Use of UHF Tags in Deer and Sheep

Project Report

Prepared for

New Zealand Trade & Enterprise
Deer Industry New Zealand
Meat Industry Association
ANZCO Foods
Landcorp Farming
NZ RFID Pathfinder Group
GS1 New Zealand

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1 Executive Summary

Radio-frequency Identification (RFID) systems have been used for a number of years in identification applications ranging from library books to beer kegs. RFID tags have been used in animal applications since the late 1980s and the low frequency system was standardised in 1994-6. RFID rumen bolus and ear tag technologies are widely used for livestock management and inventory, and are mandated in some parts of the world for food traceability and biosecurity.

Ultra-high frequency (UHF) technologies were standardised more recently in 2006 and have been widely adopted in many industries. The trials described in this report built on work by the New Zealand RFID Pathfinder Group in 2008, and sought to assess the utility of commercially available UHF tags and readers with more than 400 cattle, sheep and deer across four farms. We compared our results with the use of available low frequency (LF) tags and equipment where possible.

Our trials established that commercially available UHF tags can be used effectively in a farm environment, performing standard animal handling operations for restrained or single-file moving animals to the same standard as LF tags or better. We also noted that a LF tag reader when tuned for its environment also produces good performance with restrained or single-file moving animals.

We tested movements of mobs of animals at pace through a 2m+ wide gateway. LF tags are not typically used for this sort of identification, although an advanced reader is available (at significantly higher cost) that may be effective for this scenario. UHF tags and standard readers showed promise for this sort of application, although there was much to learn about antenna positioning and orientation. We concluded that antennas had to be positioned at the animal's head height or above (to avoid attenuation of the radio signal by body tissue). For animals such as deer moving at pace, antennas needed to be oriented to maximise coverage along the direction of movement, in order to give the tags time to charge and transmit.

The UHF tags that we assessed were not completely suitable. The tag used for the majority of our trials was a small round flag style tag: a button tag would be preferable for retention. We recommend that UHF tag developers should partner with existing tag manufacturers or industry experts to improve tag design, application, and tamper proof features.

The purchase price of tags for this trial was very similar to the recommended retail for LF tags, which is promising given the very short run and direct import. We caution however that even if price decreases with quantity, local distribution and printing will continue to be major factors in retail tag costs.

We also considered the use of UHF reader protocols for on-farm devices and systems, and discussed how the EPCglobal tag data standards could be used in databases and traceability systems.

On-farm technologies are typically designed to work with the simple ASCII LF tag protocol popularised by Texas Instruments in the late 1990s. However, simple use of the EPC reader protocol could be accomplished by a firmware upgrade in existing devices, or by programming the UHF reader to emulate the older devices.

For those developing databases or software systems, we recommend the addition of a 96-bit or larger EPC data field, or enlarging the electronic ID field to support longer identifiers. We also recommend that software developers ensure that the type of ID is passed along with data, so that systems know whether to expect LF or UHF/EPCglobal data.

We acknowledge with gratitude the substantial assistance of the project sponsors (NZTE, Deer Industry New Zealand, the Meat Industry Association, ANZCO Foods, Landcorp Farming, the New Zealand RFID Pathfinder Group and GS1 New Zealand), the farmers and their staff at Ngaponga, Ngakuru Deer Farm, Totara Hills and Landcorp Hindon Farm. Members of NAIT, farm technology manufacturers, and LF tag manufacturers have all provided support, assistance and open-minded discussion for which we are very grateful.

Figure 1: Tony Pearse of Deer Industry New Zealand holds a cable out of the way.

2 Introduction

Radio-frequency Identification has been used for animal identification since the late 1980s, based on earlier experiments undertaken during the 1970s. In recent years the use of RFID for livestock identification has become more widespread, partly in response to calls for traceability within food supply chains, and partly for productivity and inventory management purposes on farm. The technical specifications for livestock tags were standardised during 1994 to 1996, with the result that low frequency (usually 134.2 kHz, occasionally 125 kHz) tag systems have become widespread and generally interoperable.

Outside of the livestock arena, RFID tagging systems have moved to high-frequency (13.56MHz) and ultra-high frequency (862-928MHz). The higher frequencies enabled faster communication with more tags being read per second, longer read ranges, smaller antenna, and lower manufacturing cost. In theory the spread-spectrum technologies used allow better performance in electrically noisy environments, and have a lower power requirement. UHF technical specifications were formalised by industry body EPCglobal during the early 2000s, and became an ISO/IEC standard in 2006. With the high level of interest in this technology and the potential for performance improvements, calls have been made to review the use of UHF RFID in livestock.

This trial seeks to compare ultra-high frequency (UHF) technologies operating at 862MHz to 928MHz with traditional low frequency (LF) tags operating at 134.2 kHz.

One perceived advantage of UHF technologies over LF RFID systems is the ability to read multiple animal tags simultaneously, so that animals do not have to pass the reader in single file. A longer read range is also achievable with appropriate tags and antenna, which allows for the use of RFID in conjunction with wider races or gateways. This potentially makes UHF RFID technology suitable for use at sale yards, for receipt of animals from transport, and for handling deer and sheep.

Further, LF numbering standards are administered by the International Committee on Animal Recording (ICAR) and are naturally animal focused, while the EPCglobal standards used with UHF offer significant potential for entire supply chain management in which an animal and farm are viewed as components in an end-to-end supply chain that potentially achieves:

- Unique identification at all stages of pasture to plate supply chains;

- Linkages between successive hierarchies (cut to animal, consumer unit to shipper, shipper to consignment etc) ;
- Links management; and
- Electronic communication of core traceability information to trading partners.

In 2008, the New Zealand RFID Pathfinder Group undertook a trial of UHF technologies for animal identification with promising results[1]. This trial used custom-built tags and showed promising results, testing the technology with deer, cattle, and sheep under a range of conditions.

With the commercial availability of UHF animal ear tags in 2009, Rezare Systems led a further trial to consider the suitability and potential benefits of UHF tags in animal applications, particularly for species other than cattle. This project is supported by New Zealand Trade and Enterprise, ANZCO Foods, Deer New Zealand, GS1, the New Zealand RFID Pathfinder Group, and the Meat Industry Association.

The scale of the trial involved over 400 animals (a mixture of deer, cattle and sheep) across four farms.

3 Methodology

We designed the trials to assess the suitability of EPCglobal[2] Class1 Gen2 UHF RFID encapsulated in animal ear tags for identification of deer and sheep (and cattle, for comparison). The objective was to assess commercially available UHF tags and compare these with Low Frequency (LF) tags for the following factors:

- Ability to read single animals in a crush or weigh crate, for comparison with existing (LF) RFID tags. The goal was single animal reading with a range of 800 to 1000mm, to match the requirements of many livestock traceability schemes.
- Ability to read multiple animals moving rapidly in a narrow (typically 1 to 1.2m) loading race or similar environment to that encountered in a sale yard or abattoir. The goal was efficiency, allowing tags to be read quickly as animals moved between locations. In some circumstances standard LF readers can be tuned to perform this function, while in others substantially more expensive equipment is currently required.

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[1] This report is available at www.rfid-pathfinder.org.nz with registration required.
[2] EPCglobal is a subscriber driven organisation responsible for electronic product code standards. See www.epcglobalinc.org

- Ability to read multiple animals moving through a 2m+ gateway (for example, animals leaving a shed or moving between yards). Examples of this use might be for performing a regular inventory of animals, identifying animals moving in a high-throughput sale yard or processor information, or recording which animals are placed into mobs for grazing.
- Directional distance reading (use with a long range reader, for instance, for cow-calf identification).
- Visually assess the size and shape of the tags for retention, and ease of application. We did not carry out a long term retention test. Most official traceability schemes do require such a test for a new manufacturer or tag design.

The initial series of tests were carried out at the following New Zealand farms:

- Ngaponga, a sheep farm at Ngaroma near Te Awamutu in the North Island;
- Totara Hills, primarily farming deer in South Otago;
- Hindon Farm, a Landcorp property west of Outram in Otago, where both deer and cattle were assessed;
- The Ngakuru deer farm of Dave Dewars and Kay Garland, near Rotorua.

