastructural investment while maintaining high performance.
- Tests on more than one tag type were eliminated. The research team opted instead to use a single tag that complied with NAIT requirements – a tag that offered best performance characteristics with a likelihood of optimum results.
- Explicit tests to validate reader independence and performance equivalence were not conducted because previous tests had conclusively shown that outcomes were not reader dependant.

4.1.2 Tagging the Animals

A single tag measuring approximately 30 mm in diameter was fitted to each animal in its right ear. A control run validated that the 20 test tags were not damaged during the application process and were fully functional.

Tag A: button tag,
narrow spectrum (866 MHz)

Tags are applied to each animal in the test group on their right ear

Figure 4-1

4.1.3 Test Conditions

A restricted number of antenna configurations was used to test minimal deployment scenarios. Three different read portals were examined during the tests:

- a narrow portal (1.3m wide) – a narrow section of an internal race
- a wide portal (2.35m wide) – a wider section of the same race
- an outside portal (1.62m wide) – the entrance to the shed

The narrow portal was used to simulate normal conditions in a drafting race. The second wider portal was used to experiment with tag performance across a wider pathway to evaluate the potential for use in farm gateways and to look at the affects of maximum reliable reads at longer read ranges.

A third portal was tested outside to simulate vehicle loading and unloading conditions. The outside portal was also chosen because the inside portals were known to be operating inside a metal shed and concerns were expressed that these may be having a measurable effect on tag reading performance.

The same test scenario was used for all tests conducted: the entire test group (20 animals) was herded through the read portal, without impeding the animals movement. Invariably, this resulted in the mob of animals running (and jumping) through the portal in less than 5-10 seconds on average. This applies to all the portals though space constraints inside meant that animals were not inclined to run at will.

For single antenna experiments the direction in which the animals were herded was noted in order to record the position of the tag in the animals' ears relative to the antenna. This would enable the effects of animal body mass on tag readability to be studied.

The vertical positioning of the antennas was configured to correspond to the head height of the animal. However some variations in displacement were required to allow for suitable antenna fixing positions. In general, all antennas were placed between 0.7 and 1.0 m above the floor/ground. A number of antenna configurations were evaluated for each portal arrangement, Details of antenna layouts, antenna dimensions and portal configurations are published in the appendices.

4.2 Test Results

4.2.1 Tag Sensitivity

Each tag was checked in the 'Control Run' to ensure readability with readers. Tag A was specifically tuned to 866MHz. The incidence of each tag being read was recorded for each run. The results indicated that some tags appeared to be fairly consistent in their response. Figure 4-2 shows the distribution of tag responses based on how often individual tags were observed during all the tests.

Type A tags had a fairly narrow distribution skewed towards 100% indicating that this tag was consistently seen by a reader, more frequently; a good indicator of performance given that the ideal outcome would be 100% readability of all tags on every read.

It should be noted that the tag used in the sheep trials was an improved version of the tag used in the Balclutha deer trials (see part 2 – Deer farming). Whilst this tag had an improved sensitivity, the tag's bandwidth was less than 10 MHz with a +/-2 dB of sensitivity variation. For global operation (in which tagged livestock might move from country to country) tag sensitivity would need to span all the spectra allocated by different countries, between 860 – 960 MHz. Further work is recommended to develop a more wide-band tag if a commercial tag for operation in other regions/countries is desired.

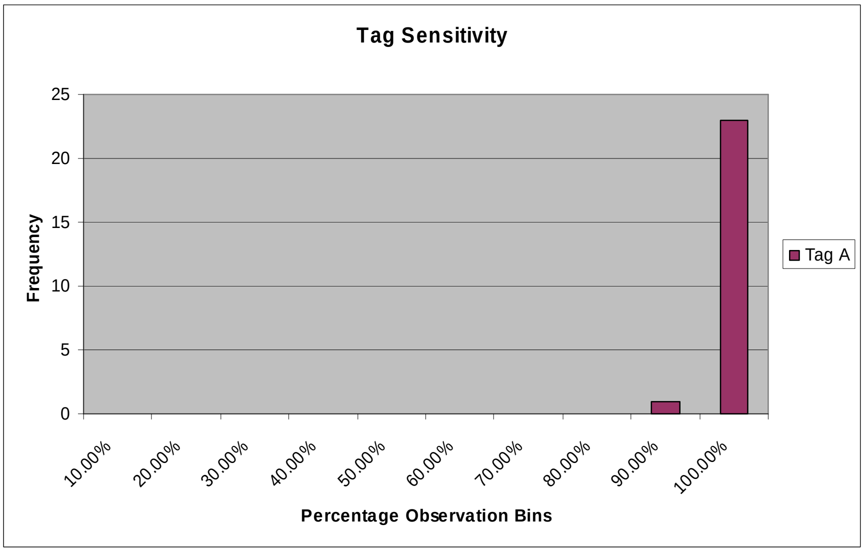


Figure 4-2

Results from seven tests were not included in Figure 4-2 as the actual tag numbers were not recorded. This limited the ability to analyse individual tag sensitivity. In those tests, (mostly conducted using the wide portal) overall readability was diminished to +/-80%. Implicitly, Figure 4-2 should be read within this context. Notwithstanding, the results indicate that the new "improved" tag appears to be more sensitive than the one used in the deer trails.

4.2.2 Overall Readability

Test runs were conducted using different vendor's readers, antenna layout arrangement and portal configurations in order to establish if one or more of any of the arrangements could read the tags on all the animals and thereby satisfying a systems design objective, namely to accurately count and identify animals in a range of use cases. The results shown in Figure 4-4 indicate that of the 32 test runs conducted (excluding the control run) 16 resulted in a 100% read rate. Figure 4-4 shows that in general tag responses varied according to portal width and layout as expected.

Runs 19 to 30 were conducted with a wider portal and readability showing a range of 70-95% compared to the narrower portal (95-100%). Results reflect a drop off in readability which is likely attributable to r.f. path loss, because the power required to illuminate the tag falls away at approximately as a square law relationship to the distance to the tag. Nevertheless, Tag A displayed encouraging results in the 2.35m portal. The expectation with a low frequency operation would be diminished readability rapidly towards zero beyond +/- 0.5-1 m. Side by side tests using low frequency reader equipment would provide for a better comparison.

Readability is usually exacerbated by having to resolve multiple tag IDs if there is more than one animal in the read zone. It was observed in the trial that with some tests there was up to 6 tags in the read field simultaneously. The results indicate that tag density did not appear to be an issue.

Figure 4-3

The outside portal test revealed 100% readability (notability runs 31-33) and under conditions where the animals were often jumping through the read footprint and potentially outside the read zone of the antennas. The animals speed through the read zone was not measured however the successful readability of tags indicates that the speed of reads may be sufficient to compensate for animals that are potentially and/or momentarily outside the read zone.