Our trials were carried out with the assistance of farm managers at each farm. Additional assistance at various farms was provided by Tony Pearse (Deer NZ), Andy Mitchell (Rodway Park), and John Rutherford (Allflex).

4 RFID Equipment Selection

We sourced UHF livestock ear tags from Invengo[3], a manufacturer based in China. These tags use an NXP chipset, and come in a range of form factors. We initially sourced three form factors – a button tag used in China for pig identification, a larger circular tag with the attachment point offset on the side, and a long narrow tag with the attachment point at the end. Each physical form factor necessitates a different antenna design and hence has different performance characteristics.

Times-7[4] engineer Arthur Roberts carried out evaluations of the tags using an anechoic chamber to simulate free space performance, and also placing the tags within 30mm of skin. Arthur measured performance across the whole RFID band

[3] Invengo Information Technology Co Ltd (www.invengo.cn)
[4] Times-7 (www.times-7.com) is a New Zealand company specialising in RFID technologies. It is known for its innovative sports timing products and baggage/airport RFID devices.

(860 to 960 MHz), and used a low power reader (the M5e from ThingMagic[5]) with adjustable power and distance used to predict reading distance when using a 4W EIRP reader.

4.1 Invengo XCTF-8605 Round Tag

This tag was tuned by the designer to operate in the US (902-928MHz) band in a free space environment, where it achieves read ranges of up to 6m. However, the tag does operate over a reasonable range of frequencies.

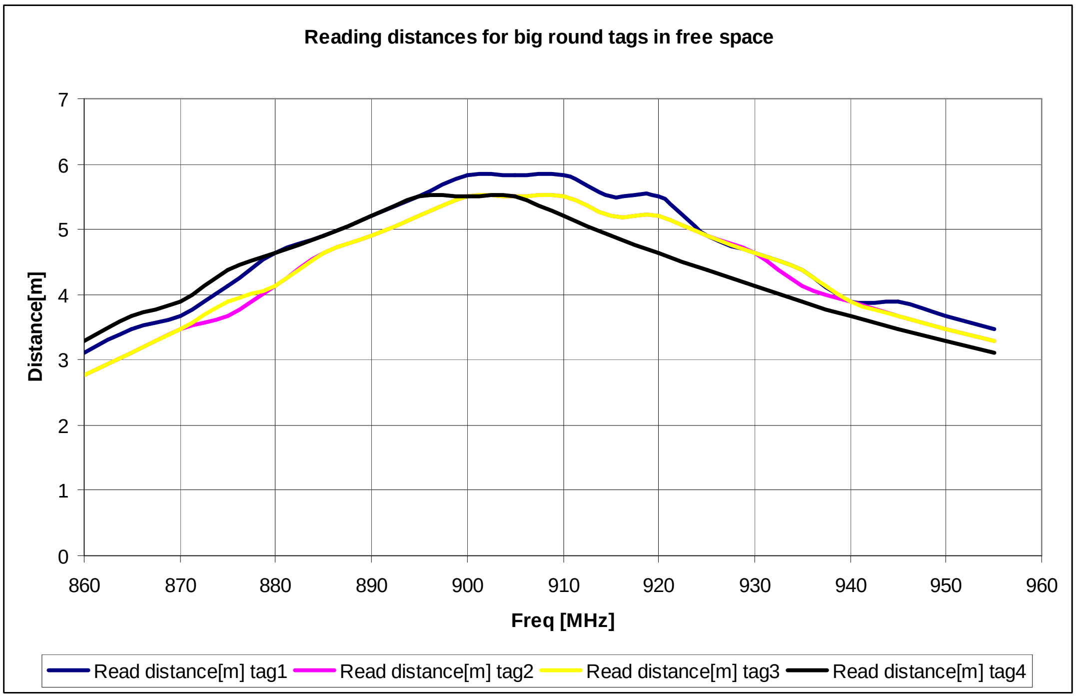


Figure 2: XCTF-8605 free space range

When close to skin, the read range is reduced (typically around 3m) and variability increases.

[5] ThingMagic M5e http://www.thingmagic.com/embedded-rfid-readers

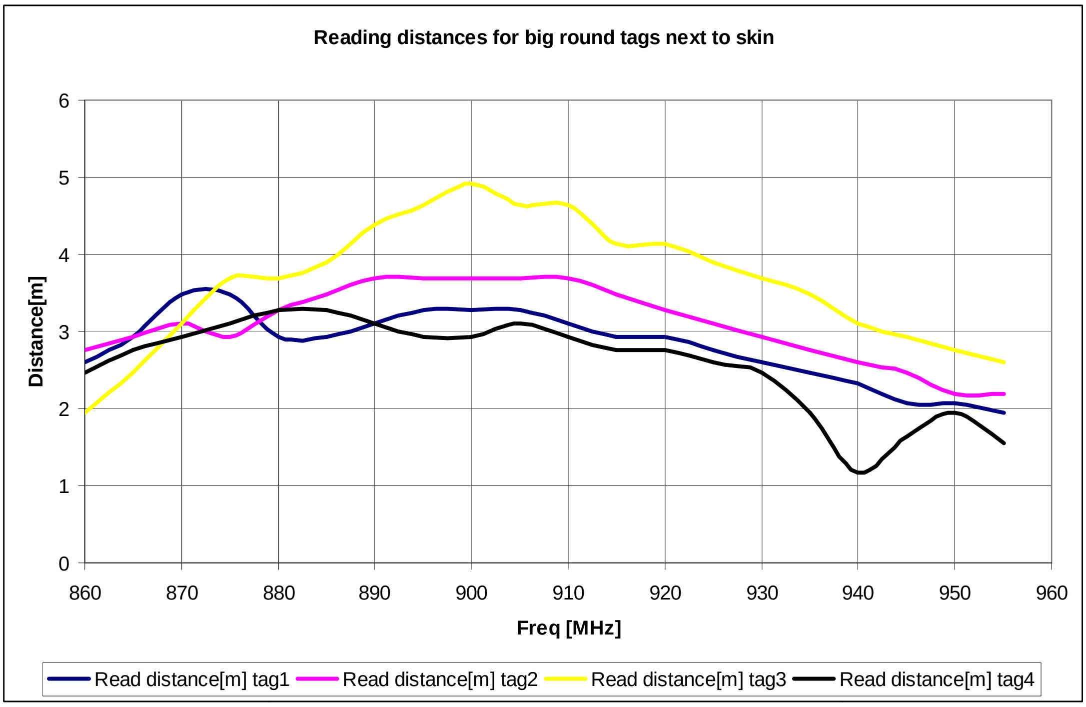


Figure 3: XCTF-8605 range near skin

4.2 Invengo XCTF-8604 Rectangular Tag

This tag is also designed to be used where United States frequency bands are legal, with read range peaking at 7-8 metres between 902 and 928MHz.

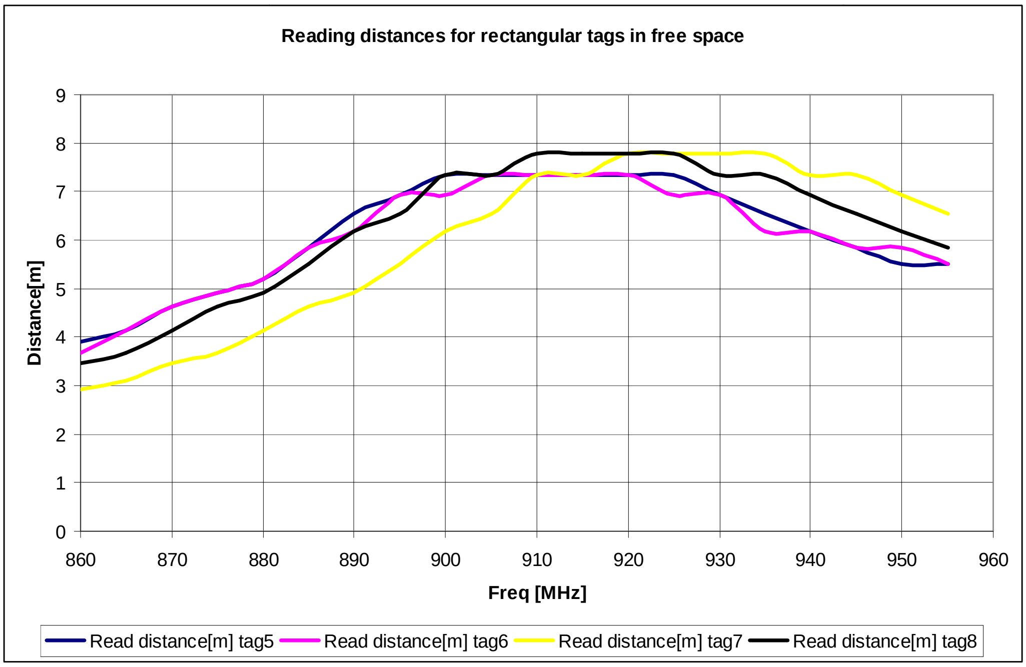


Figure 4: XCTF-8604 free space range

This tag is affected slightly less by placement close to skin than the XCTF-8605 tag, but may also be more directional.

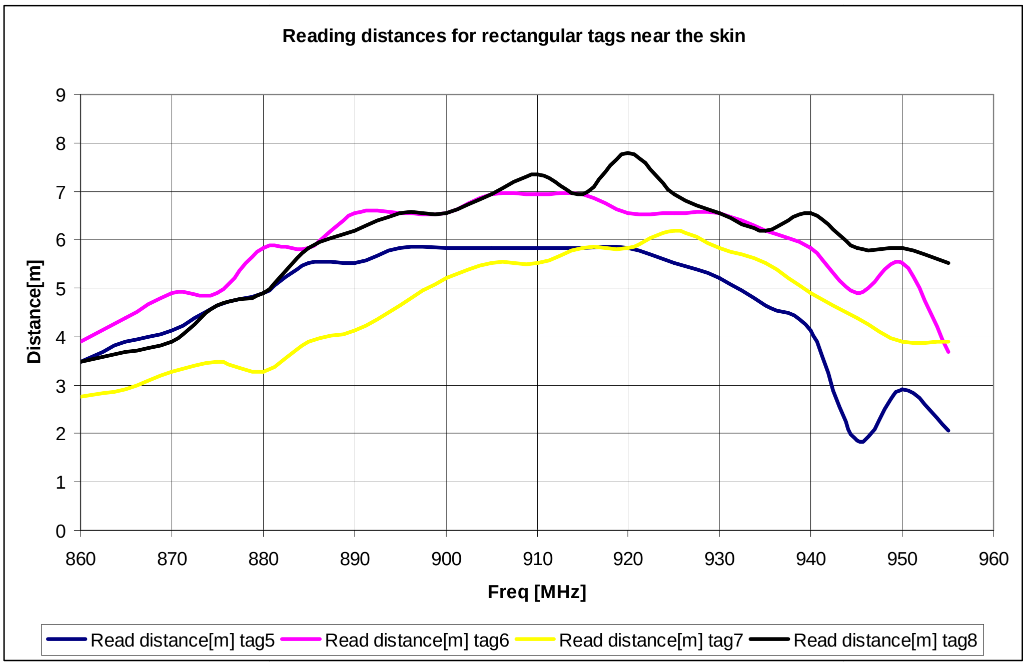


Figure 5: XCTF-8604 range near skin

4.3 Invengo XCTF-8602 Button Tag

We also assessed a few samples of the XCTF-8602 button tag. Our in-office testing showed that this tag had a very short read range that was not suitable for the project. While optimised for 868MHz, its performance against skin was very poor.

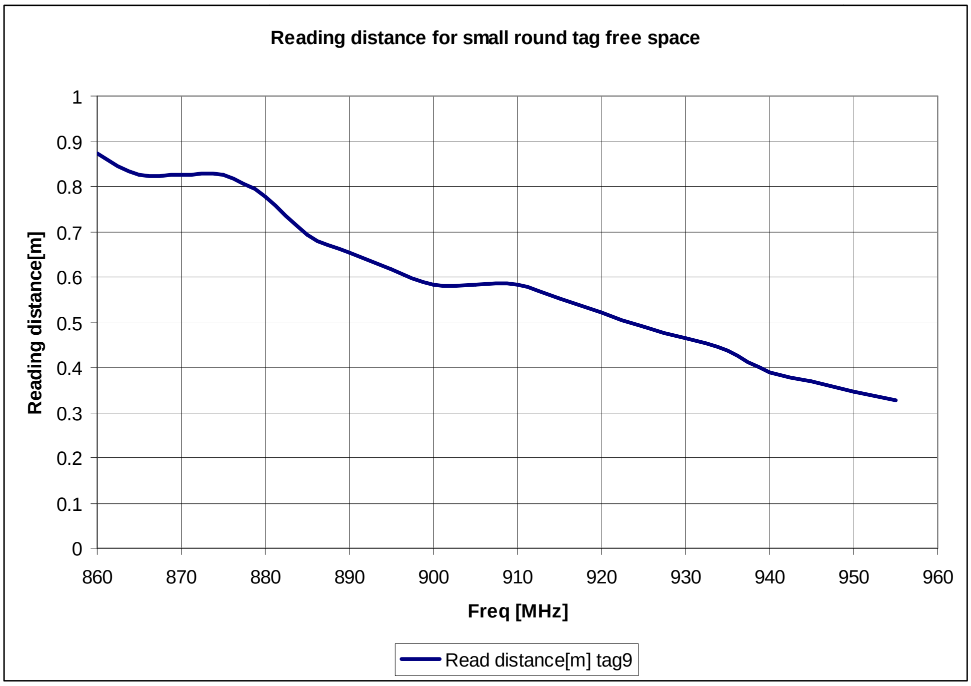
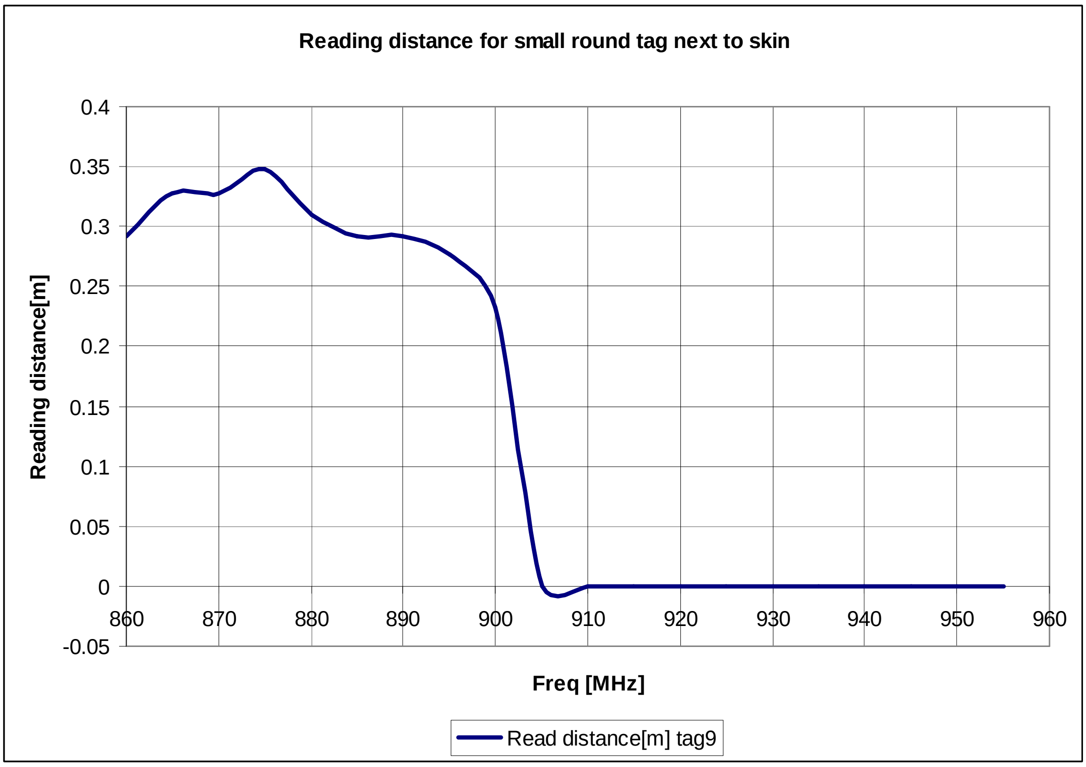