Analysis of test run 5 suggests a performance anomaly. The reads were distinctly reduced. It was noted that a mobile hand reader was also in use at the same time as the fixed readers and pointing towards other fixed operating antennas. This test run has been included in the Figure 4-4 below but has been ignored for other aggregated results. The result does however indicate that further research may be required to understand the performance of readers in dense reader mode within this environment notwithstanding that global UHF standards for dense reader mode applications are published.

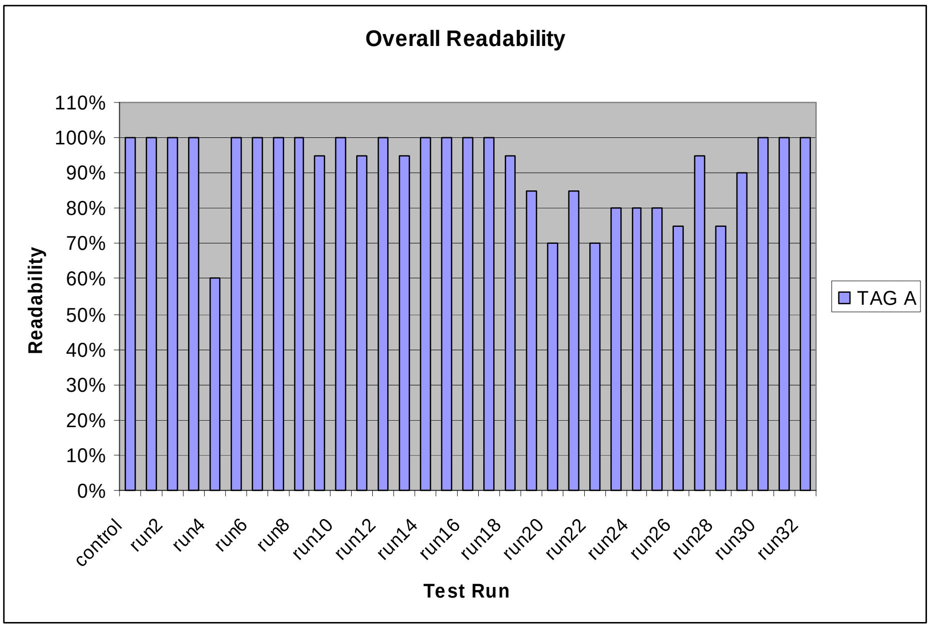


Figure 4-4

4.2.3 Tag Readability Relative to Antenna Layout

Six layout/portal configurations were used in the sheep testing regime -(see Appendix). Lateral arrangements were utilised and antennas were mounted approximately in line with the head of the animal. In some layouts mono-static configurations were used. In this arrangement, antennas act as both transmitter and receiver. Conversely, bi-static antenna configurations were also utilised.

For each test run, tag reads were recorded against the antenna configuration and Figure 4-6 indicates the average readability. The error bars indicate the range of reads for each configuration. As an example, configuration 4 shows an average readability of 81% but overall readings ranged from 70-95%.

Figure 4-5

Combined highest recorded readabilities were achieved with the narrow and outside portal configurations. Readability appears to drop off with wider portals but tests were performed with only one side of the portal having an antenna. Further tests should be conducted to determine the optimum number of antennas for wider portals configurations.

The configurations utilised were:

- **Configuration 1**: 2 Antennas paired across, Narrow portal, antennas mounted both side of portal
- **Configuration 2**: 1 Monostatic Antenna, Narrow Portal, antenna mounted one side of portal only
- **Configuration 3**: 4 Monostatic Antennas , Narrow Portal, antennas mounted one side of portal only
- **Configuration 4**: 4 Monostatic Antennas , Wide Portal, antennas mounted one side of portal only
- **Configuration 5**: 1 Monostatic Antenna, Wide Portal, antenna mounted one side of portal only
- **Configuration 6**: 2 Antennas paired across, Outside Portal, antennas mounted both side of portal

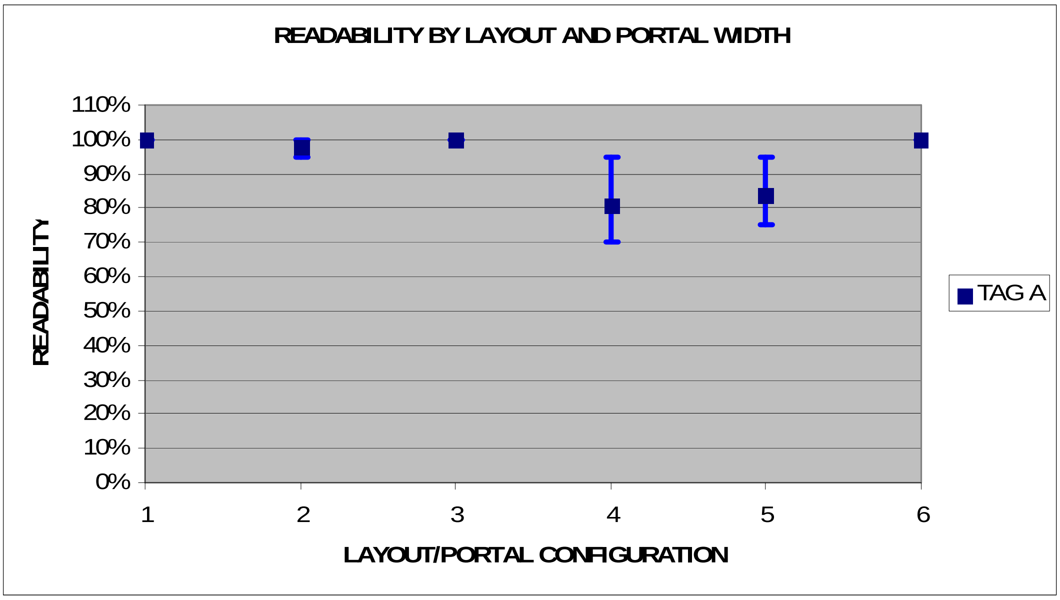


Figure 4-6

4.2.4 Tag Readability Relative to Proximity of Antenna

Tag readability appeared to be influenced by the direction of animal movement past the antenna. The most likely reason would be due to the position of the ear tag relative to the RFID antenna. – i.e.: either adjacent to, or opposite the animals' head relative to the antenna and depending on which direction the animal moved past the antennas. This effect was undetectable on tests involving the narrow portal and when antennas were used on both sides of the portal. However, the effects were noticed when testing with the wider portal and when only one antenna was deployed.

Table 4-1below indicates tags performance relative to tag position and antenna location.