Figure 6: XCTF-8602 free space range



4.4 Tag Selection

We selected the Invengo XCTF-8605 round tag for use in the trial. It had reasonable performance across a wide range of frequencies, and while larger than a button tag, its form factor was similar to some small triangular tags approved for AHB and NAIT purposes. We considered that the longer XCTF-8604 tag would not be suitable for sheep, and while this was a higher performance tag we were concerned that its more directional characteristics might make it less effective in some situations.

A number of other companies are also producing UHF livestock ear tags. However, Invengo was the only company able to supply quantity at the commencement of our trial. The purchase price of tags for this trial was very similar to the recommended retail for LF tags, which is promising given the very short run and direct import. We caution however that even if price decreases with quantity, local distribution and printing will continue to be major factors in retail tag costs.

We would have also considered including custom 868MHz tags developed by Times-7 in the trial, if these were commercially available. We believe that a tag developed specifically for the New Zealand frequency bands should have higher performance when operating in these bands. We note that Radio Spectrum Management, part of New Zealand's Ministry of Economic Development, is currently consulting regarding extending licenses for UHF RFID into the 915-929MHz band, with a 4W band between 920-926MHz[6]. This means that tags designed for United States bands are more likely to perform acceptably in New Zealand in the future.

4.5 Reader and Antenna Selection

The RFID reader is the component of the system that transmits a radio signal to "wake up" and communicate with the tags. The tags used in our trials are "passive tags", which means that they have no battery of their own, but are powered-up by the signal from the reader. The RFID reader also listens for the identification transmitted back from the tags, and returns this to a computer or other system.

Antennas are used to transmit and focus the signals from the reader, and to amplify signals received from tags.

The New Zealand RFID Pathfinder group and GS1 New Zealand take a "technology agnostic" approach to trials. They are not vendor organisations and nor do they endorse a specific vendor's technology. Reflecting these principles, we opted to use technology from multiple manufacturers:

- RFID readers from Intermec[7], Motorola[8], and SICK[9];
- Antennas from Times-7[10], Intermec, and Motorola;

Our preference was for equipment that was designed for industrial use as this lends itself to the harsh environments experienced on New Zealand farms. At least one RFID reader, the Intermec IV7 was selected as it was specifically a portable, battery powered reader.

We also experimented with two hand-held devices:

- A combined long-range (3m+) reader and hand-held computer developed by Convergence Systems[11]; and
- A short-range hand-held reader, the Padl-R UF developed by Tracient[12].

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[6] http://www.rsm.govt.nz/cms/policy-and-planning/current-projects/radiocommunications/806-960-mhz-band-replanning
[7] The Intermec IF30 fixed reader and Intermec IV7 vehicle mount reader, with IA33 and IA36 antennas (www.intermec.com/products/rfid)
[8] The Motorola XR440 fixed reader and AN400 antenna (http://www.motorola.com/Business/XP-EN/Business+Product+and+Services/RFID)
[9] SICK (Sensor Intelligence) RFI641 (http://www.sick.com/group/EN/home/products/product_portfolio/identification_systems/Pages/rfid.aspx)
[10] Times-7 slimline antenna (http://www.times-7.com/products/antennas)
[11] Convergence Systems CS101 Handheld reader (http://convergence.com.hk/)
[12] Tracient Padl-R UF (http://www.tracient.com/)

5 Deer Trials

5.1 Restrained Animals

At Totara Hills and Hindon Farm we used a SICK RFI641 reader paired with either an Intermec IA36 antenna or antenna provided by Lower Hutt RFID specialists, Times-7. At the Ngakuru deer farm we utilised a Motorola XR440 reader, with one or two Motorola An400 antennas.

In all cases reliable and fast reads were achieved. At the Ngakuru deer farm, our count of animals was consistently one less than the number of animals visually counted across all trials, which indicated to us that either our manual count was incorrect, or one tag was "dead" on arrival. At all other farms, 100% of animals were read.

We noted that depending upon antenna position and orientation it is possible to obtain unwanted reads from animals outside and pressed up against the side of the crate. This may be remedied by turning down the output power from the RFID reader, or by placing foil or a similar signal retardant around the crate.

Our comparison with LF technology also performed very reliably, reading 100% of animals.

5.2 Animals in Single File

On all three deer farms we tested single file free movement of animals by opening both the back and front doors of the deer weigh crate, and allowing free flow of a mob of animals through the crate to simulate movement in a narrow loading race. The width of crates varied from 1 to 1.2m wide. As a mob of deer begin to run through the narrow race, they accelerate, and it is possible to have more than one deer pass through the crate at once (the head of one deer overlapping the tail of the previous animal).

At Totara Hills and Hindon Farm we used a SICK RFI641 reader paired with either a single Intermec IA36 antenna or one antenna provided by Lower Hutt RFID specialists, Times-7. At the Ngakuru deer farm we utilised a Motorola XR440 reader, with one or two Motorola AN400 antenna.

We experienced repeatable 100% reads with this approach on Totara Hills and Hindon Farm. At the Ngakuru deer farm we placed a single Motorola AN400 across the crate, and had relatively poor performance (89% read) with the first mob of animals measured. We added a second AN400 antenna, and achieved 100% read performance. On reflection, we should have oriented the antenna along the course of the crate rather than across it (this is the orientation that was used on the other deer farms) which would have provided a larger coverage area, appropriate for animals moving at speed.

We carried out a single repeat of this exercise at Ngakuru using LF equipment, and achieved 90% read, a good result considering that we used a single Aleis panel normally used with single, restrained animals.

5.3 Mob Movement

When deer are moved in mobs through a 2m+ wide gateway, they typically move as a fairly tight group and accelerate rapidly (deer have a top speed of between 48 and 60km/h, depending upon size and breed). Along with the physical width of the gateway, these characteristics can make it hard to read RFIDs.

Our South Island trials used the SICK RFI641 reader paired with two Times-7 antennas. A shortage of connectors meant that one antenna was configured as send and one as receive, a very ineffective combination. We achieved 82% tag reads when the antennas were placed on either side of the race, and considered that signal attenuation due to body mass (particularly with the limited antenna configuration) was the primary cause of this poor performance. The performance improved significantly when the antennas were placed above the animals. There was still some variation, but we typically achieved 98% or 100% reads.

At Ngakuru, we used the Motorola XR440 reader in combination with two AN400 antennas. We started by mounting these above and across the race, but this provided very poor performance – only reading 75% of tags. We found that mounting the panels along the side of the race but at deer head height provided the best performance, reading 97 - 100% of tags.

Our assessment is that antenna design and positioning will be a critical factor in the success of reading deer across a wide race. The body-mass effect of many running animals will attenuate the UHF signals, making it take longer for tags to power up, and reducing the signal power in communications between the tag and reader. When this is combined with the fast pace of moving deer, it can make it difficult to power up and communicate with a tag before it moves out of antenna coverage.

Figure 7: Deer run past a side mounted panel at Ngakuru

These challenges have been faced and overcome in other industries. In cycle racing, tags are typically placed on the spokes within cycle wheels, and in running events tags can be placed on the athletes' shoes. This removes the attenuation effect, and allows readers to be oriented towards the appropriate area. We consider that the use of ear tags is the closest equivalent with animals, and placement of antennas at head-height or just above is important.