Tag Position	Test Runs	Average Readability
Adjacent, narrow portal	9, 11, 13, 15, 17	100%
Opposite, narrow portal	8, 10, 12, 14, 16, 18	97.50%
Adjacent, wide portal	20, 22, 24, 26, 28, 30	85.83%
Opposite, wide portal	19, 21, 23, 15, 27, 29	77.50%

Table 4-1

Part Four
Cattle Trials

5 Part Four – Cattle Trials

5.1 Test Methodology

The results presented in this section are those of tests conducted at sheds nearby Canterbury Meat Packers processing site in Ashburton. The tests were undertaken inside a shed with a test group of 11 animals. The animals were tagged with a single tag in the right hand ear then herded past a read and antenna systems. Multiple reader systems were employed and various antenna configurations tested.

5.1.1 Assumptions

The results of the deer trials having been analysed rendered some of the tests redundant for the cattle trials. These included the following:

- Wet/dry tests were not repeated because a separate more comprehensive all weather test is warranted and no performance issues were identified in the previous, limited test.
- Overhead antenna tests were eliminated because they were unlikely to be implemented in practice.
- Multiple antenna systems with phasing relationships were eliminated because of the desire to minimise infrastructural investment while maintaining high performance.
- Testing on more than one tag type was eliminated. The research team opted instead to use a single tag that complied with NAIT requirements – a tag that offered best performance characteristics with a likelihood of optimum results.
- Explicit tests to validate reader independence and performance equivalence was not conducted because previous tests had conclusively shown that outcomes were not reader dependant.

5.1.2 Tagging the Animals

A single tag measuring approximately 35 mm in diameter was fitted to each animal in its right ear. A control run validated that the tags were not damaged during the application process and were fully functional.

Tag A: button tag,
(actual size 35mm)
narrow spectrum (866 MHz)

Tags are applied to each animal in the test group on their right ear

Figure 5-1

5.1.3 Test Conditions

Three different portal configurations were utilised during the cattle tests:

- a narrow portal (1.5m wide) – a narrow section of an internal race
- a wide portal (2.1m wide) – a wider section of the same race

The narrow portal was used to simulate normal conditions in a drafting race. The second wider portal was used to examine tag performance across a wider pathway to evaluate the potential for use in farm gateways and to assess the affects of maximum reliable read performance over longer read ranges.

Eleven (11) animals were used in all tests. In all tests, the animals were allowed to move thought the read portable unimpeded. The direction the animals moved was recorded in order to record the position of the tag relative to the position of the single antenna.

For each portal, a number of different antenna configurations were evaluated. The details of the antenna layouts, as well as the exact dimensions of each of the portals, can be found in the appendices.

The vertical positioning of the antennas was made to correspond approximately to the head height of the animal. However some variations in displacement were required to allow for a suitable fixing position of the antenna. In general all antennas were place between 1.3 and 1.7 m above the ground.

A number of observations were made concerning the test setups and animal walkway.

- The far end of the race was blocked off. Animals were not free to move forward well clear of the readers. Subsequently some animals did not enter the read zone on a few runs.
- The commercial (off the shelf antennas were small compared to the vertical distance that the animal's head could move through. Longer antennas with more elements would have been more desirable.
- Consequently it was difficult to judge the correct height to set the antennas at without potentially missing animals that bowed their heads as they moved through the read zone.

5.2 Test Results

5.2.1 Tag Sensitivity

Each tag was tested to ensure that it was functional and performed appropriately with the readers. Tag A was specifically tuned to 866MHz. The incidence of each tag read was recorded for each run. On analysis, the results indicated that some tags appeared to be inconsistent in their response. It must be noted that the sample is considered small and the number of tests limited and therefore warrants further research involving both a larger sample size and number of tests. Figure 5-2 below illustrates the distribution of tag responses relative to test observations.

Type A tags had a wide distribution spread but skewed towards 100%; a good indicator given that the ideal outcome would be 100% readability of all tags on every read. Less sensitive tags may be an indicator that other effects were impacting readability such as the animal body mass separating the reader from the animal's right side.

It should be noted that the tag used in these trials was an improved version of the one used in deer trials - (see part 2 – Deer farming).

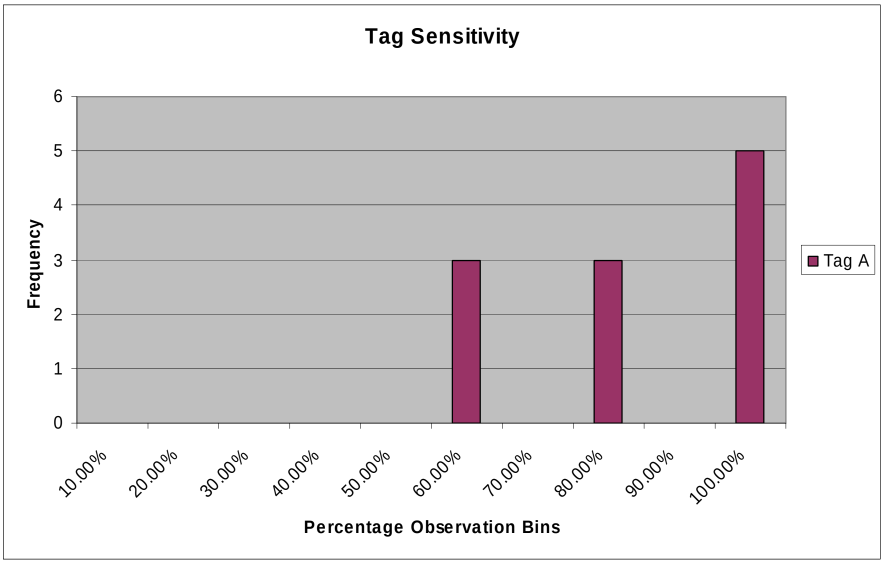


Figure 5-2

5.2.2 Overall Readability

A limited number of test runs were conducted using different vendor's readers, antenna layout and portal configurations in order to establish if any of the arrangements could read the tags on all the animals thereby satisfying a systems design objective namely; to accurately count and identify animals in a range of use cases. The results shown Figure 5-3 indicate that of the 11 test runs, 4 resulted in a 100% read rate. Figure 5-3 also suggests that in general tag responses varied according to portal width and layout configuration as expected.

Runs 10 and 11 were conducted using the wider portal and recorded a lower level of success.

Most of the tests (all runs except runs 1 and 2, which resulted in 100% reads) were conducted with a single system where the antenna was positioned on one side of the animal in order to evaluate the minimum infrastructure requirements for reliable performance. Lower levels of performance compared to the sheep trials are evident. Possible reasons for this include:

- Antenna position relative to tag position and the effects of body mass on tag performance.
- The animals occasionally brushed their ears very close to antennas. This may affect readability because the readers work best when tags are read in the far field (as opposed to the near field), the tags too were designed to operate in the far field. This suggests that a greater gap between antenna and animal may be more amenable.
- The testing race was closed at one end. This restricted the forward movement and some animals tended to bow their heads, potentially missing the antenna beam.

The research team recommend consideration on the utilisation of longer antenna design to ensure the read zone attains adequate coverage during loading and unloading applications.

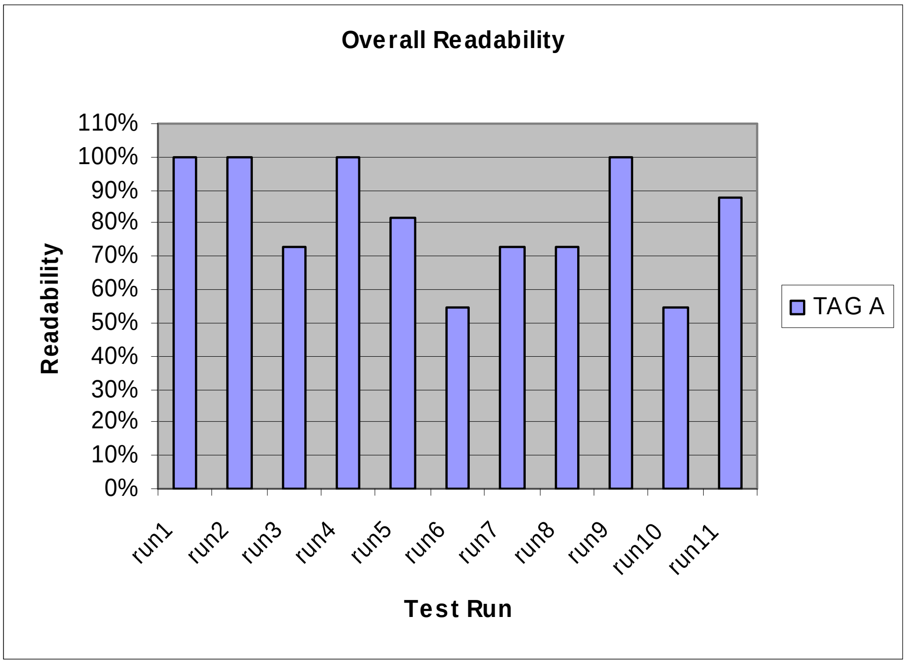


Figure 5-3

5.2.3 Tag Readability by Layout

The research team was cognisant of the relationship between portal position and antenna layout. Six layout/portal configurations were used during the tests (refer appendices). Lateral antenna arrangements were utilised and were mounted approximately in line with the head of the animal. In some layouts, mono-static configurations were used where the antenna acts as both transmitter and receiver. In other cases bi-static antennas were utilised.

For each test run, tag reads were recorded against the layout. Figure 5-5 below illustrates the average readability scores. The error bars indicate the range of reads for each antenna layout. For example, configuration 2 shows an average readability of 76% but readings ranged from 55-100%.

The combined highest readabilities were achieved with the narrow portals where antennas were mounted on either side of the portal. Readability appears to drop off over wider portals but tests were performed with only one side of the portal having an antenna. Further tests should be conducted to determine the optimum number of antennas for wider portals configurations.

Figure 5-4

The configurations were:

- **Configuration 1**: 2 Antennas paired across, Narrow portal, antennas mounted both side of portal
- **Configuration 2**: 1 Monostatic Antenna, Narrow Portal, antenna mounted one side of portal only
- **Configuration 3**: 4 Monostatic Antennas , Narrow Portal, antennas mounted one side of portal only
- **Configuration 4**: 4 Monostatic Antennas , Wide Portal, antennas mounted one side of portal only

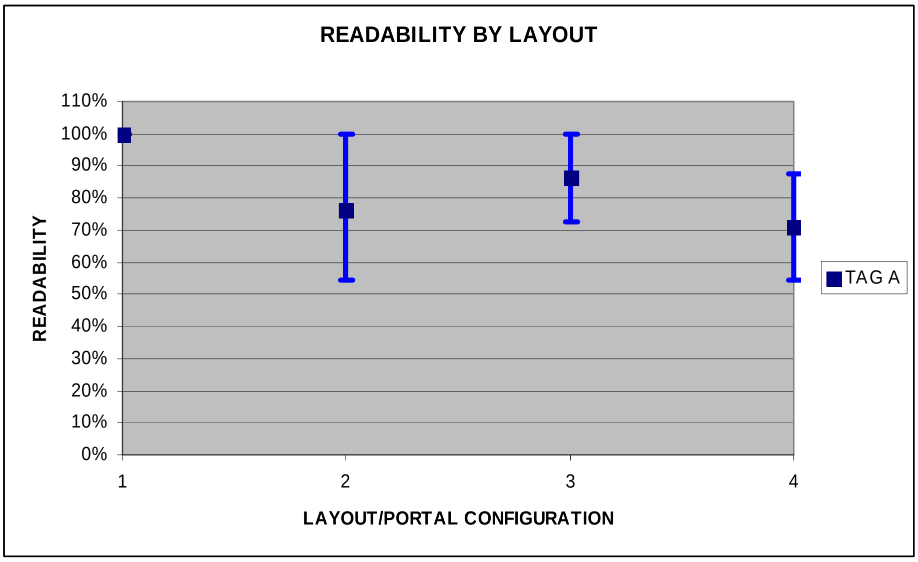


Figure 5-5

5.2.4 Tag Readability by Relative Proximity to Antenna

Tag readability appeared to be influenced by the direction of animal movement past the antenna. The most likely reason would be due to the position of the ear tag relative to the RFID antenna. – i.e.: either adjacent to, or opposite the animals' head relative to the antenna and depending on which direction the animal moved past the antennas. This effect was undetectable on tests involving the narrow portal and when antennas were used on both sides of the portal. However, the effects were noticed when testing with the wider portal and when only one antenna was deployed.

Table 5-1 below illustrates which test runs had the animal's right ear adjacent to the antenna and which had the tag on the opposite side to the antenna:

Tag Position	Test Runs	Average Readability
Adjacent, narrow portal	3, 4	86%
Opposite, narrow portal	5,6,7,8,9	76%
Opposite, wide portal	10,11	71%

Table 5-1

6 Bibliography

- "Venison Industry Strategic Intent 2005-2010", A report published by Deer Industry NZ, July 2004
- "Investigation on the Deployment of HF and UHF RFID Tag in Livestock Identification", Kin Seong Leong, Mun Leng Ng, and Peter H. Cole, Auto-ID Laboratory, The University of Adelaide, SA, Australia. Reprinted from Proceedings of 2007 IEEE Antennas and Propagation Society International Symposium
- "Preparing for the e-Sheep revolution." Presentation by James Rowe, Australian Sheep Industry CRC, EPC/RFID Conference , Auckland, 8-9 February 2005
- "RFID Handbook -Fundamentals and Applications in Contact-less Smart Cards and Identification", Second Edition, Klaus Finkenzeller, Giesecke & Devrient GmbH, Munich, Germany
- "Provisional Permanent Radio Frequency Identification Device Standard (Cattle and Deer only)", National Animal Identification and Traceability, Draft V5.5. (March 2008)
- ISO 11784/85 "STANDARD" WITH BLEMISH. A discussion of the ISO standard for RFID: its provenance, feasibility and limitations. http://www.rfidnews.com/iso_11784.html

Appendices

7 Appendix: International Projects and Mandates

Many governments are encouraging or mandating the use of RFID tags to track livestock, to protect their food chain from contamination and spoilage. Below is an overview of the most important projects in various countries/regions:

- **Australia**: The Australian National Livestock Identification System (NLIS) is the first and the largest implementation of RFID for animal tracking in the world, with millions of tags deployed to date. NLIS became mandatory in Australia in 2005 and is operated by Meat & Livestock Australia, an organization made up of cattle owners and beef producers. NLIS approved devices come in the form of an ear tag or rumen bolus/ear tag combination. Cattle are tagged with NLIS devices only once in their life (unless the device becomes detached). The main advantages that NLIS delivers are market access, consumer confidence and the reduced impact of disease outbreaks.