At the same time, antennas need to be oriented to increase coverage in the direction of movement. When our antennas were longitudinally-oriented (placed along the race) we had significantly better performance than when the antennas were placed across the race.

We did not undertake a comparison of LF technologies across a 2m+ wide race. All the equipment that was available was designed to read 80-100cm, and LF vendors assured us that the equipment would not perform across a wide race. LF vendor Aleis has demonstrated a multi-panel tunnel reader for sheep that is able to read across a 2m wide race.

6 Sheep Trials

The sheep trial comprised two visits to John and Anne Brier's property "Ngaponga", at Ngaroma, east of Te Awamutu in the North Island of New Zealand.

6.1 Restrained Animals

We utilised both a SICK RFI641 reader and a battery powered Intermec IV7 reader (design for use on a forklift) for these trials, paired with either a small Intermec IA33 antenna, or custom antenna from Times-7.

We trialled the equipment in a Racewell sheep handler which captures and holds a single animal at a time. We compared the results with a Gallagher low frequency reader in the same configuration.

Both the LF reader and all UHF configurations provided 100% reads, although the UHF reader was slightly more consistent in the time taken to read a tag (the LF equipment would sometimes take one to two seconds to capture a tag where the animal was held in a non-optimal position).

Figure 8: Sheep about to move into a Racewell animal handler at Ngaponga

6.1 Animals in Single File

We utilised both a SICK RFI641 reader and a battery powered Intermec IV7 reader, paired with either a small Intermec IA33 antenna, or custom antenna from Times-7.

The equipment was placed beside a 1m wide race, just in front of the Racewell drafter, with animals flowing freely (and often quickly) past in single file. On exit, the animals proceeded through the Racewell unit (which was turned off), and past the LF reader.

Both LF and UHF readers read 100% of tags presented. We were pleased with the performance of the LF reader, as we have in the past observed situations where free-flowing sheep in single file were not always recorded by LF technologies.

6.2 Mob Movement

We trialled reading animals across a 2.2m race (the maximum width of the races in the Ngaponga sheep yards). Based on our learning from the South Island deer farms, we mounted one or two antenna above the sides of the race, tilted on a 45° angle towards the sheep.

The small Intermec IA33 antenna was not suitable for this situation, and the Intermec IV7 reader also had relatively poor performance. We surmise that the battery-powered reader may have used a lower power output in order to prolong battery life.

The SICK RFI641 reader and either the larger Intermec IA36 antenna or the Times-7 antennas provided good performance. Over a number of repetitions, this combination yielded either 94% (one animal missed) or 100%.

Figure 9: A mob of sheep pass under an Intermec IA36 antenna at Ngaponga

We repeated this exercise in a second visit with the Motorola XR440 reader and a single Motorola AN400 panel antenna suspended over the race at either 3m or 2.4m height. This combination provided reliable reads of all animals, but would occasionally miss one animal when a mob was run at high speed through the race (giving an aggregate read of 98% across our runs). Mounting the antenna at 2.4 metres rather than 3m above the ground made a slight improvement when animals were moving at speed, but was not necessary when free flowing. Turning the antenna so that it faced on a slight angle towards the oncoming animals produced a further improvement, missing one animal in four replicates.

We did not move the LF reader across to the wide race, as our tests with hand-held LF tags had shown a range for the particular reader of up to 80cm.

Our conclusion is that UHF tags and readers are suitable for use with sheep for both individual animal and mob data capture. While tuning of the antenna for the environment does not appear to be needed, consideration does need to be given to the placement and orientation of the reader for race reading, particularly if animals are to be moved at high speed.

7 Cattle Trial

Cattle tests took place with our very first trial, at Landcorp Farming's Hindon Farm. We were not able to compare with low frequency equipment, and were unable to use mains-powered readers at the site, so utilised the Intermec IV7 reader on batteries.

7.1 Restrained Animals

100% read performance was achieved for individual cattle in a weigh crate or crush, using the Intermec IV7 reader and a single small Intermec IA33 antenna mounted on the side.

Previous trials carried out at a nearby cattle operation showed that LF panel reader technology worked effectively in a confined situation, but that a hand-held wand reader was more effective where cattle were managed through a wider and longer weighing and drafting system, as the animals could move away from the LF panel antenna.

7.2 Animals in Single File

Initial reads of free-flowing cattle through a 1.2m race utilised the Intermec IV7 reader and Times-7 panel mounted on the side of the wooden race. This achieved a 96% tag read rate.

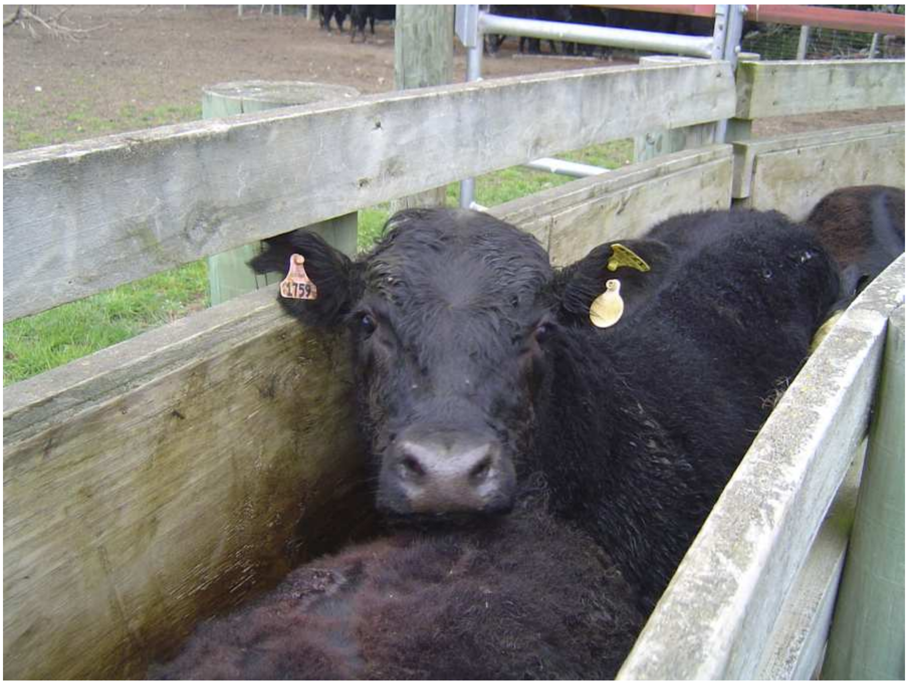

Figure 10: Cattle moving in single file. The round UHF tag is visible in the left ear.

We surmised that the drop in read performance was caused by attenuation from the animals' bodies, in combination with the lower power output from IV7 reader. As cattle flow freely, it is common for the head of one animal to be positioned low and behind the rear of the preceding animal. We repeated the 1.2m race reads with the panel mounted over the top of the animals to reduce this body effect and achieved reliable 100% reads.

7.3 Mob Movement

We carried out the 2.6m race trials using one or two panels mounted on the sides of the race. Due to a lack of connectors, we were only able to connect the transmit antenna in one panel, and the receive antenna in the other panel. Previous trials carried out by the NZ RFID Pathfinder Group in 2008 had shown this combination to be particularly ineffective when dealing with mobs of animals.

We achieved particularly poor results, reading only 72% of the cattle tags. Our subsequent work with deer and sheep trials showed that much better performance can be achieved by mounting panels over the race or at head height, and maximising the coverage area in the direction of movement of the animals. It is likely this would have resulted in performance for cattle that was very similar to the deer trials.

8 Tag Numbering Systems

RFID tags may be used in support of a traceability system, as part of an animal breeding programme, or for on-farm management. In all cases however, the physical tags are only a component of the system. Tags are used to store numbers or codes that are transferred between devices and computer systems, and stored in databases. LF and UHF tags store and represent codes in different ways and this has implications for integration with other devices, storage in computer systems, and supply chain integration.