- **Canada:** Since 2001, all Canadian cattle have been tagged with an approved ear tag before leaving their home of origin. In response to foot and mouth disease (FMD) and bovine spongiform encephalopathy (BSE), industry leaders developed the Canadian Cattle Identification Agency (CCIA) - an organization that oversees the country's trace back system designed for the containment and eradication of animal disease. CCIA has mandated that - as of 1st Sep. 2006 - all Canadian cattle leaving their farm of origin need to be tagged with a CCIA approved RFID ear tag. Bar code ear tags have been recognized until Dec. 31, 2007. According to CCIA, RFID tags allow for more secure tag retention, accurate and efficient trace back information, electronic reading of numbers and the basis for animal movement tracking.

- **United States:** The US Department of Agriculture is aiming at getting 70% of all cattle enrolled in the National Animal Identification System (NAIS) by the end of 2009. NAIS is an information system that tracks the animals as they pass through various premises, with a goal of making it possible to trace back an animal's history to its point of origin within 48 hours. The NAIS program doesn't require participants to employ RFID technology, though it does offer recommendations with regard to specific RFID standards and ID numbers.

- **Europe:** Cattle tagging is being explored by a number of European countries. In Spain, for example, 2,500 cattle farmers in the largest farmers' association in the European Union are using RFID to track 300,000 animals as part of a trial. Part of the reason Europe has not rushed to adopt RFID is that there is already extensive data collection and tracking of individual animals without RFID because of actions taken in response to outbreaks of diseases among member countries. For example, the United Kingdom has operated a cattle-tracking system since 1998. It uses a bar-coded ear tag on the animal. Each ear tag has a unique number that is duplicated on a "cattle passport"—a paper document that has information needed to identify an animal and that lists the movements of that particular animal. The passport remains with the animal throughout its life.

As a result of such government programs and mandates, the use of RFID technology for tracking animals and food is rapidly increasing. According to "RFID for Animals, Food and Farming 2007-2017" (IdTechEx), the food market (including the tagging of farm animals and the tracking of fresh produce throughout the supply chain) will rank as the largest RFID market by 2017. The report forecasts worldwide sales of RFID systems (including tags) will rise from 531 million USD in 2007 to 6.53 billion USD in 2017.

8 Appendix: Extract from NAIT RFID Requirements

The following extracts are taken from "Provisional Permanent Radio Frequency Identification Device Standard (Cattle and Deer only)", National Animal Identification and Traceability, Draft V5.5. (March 2008). They are included here for comparison of the test conditions of the study.

3.1 NAIT RFID devices shall be in the form of a white button ear tag. Devices shall contain a half duplex (HDX) transponder or full duplex (FDX) transponder complying with NZ/ISO 11784:2001, or an approved equivalent machine readable technology. The unique number encoded within each transponder must be non-reprogrammable.

3.2 The electronic radio frequency identification (RFID) device shall be low frequency as specified in NZ/ISO 11785:2001.

3.3 Transponders included in a NAIT RFID device shall be encoded with the relevant manufacturer's code granted by the International Committee on Animal Recording (ICAR).

6.3 In the absence of electromagnetic interference, 99.5% of all RFIDs must be able to be machine readable in animals moving freely at a rate of up to 2m/second in single file past a reading point with a portal width of 0.8m.

9 Appendix: Test Configurations and Layouts - Deer

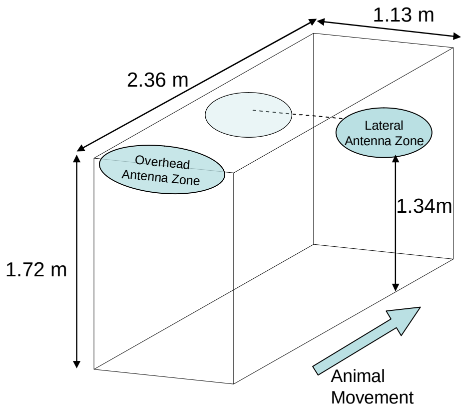
Tests were undertaken to identify if performance (tag readability) was sensitive to the number of antennas, the relative position, the overall location (overhead or adjacent to the animals) and the width of the portal through which the animal moved. This appendix details the antenna and portal arrangements that were used.

9.1 Portals

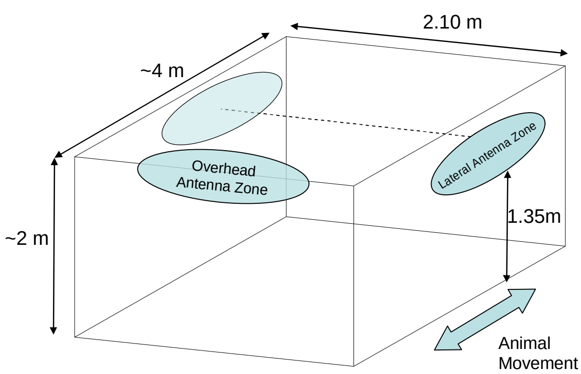
Animals were herded through a weigh scale similar in width to a drafting race. The width of the portal 1 was 1.13m. Note that weigh scales are not used widely in the industry but the dimensions of the portal provided a suitable test bed. Additionally the ends of the weigh scale could be closed off enabling individual animals to be held in the read zone to verify that each tag was readable and returned a unique value.

Portal 2 was used to experiment with tag performance across a wider pathway to evaluate the potential for use in farm gateways and to look at the affects of maximum reliable reads at longer read ranges.