8.1 Low Frequency ISO 11784 Code Format

Low frequency animal tag systems use the ISO 11784 code format, a 64-bit number. Only the 48 bits representing the country or manufacturer code and the unique ID within that country or manufacturer are typically stored in computer systems. Figure 11 illustrates how the code can be broken down.

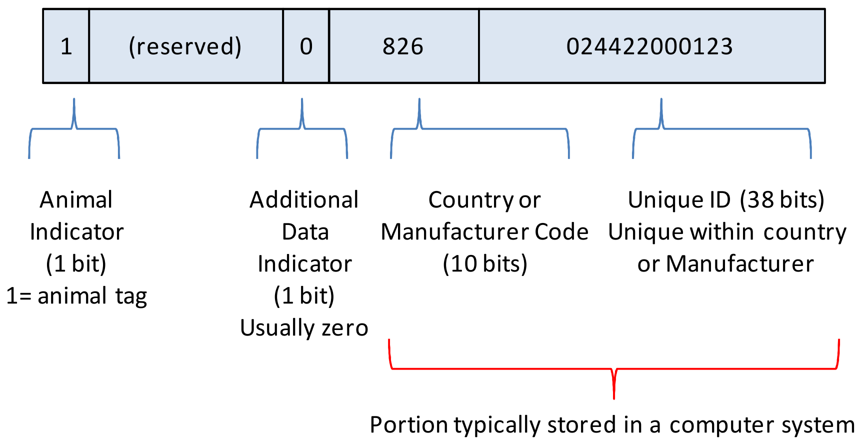

Figure 11: ISO 11784 code format

8 bits of the code are reserved for future use, and are currently not used.

The International Committee for animal recording (ICAR) is responsible for allocating manufacturer codes, and specifies that each manufacturer is to ensure that tag numbers are unique within their manufacturer code.

Alternatively, countries can choose to mandate a numbering system that uses the ISO-3166 standard country code. This requires a national mechanism where manufacturers can coordinate to ensure that tags are unique within the country code.

- The United States National Animal Identification System (NAIS) is a voluntary system administered by the United States Department of Agriculture (USDA). Tags use the US (840) country code, and a database and computer system are used to manage allocation of Unique ID codes by manufacturers. The entire tag number (including the 840) must be printed on the outside of the tag.
- The United Kingdom has recently adopted an RFID identification system for sheep. In this system, the UK country code (826) is used, and a database is used by manufacturers to ensure that unique codes are issued. However, the "Unique ID" field is broken down further. The first digit specifies the species of animal or type of tag, the next six digits identify the holding or property on which the animal was tagged, and the last five digits are a unique number for the animal within that farm. The entire number (with "UK" instead of "826") must be printed on the outside of the tag, so that it can be read manually or electronically.
- New Zealand systems to date have not made use of the NZ country code (554), and instead have used manufacturer code tags. A central database is used to record tags issued for AHB purposes, and manufacturers typically provide farmers with a file that matches the ISO 11784 code inside the tag with the number printed on the outside.

Examples of tag numbers as displayed on a computer might be:

- 982 009104636715 (a manufacturer code tag currently used in NZ); or
- 826 024422000123 (a country-specific code used to identify animal 123 on farm 244220 in the United Kingdom).

8.2 Ultra-High Frequency SGTIN Code Format

As with barcodes, there are a number of alternative ways of representing data in an EPCglobal Gen2 tag[13]. There are several code formats that could be used as a primary identifier in a UHF RFID tag, however our preference and recommendation is for an EPCglobal Serialised Global Trade Item Number (SGTIN).

The SGTIN is a standard coding format used in many global end-to-end supply chains. It is sector agnostic, flexible, and well-understood by many devices and software systems. Data standards also define how the SGTIN can be exchanged between computer systems and represented in other forms, such as bar codes. For

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[13] EPC Tag Data Standard (TDS) 1.4, June 2008 (www.epcglobalinc.org)

livestock recording systems, an SGTIN provides an effective mechanism to identify the issuing authority, type of tag or species of animal and unique identification. Downstream processing and manufacturing systems will expect to use SGTIN codes to track component ingredients in products.

EPC numbers are issued in New Zealand by GS1 New Zealand[14].

Figure 12 below illustrates graphic representation of a SGTIN-96 scheme. The current EPC Tag Data Standards (TDS) includes support for 96-bit and 128-bit tags but as more tag manufacturers use 256-bit and 512-bit memory banks, support will follow. Support for larger memory capacities is considered important as business needs continue to evolve over time. A 96-bit ID can be encoded into a 128-bit tag.

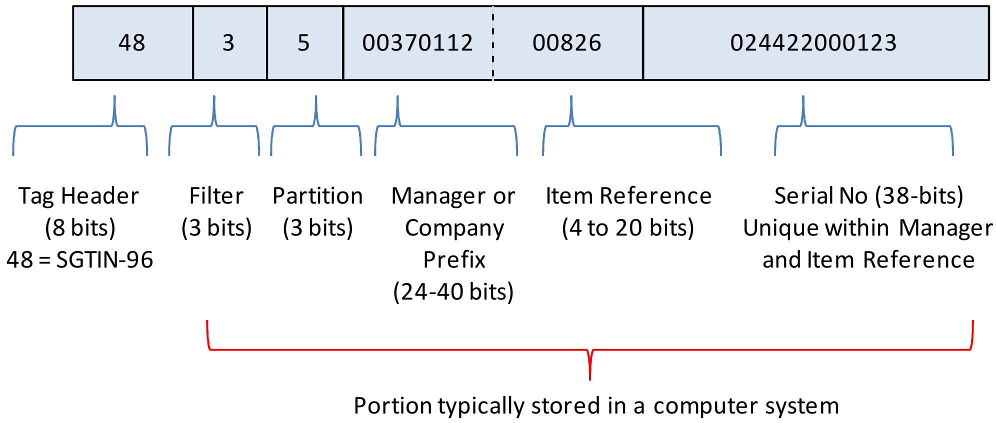

Figure 12: EPC SGTIN-96 code format

Some components of the SGTIN require further explanation:

- A **filter** value is frequently used within supply chains to differentiate between shipping configurations such as a pack, pallet, or individual items. The value "3" indicates a single trade item (be it a television screen, a live sheep, or a chilled lamb chop).
- The size of the **Manager/company prefix** and **Item reference** fields can vary, as indicated by the dashed line between the two fields. This is an efficient mechanism that allows GS1 to issue codes to manufacturers with a large number or very few trade items. The value of the **partition** field tells computer systems where this split occurs.

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[14] GS1 New Zealand is New Zealand's member organisation of GS1, the global not-for-profit standards organisation driving the development and promulgation of identification standards and systems such as barcodes and RFID. GS1 has offices in 145 countries and territories worldwide.

The **Manager/Company Prefix** of the SGTIN could be the issuing authority for animal tags (for instance MAF, AHB, or NAIT in New Zealand). This would avoid the need for individual farmers to become members of GS1.

A small number of **Item Reference** values could be used to identify the species of animal (for instance, if NAIT were to administer cattle and deer, then 0001 could be cattle, and 0002 could be deer). Alternatively, the Item Reference component could be used to identify each farm (as per the UK sheep system), although this might increase administrative overhead. Fortunately, it is very feasible for trusted distributors to programme the EPC number of tags (interacting with a central database to ensure uniqueness), and then lock those numbers so that they cannot be changed. This lock capability is important for a robust traceability system.

9 On-Farm Data Capture and Management

While RFID is often seen as a tool for traceability, in New Zealand livestock farming it has often been implemented as an on-farm management tool, and is integrated with other hardware and software products to make it easy to manage animals.

Typical animal management systems comprise several of the following:

- A device for holding animals (a crush, crate, cage, or bail);
- An identification device (the RFID reader, possibly a keypad for visual tag entry, and possibly a bail ID system);
- Measurement devices (weigh scales, milk meters, somatic cell sensors and ultrasound scanners);
- Control units (indicators, computer systems, touch screens);
- Drafting or selection devices (drafting gates of various sorts)

The identification device performs a critical function in linking measurements to individual animals and enabling decisions (manual or automated). It will be essential for any UHF-based identification system to integrate with the other components of on-farm animal management systems.