Portal 1



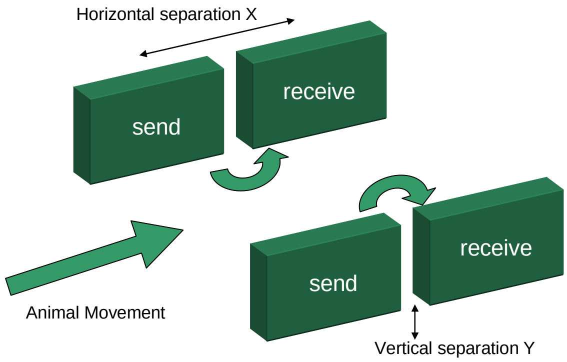
Portal 2



9.2 Antenna Layouts

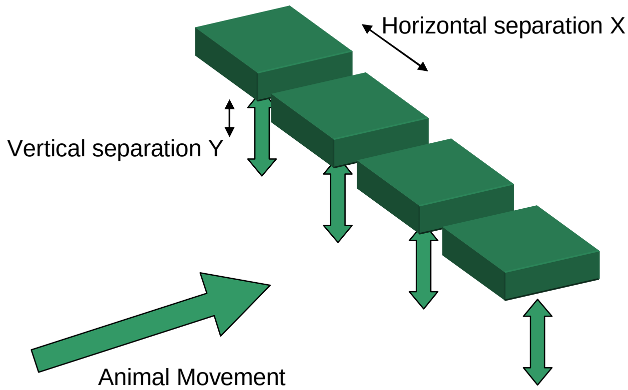
The diagrams below define the seven layouts for antennas and their relative pairing that were used for the portals.. Individual antennas are shown as blocks separated by the width of the portal. Where more than one antenna is used the relative spacing between antennas (horizontal and vertical separation) is indicated. Antenna send/receive pairs are shown where paired, bi-static arrangements were used.

Layout 1: 4 Antennas Paired Side by Side — **Portal 1** — **Portal 2**



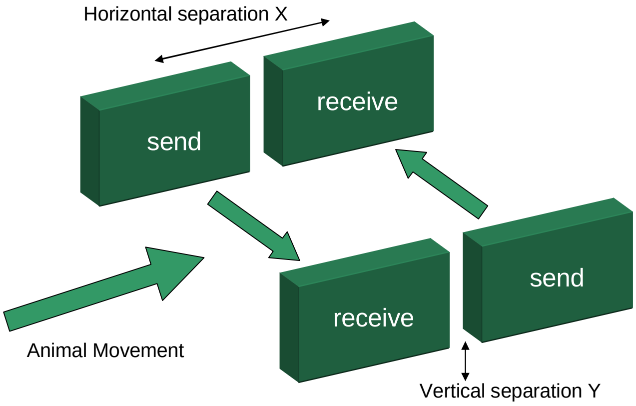
	Portal 1	Portal 2
Horizontal Separation:	0.55 m	0.75 m
Vertical Separation:	0.30 m	0 m

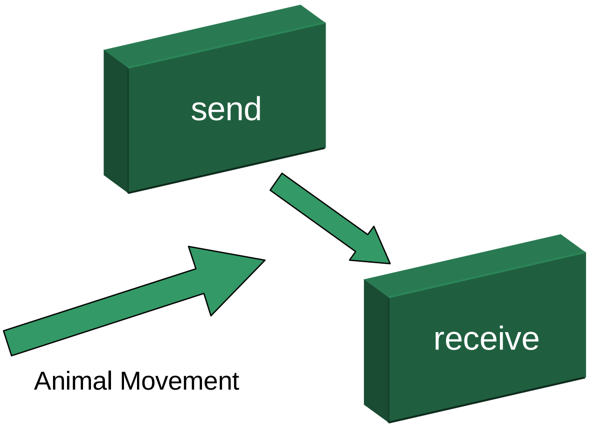
Layout 2: 1-4 Antennas mounted overhead — **Portal 1** — **Portal 2**

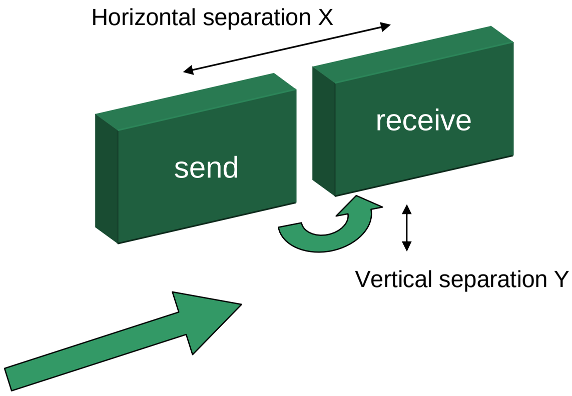


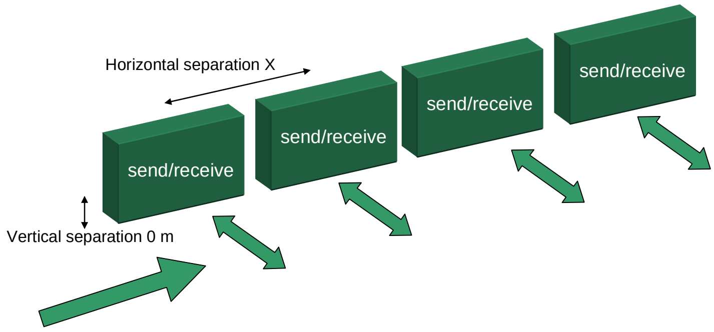
	Portal 1	Portal 2
Horizontal Separation:	0 m	0.5 m
Vertical Separation:	0 m	0 m

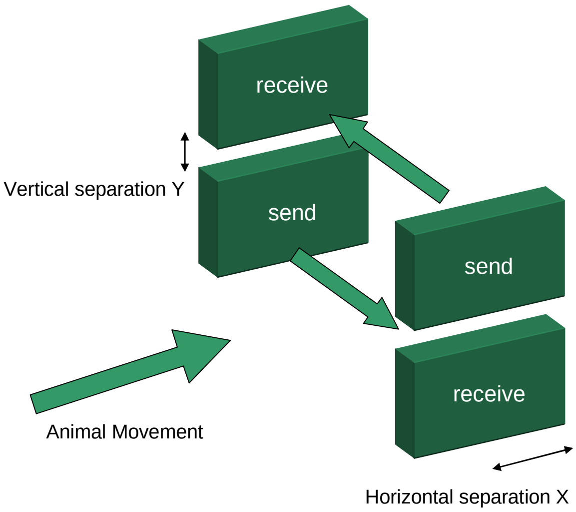
Notes: Antennas are either combined in one enclosure or separate

Layout 3: 4 Antennas Paired Across	Portal 1	Portal 2
		
Horizontal Separation:	0.55 m	0.75 m
Vertical Separation:	0.30 m	0 m

Layout 4: 2 Antennas Paired Across	Portal 1	Portal 2
		No test performed with this layout
Horizontal Separation:	0 m	0 m
Vertical Separation:	0 m	0 m

Layout 5: 2 Antennas Paired Side by Side	Portal 1	Portal 2
		No test performed with this layout
Horizontal Separation:	0.55 m	0 m
Vertical Separation:	0.3 m	0 m

Layout 6: 4 Antennas Side by Side	Portal 1	Portal 2
	No photo available for this layout	
Horizontal Separation:	0.55 m	0.75 m
Vertical Separation:	0.3 m	0 m

Layout 7: 4 Antennas above and below paired across	**Portal 1**	**Portal 2**
	No test performed with this layout	
Horizontal Separation:	0 m	0 m
Vertical Separation:	0 m	0.5 m

9.3 Test Descriptions

The following Table summarizes the Tests undertaken with equipment used, layout, portal and other conditions.