The ISO 11784[15] and 11785[16] standards for livestock RFID define a numbering system and a radio interface, but do not provide a standardised method for communicating with a reader. In practice however, vendors of LF readers implement a simple communications protocol (often referred to as the TIRIS ASCII

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[15] ISO 11784:1996 and ISO 11784:1996/Amd:2004 (www.iso.org)
[16] ISO 11785:1996 and ISO 11785:1996/Cor1:2008 (www.iso.org)

protocol[17]). With a few minor variations in response format, this protocol works across all common LF livestock readers. The protocol only provides for receiving a tag from a reader: other functions that may be implemented are often specific to the manufacturer.

The GS1 standards define a multi-layered reader protocol[18] that allows software or devices to communicate with readers from a number of manufacturers. Again, manufacturers may also implement their own additional protocols, although the presence of a low-level reader protocol[19] reduces the need for this.

Importantly, virtually all animal management equipment utilises serial communications protocols (usually across RS232 serial cables, although recently some devices have added USB or Bluetooth wireless). In contrast, most UHF readers are designed to support Ethernet communications, which are commonly used in commercial and warehouse environments. Some UHF readers do support serial port communications (the Intermec IV7 in our trial has an RS232 port, and the Motorola XR440 has a USB port).

The issue of different communications protocols (TIRIS protocol vs. EPC reader protocol) can be resolved using one of three approaches:

1. Substituting a new control device or software that understands EPC reader protocol. For instance, a software upgrade could be installed in a dairy automation system, or a PDA or laptop computer could be inserted as a control device.
2. Providing a firmware upgrade for embedded control devices. For instance the leading Gallager, Iconix, and Trutest indicator units may have firmware updates applied. If UHF tags and readers gain market share, device manufacturers will be motivated to ensure compatibility.
3. Utilise the on-board features of the UHF reader to simulate the TIRIS protocol. Many UHF readers are intelligent devices, running an operating system such as Linux or Windows CE, and are able to run custom software or scripts. It would be feasible to make a UHF reader appear to be a LF reader, as far as other animal management devices are concerned.

[17] TIRIS is a trademark of Texas Instruments (www.ti.com). The protocol was developed during the late 1990s and is used by other devices (ref. the Allflex RFID panel antenna user guide).
[18] EPC Reader Protocol (RP) Standard v 1.1 2006 (www.epcglobalinc.org)
[19] EPC Low Level Reader Protocol (LLRP) Standard v1.0.1 2008 (www.epcglobalinc.org)

In parallel with this project, Rezare Systems' software developers prototyped reading UHF tags with embedded software that we maintain for Racewell Limited[20]. This Windows CE-based software controls a sheep, cattle, or deer auto-drafter, and interacts with weigh scales. This prototype was sufficient to demonstrate to us that it is feasible for the next generation of on-farm devices to utilise UHF RFID.

10 Databases and Recording Systems

Ultimately a subset of information about animals will reside in a recording system or database. This may be a centralised system designed for multiple users, or a more localised tool on a farmer's home office computer. Examples of such systems include:

- Productivity, breeding, or animal management software operating on a famer's own computer (New Zealand examples of such applications include CRS Livestock[21], Landmark Farm[22], P-Plus[23], MacroStoc k[24], and MINDA Pro[25]);
- Custom databases used as part of group recording and progeny test schemes or market supply contracts;
- National animal evaluation and stud breeding databases such as MINDA[26] and SIL[27];
- National animal tracing systems (such as NLIS[28], NAIS[29], and NAIT[30]).

Virtually all these systems allow for more than one form of animal identification, typically supporting two or more of the following:

Identifier	Description	Example
Electronic ID or EID	RFID Tag value	"982 718239412"
Management Tag	On-farm visual tag	"23"
Official Tag	Canonical scheme tag	"7116532 2010 23"

In some schemes, the Official Tag and Electronic ID may be the same.

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[20] Racewell Limited animal handling equipment (www.racewell.co.nz)
[21] CRS Livestock from www.crssoftware.co.nz
[22] Landmark Farm Stock Diary from www.iagri.com
[23] P-Plus Stock module from www.farmworkspfs.co.nz
[24] MacroStock from www.macrostock.com
[25] MINDAPro and other software from www.lic.co.nz
[26] MINDA Herd Records Service at www.lic.co.nz
[27] SIL database and evaluation system at www.sil.co.nz
[28] Australian National Livestock Identification System (NLIS) at www.mla.com.au
[29] United States National Animal Identification System (NAIS) at www.usda.gov/nais
[30] New Zealand National Animal Identification and Tracing (NAIT) at www.nait.org.nz

There are two principal issues with substituting UHF tags for LF tags in conjunction with animal recording software and databases:

1. Identifying the type of tag used with each animal (particularly for voluntary schemes, or in transition periods), both in the database and in communication between systems; and
2. Ensuring that the database field is sufficient in size to store an EPC tag value, and that software is capable of displaying it.

If a recording system uses a single field to contain the RFID value, it will need a mechanism to distinguish the type of tag, particularly for display purposes and for interpretation by other systems and devices. This may be achieved by adding another field to specify the RFID tag type.

Ideally interchange between computer systems should identify tag types by using specialist fields (e.g. an ISO 11785 field and a separate EPC field), or by using a formal notation, such as the URI form. The following example shows URI form of both an EPC tag and a LF ISO 11784 tag.

ID
urn:epc:id:sgtin:3.003700.00542.77346595
urn:iso:std:iso:11784:982.009104636715

Many existing systems have been designed to store the 48 bits of an ISO 11784 tag that encode the country or manufacturer code and the unique serial number within that country or manufacturer. These are stored as a 48-bit number or as a string.

While it may be technically feasible to “squeeze” a 96-bit EPC SGTIN into this field (by recoding Manager/Company Prefix and Item Reference for the specific purpose), our recommendation to software designers and database administrators is that the EID field should be widened to store 96 or 128 bits, or preferably that an EPC field of this length should be added. The additional EPC field will allow for a smoother transition from LF to UHF where this is necessary.

11 Tags as Information Carriers

One of the claimed benefits of UHF Tags is the ability to read and write additional data to the tags. Information such as date and batch of manufacture, country of origin, expiry date and other identifiers can be stored in a very compact fashion in the "User Memory Bank" of the tags[31]. This feature has been used to great effect in industries including tyre manufacture, air transport, and postal services.

Tag User Memory cannot approach the storage size, flexibility, and overall utility of databases, but it does provide a mechanism for simple in-field indication of a few key characteristics. This is particularly relevant where Internet and cellular coverage is poor (most New Zealand farms), making it hard to look up information in remote databases.

Useful livestock information might comprise:

- Date or year of birth;
- Farm of origin (particularly if this is not obvious in the ID);
- Recent veterinary treatments and withholding dates;
- Movement records and dates.

However, there are some important caveats which might make tags less useful as information carriers, and will at least require some consideration if implementing a system:

1. User Memory is an "optional" feature in the EPCglobal Gen 2 specification. Not all tags will have user memory, and the size of the user memory may vary. The Invengo tags used in our trials have 224 bits of user memory – sufficient to store a few key fields, but definitely not a lifetime history.
2. Reading User Memory is an additional operation for a reader, and will slow down the reading process, reducing the number of tags that can be successfully read if animals are moving at speed. It may not be necessary to read the additional data on all occasions, so this could just be utilised when circumstances require.
3. Updating, or storing data into User Memory is significantly slower and requires the tag to be close to the reader for a longer period. For instance, some RFID readers can read tags at 600 tags per second, but can only write tags at 5-10 tags per second. This speed is suitable for writing birth and origin data onto tags as animals are first tagged, or during a vaccination or hormone treatment. It may not be suitable for recording a drench treatment as animals are released at speed from the yards.
4. Most traceability schemes do not require farmers to actively use RFID readers, except possibly for a minimum of activities (movements), or

[31] Detailed in ISO/IEC 18000-6:2004 (www.iso.org)

through a central reading point. As a result, farmers will not be able to rely on User Memory data being complete or up-to-date for animals that they purchase, unless a much broader set of mandatory requirements are enforced. This does not reduce the potential utility of User Memory information for within-farm management (or even within a corporation or breeding group).