Test no	Run	Scenario	Layout	Reader	Portal
1	0	Control Test - One animal at a time, keeping the gate shut until both tags are read, then opening the gate	1	X	1
2	1	Narrow portal, 10 animals at a time, gate open	1	X	1
3		Narrow portal, 10 animals at a time, gate open	1	X	1
4		Narrow portal, 10 animals at a time, gate open	1	X	1
5	2	Narrow portal, 10 animals at a time, gate open	2	Z	1
6		Narrow portal, 10 animals at a time, gate open	2	Z	1
7		Narrow portal, 10 animals at a time, gate open	2	Z	1
8	3	Narrow portal, 10 animals at a time, gate open	3	X	1
9		Narrow portal, 10 animals at a time, gate open	3	X	1
10		Narrow portal, 10 animals at a time, gate open	3	X	1
11	4	Narrow portal, 10 animals at a time, gate open	4	X	1
12		Narrow portal, 10 animals at a time, gate open	4	X	1
13		Narrow portal, 10 animals at a time, gate open	4	X	1
14	5	Narrow portal, 10 animals at a time, gate open	5	X	1
15		Narrow portal, 10 animals at a time, gate open	5	X	1
16		Narrow portal, 10 animals at a time, gate open	5	X	1
17	6	Narrow portal, 10 animals at a time, gate open	6	Y	1
18		Narrow portal, 10 animals at a time, gate open	6	Y	1
19		Narrow portal, 10 animals at a time, gate open	2	Y	1
20	7	Wide portal, 10 animals at a time	1	X	2
21		Wide portal, 10 animals at a time	1	X	2
22		Wide portal, 10 animals at a time	1	X	2
23	8	Wide portal, 10 animals at a time	3	X	2
24		Wide portal, 10 animals at a time	3	X	2
25		Wide portal, 10 animals at a time	3	X	2
26	9	Wide portal, 10 animals at a time	7	X	2
27		Wide portal, 10 animals at a time	7	X	2
28		Wide portal, 10 animals at a time	7	X	2
29	10	Wide portal, 10 animals at a time	2	X	2
30		Wide portal, 10 animals at a time	2	X	2
31		Wide portal, 10 animals at a time	2	X	2
32	11	Wide portal, 10 animals at a time	6	X	2
33		Wide portal, 10 animals at a time	6	X	2
34		Wide portal, 10 animals at a time	6	X	2
35	12	Narrow portal, 10 animals at a time, gate kept open	6	Y	1
36		Narrow portal, 10 animals at a time, gate kept open	6	Y	1
37		Narrow portal, 10 animals at a time, gate kept open	6	Y	1
38	13	Narrow portal, 10 animals at a time, gate open, **wet**	6	Y	1
39		Narrow portal, 10 animals at a time, gate open, **wet**	6	Y	1
40		Narrow portal, 10 animals at a time, gate open, **wet**	6	Y	1

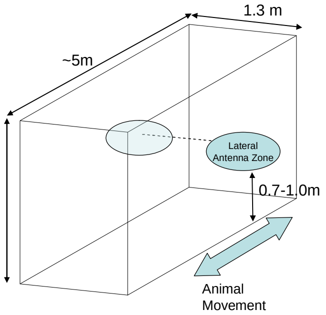
10 Appendix: Test Configurations and Layouts - Sheep

Tests were undertaken to identify if performance (tag readability) was sensitive to the number of antennas, the relative position, the overall location (overhead or adjacent to the animals) and the width of the portal through which the animal moved. This appendix details the antenna and portal arrangements that were used.

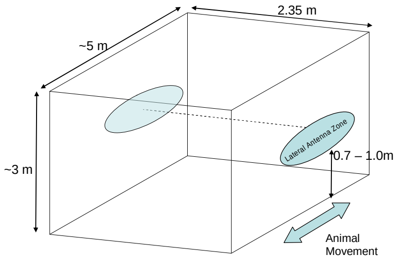
10.1 Portals

Portal widths are indicated in the diagrams below.

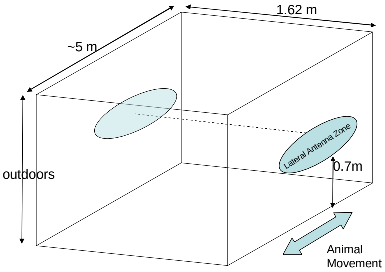
Narrow portal



Wide portal



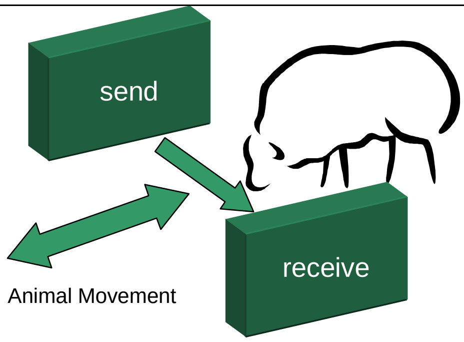
Outside portal



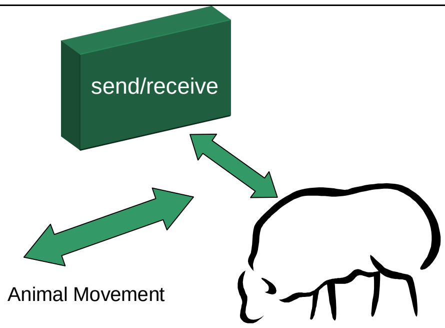
10.2 Antenna Layouts

The diagrams below define the three layouts for antennas and their relative pairing that were used for the portals. Individual antennas are shown as blocks separated by the width of the portal. Antenna send/receive pairs are shown where paired, bi-static arrangements were used.

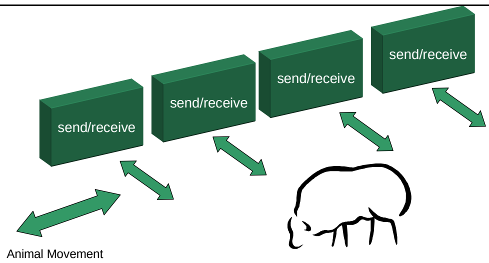
Layout 1: 2 Antennas Paired Across | **Example**



Layout 2: 1 Monostatic Antenna | **Example**



Layout 3: 4 Monostatic Antennas | **Example**



10.3 Test Descriptions

The following Table summarizes the tests conducted with equipment used, layout, portal and other conditions.

Test no	Scenario	Technical setup	Layout	Reader	Portal	Ear/Antenna
1	CONTROL Test - To verify all animal tags can be read	2 antennas, paired across	1	X	1	
2	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
3	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
4	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
5	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
6	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
7	Narrow portal 1.3m, 20 animals at a time	2 antennas, paired across	1	X	1	
8	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
9	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Adjacent
10	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
11	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Adjacent
12	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
13	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Adjacent
14	Narrow portal 1.3m, 20 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
15	Narrow portal 1.3m, 20 animals at a time	4 Antenna, monostatic	3	Y	1	Adjacent
16	Narrow portal 1.3m, 20 animals at a time	4 Antenna, monostatic	3	Y	1	Opposite
17	Narrow portal 1.3m, 20 animals at a time	4 Antenna, monostatic	3	Y	1	Adjacent
18	Narrow portal 1.3m, 20 animals at a time	4 Antenna, monostatic	3	Y	1	Opposite
19	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite
20	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Adjacent
21	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite
22	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Adjacent
23	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite
24	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Adjacent
25	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite
26	Wide portal 2.35m, 20 animals at a time	4 Antenna, monostatic	3	Y	2	Adjacent
27	Wide portal 2.35m, 20 animals at a time	1 Antenna, monostatic	2	X	2	Opposite
28	Wide portal 2.35m, 20 animals at a time	1 Antenna, monostatic	2	X	2	Adjacent
29	Wide portal 2.35m, 20 animals at a time	1 Antenna, monostatic	2	X	2	Opposite
30	Wide portal 2.35m, 20 animals at a time	1 Antenna, monostatic	2	X	2	Adjacent
31	Outside portal 1.62m, 20 animals at a time	2 antennas, paired across	1	X	3	
32	Outside portal 1.62m, 20 animals at a time	2 antennas, paired across	1	X	3	
33	Outside portal 1.62m, 20 animals at a time	2 antennas, paired across	1	X	3	

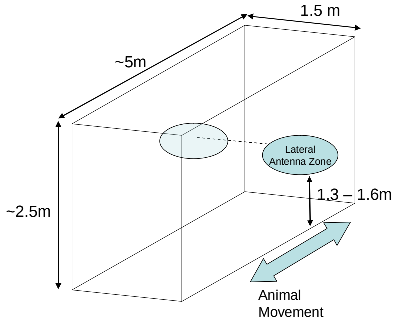
11 Appendix: Test Configurations and Layouts - Cattle

Tests were undertaken to identify if performance (tag readability) was sensitive to the number of antennas, the relative position, the overall location (overhead or adjacent to the animals) and the width of the portal through which the animal moved. This appendix details the antenna and portal arrangements that were used.

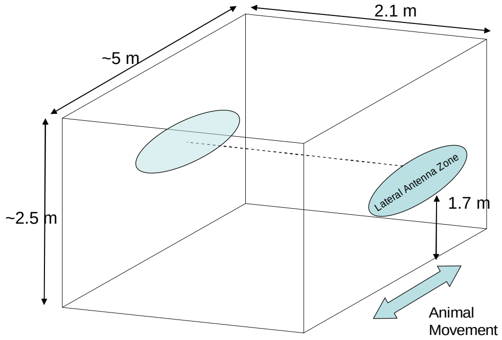
11.1 Portals

Portal widths are indicated in the diagrams below.

Narrow portal



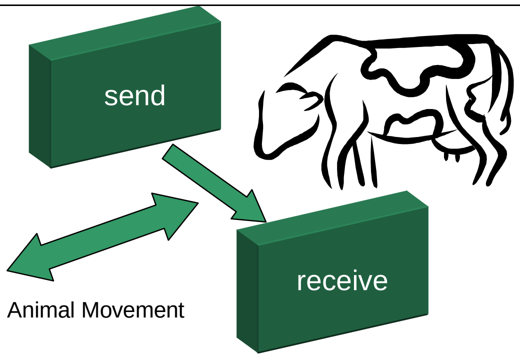
Wide portal



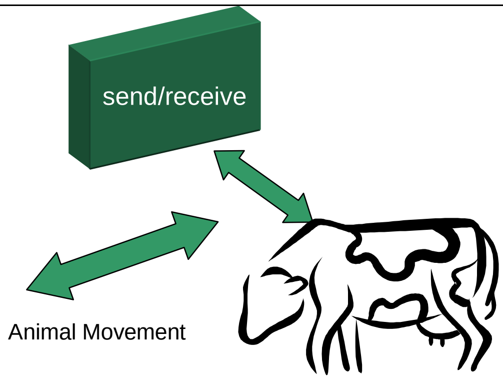
11.2 Antenna Layouts

The diagrams below define the three layouts for antennas and their relative pairing that were used for the portals. Individual antennas are shown as blocks separated by the width of the portal. Antenna send/receive pairs are shown where paired, bi-static arrangements were used.

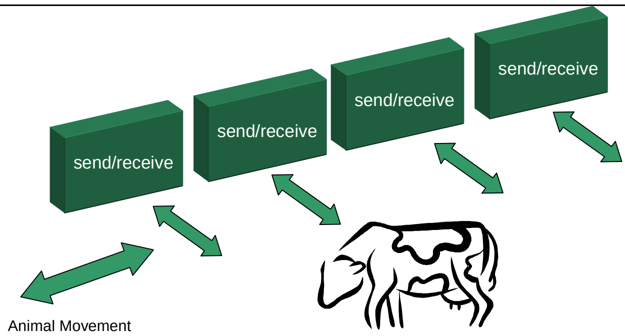
Layout 1: 2 Antennas Paired Across **Example**



Layout 2: 1 Monostatic Antenna **Example**



Layout 3: 4 Monostatic Antennas **Example**



11.3 Test Descriptions

The following Table summarizes the Tests undertaken with equipment used, layout, portal and other conditions.

Test no	Scenario	Technical setup	Layout	Reader	Portal	Ear/Antenna
1	Narrow portal 1.5m, 11 animals at a time	2 antennas, paired across	1	X	1	
2	Narrow portal 1.5m, 11 animals at a time	2 antennas, paired across	1	X	1	
3	Narrow portal 1.5m, 11 animals at a time	1 Antenna, monostatic	2	X	1	Adjacent
4	Narrow portal 1.5m, 11 animals at a time	1 Antenna, monostatic	2	X	1	Adjacent
5	Narrow portal 1.5m, 11 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
6	Narrow portal 1.5m, 11 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
7	Narrow portal 1.5m, 11 animals at a time	1 Antenna, monostatic	2	X	1	Opposite
8	Narrow portal 1.5m, 11 animals at a time	4 Antenna, monostatic	3	Y	1	Opposite
9	Narrow portal 1.5m, 11 animals at a time	4 Antenna, monostatic	3	Y	1	Opposite
10	wide portal 2.1m, 11 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite
11	Wide portal 2.1m, 11 animals at a time	4 Antenna, monostatic	3	Y	2	Opposite

12 Appendix: Contact Information

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