12 Tag Design and Retention

We did not specifically undertake tag retention trials as part of this project, but we did visually assess the tags for characteristics likely to impact application, use, and retention.

Two primary types of ear tags are used for animal identification: button tags and flag tags. Button tags are less susceptible to being caught on fences or vegetation, and thus typically have a higher retention rate. It is usually possible to position button tags well into the ear, which also increases retention. The Invengo XCTF-8602 was the only UHF button tag available at the commencement of our trial, and as we detailed in section 4.3, its performance was not adequate for our trial. We consider it highly likely that newer tag and chipset designs will allow development of button tags with sufficient performance. However, we consider that button tags are also likely to be more susceptible to attenuation from close proximity to the animal.

Non-RFID flag tags have been used in animal identification systems for many years, and for the most part have had acceptable retention. The larger size of these tags means they tend to be placed further out from the centre of the ear, and makes them more susceptible to catching on fences and vegetation. Manufacturers have countered this by the use of very flexible plastics, and by minimising sharp corners and angles.

The Invengo XCTF-8605 round tag used in the trial is roughly the size of smaller flag tags, and could be printed with a visual number in the same manner. It's round design means that it will be less likely to catch and be torn out, although it is not as flexible as some newer non-RFID flag tags.

The locking mechanism used by the trial tags was reasonably robust, but the non-RFID male component of the tag was too brittle and without a metal tip it took more effort to penetrate the ear. We found misapplications were frequent and the stem of the male component would often break. Fortunately for our purposes, an Allflex tag male component[32] could be used instead – this greatly improved the tagging process.

We noted that the trial tags were not “tamper-proof” or “tamper evident”. This means that it is feasible for someone to cut the non-RFID male component of the tag, and apply the female RFID component to a different animal. Many traceability schemes require tamper-proof or tamper evident tags. We recommend that the manufacturers of UHF tags for livestock should make contact with established livestock tag vendors, in order to benefit from the learning of many years of tag manufacture and support.

13 Conclusion

13.1 UHF Tag Performance

We are encouraged by the performance of the first generation of commercially available UHF livestock tags with off-the-shelf readers. In virtually all our trials these tags performed single-animal operations as well as a well-tuned LF reader and tag combination. UHF technology also shows promise for reading mobs of animals proceeding through a gateway – whether on farm or at a livestock sale. In order to read animals at pace, it is necessary to orient antennas to maximise coverage in the direction of travel, and to ensure sufficient output power from the reader.

Some of the uncertainties previously associated with UHF tags can be safely laid to rest:

- UHF signals are indeed attenuated by body tissue. It is unlikely that UHF will be suitable for injected or bolus tags, apart from through the use of very short range near-field technology (effectively using the magnetic field as is done with LF tags). However our trials demonstrate that UHF ear tags can be used effectively and perform well.
- The spread-spectrum nature of UHF means that devices are not likely to stop working in industrial environments with electrical noise. Our limited experiences would indicate that UHF reader performance does not degrade substantially when exposed to motor noise or switch-mode power supplies (these have been problems for some LF readers).

[32] Allflex button male 01 (www.allflex.co.nz)

There is further positive news for those interested in UHF tags for livestock:

- More sensitive chips are now being manufactured for UHF tags. These chips significantly reduce the radio signal needed to "power up" and hence response time and sensitivity. In theory this should improve performance when capturing mob animal data.
- Recently New Zealand Radio Spectrum Management (RSM) has consulted on changes to the allocation of spectrum in the UHF band. This consultation seeks to align New Zealand's spectrum allocation with that of Australia, and to an extent the United States. The result would be to allow a wider range of RFID equipment to operate in New Zealand, and to improve the performance of existing devices (number of tags read per second and read range).
- Our trials were carried out with the small range of UHF livestock tags that were commercially available from a single manufacturer at commencement in August 2009. Since that time other manufacturers have announced UHF livestock tags, and a "second generation" of tags with improved performance appears imminent. We note that at least one manufacturer has announced a UHF tag approved by USDA for use with the US National Animal Identification System (NAIS).

13.2 Adoption Considerations

All the above factors bode well for the future adoption of UHF tags. They are in line with projections of UHF proponents, who see the widespread adoption of UHF standards within many industries globally contributing to innovation, improving performance, and reducing tag costs.

However, livestock tagging may behave somewhat differently from other sectors.

Low frequency technologies are well established and are functional for individual animal recording where animals move slowly or are restrained. UHF technologies must show additional benefits in animal management, cost reduction, or supply chain management, and it is in these areas that challenges remain:

- Our trials have demonstrated there is potential for additional uses of RFID in animal management. While obviously beneficial at a sale, it is yet to be seen how reading animals in motion or travelling as a mob can be widely utilised for benefits on-farm.

- It has been claimed that the ability to store additional data on UHF tags will be an advantage when in the field. This is indeed a potential benefit for application within a single farm or cooperating group of farms. The need for widespread compliance by farmers would make this less useful for tracking animal health status across the entire industry: there is no guarantee that the previous farmer recorded all information on the tag.
- Unlike the world demand for paper RFID tags (labelling goods of many kinds), livestock RFID is a more specialist field. Ear tags must be designed for long use in a harsh and mobile environment, and must be printed and programmed in short runs for individual farmers. As a result we consider it likely that UHF livestock tags will be similar in price to LF tags. Readers and antennas for UHF are also likely to be in the same general price bracket as LF equipment.
- The international EPCglobal item identification and data interchange standards show great promise in streamlining the flow of supply chain information, and provide a useful standard for countries and organisations implementing new traceability systems – avoiding the need to reinvent the wheel in numbering and identification. The benefits for this standardisation accrue primarily from the processor onwards through the supply chain. While this will make it easier to manage and sell our products internationally, it may have little immediate return to the individual farmer.

We note that it could be feasible to develop dual-readers that cater for both UHF and LF tags. Care would need to be taken with the design of these devices to ensure that interference from UHF devices does not impact on LF read performance. We would see dual frequency readers as being a potential solution for sale yards that may cater for multiple species of animals. Farms and processors are more likely to adopt the standard technology for their primary species of animals (recognising that deer are not handled in cattle yards, nor are cattle handled in sheep yards).

13.3 Specific Recommendations

UHF tag technology has evolved rapidly over the last ten years. It is now a serious contender for widespread use in many sectors, and we believe that it has potential within the livestock industry: especially for applications where groups of animals need to be managed, or a longer read range is useful (as may be the case with deer and sheep).

1. We encourage organisations seeking (or developing) animal management and traceability solutions to consider application of UHF technology. For software and equipment manufacturers, that means planning on storing more than 48 bits of an ID, and ideally adding an EPC field to their databases.
   This is of particular consideration for New Zealand's National Animal Identification and Tracing system, which is intended to be extensible to support other species and technologies. It will be necessary to allow for different types of identifiers in both database and technology infrastructure design.
2. We consider that UHF tag developers have much to gain from partnering with traditional livestock tag manufactures. Physical tag designs, tamper proofing, and methods of distribution to farmers are critical areas where industry experience will make all the difference.
   We encourage closer collaboration between existing livestock tag, reader and equipment manufacturers and those developing UHF products.
3. We consider that UHF tags can perform at least as well as LF tags in animal traceability applications, and there may be additional on-farm and supply chain benefits. We encourage further work to explore these areas:
   - Evaluation of UHF technology to determine its suitability for capturing animal identities at the processor, particularly with regard to read ranges, interference, and integration with plant systems;
   - Quantification of the benefits of UHF animal identification technology both on farm and across the entire value chain. The brutal truth of technology adoption in business is that economics are king.

13.4 Acknowledgements

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