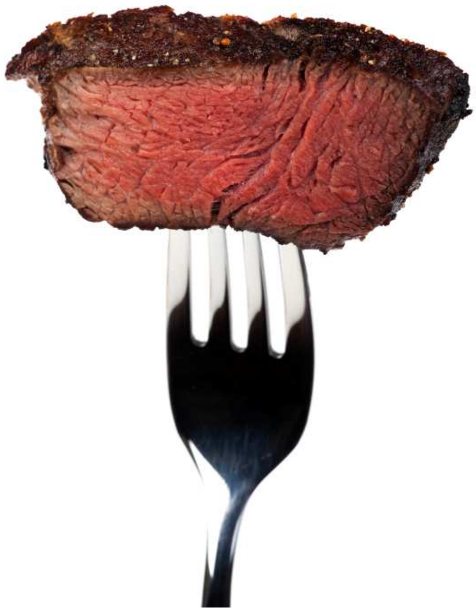
New Zealand Trade and Enterprise

UHF RFID in the Livestock Supply Chain

Technical Report



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1 Introduction

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 in 1996, and as a result low-frequency radio-frequency identification (LF RFID) tag systems have become widespread and generally interoperable.

Outside of the livestock arena, RFID tagging systems have moved to ultra-high frequency (862-955MHz). The higher frequencies enable faster communication with more tags being read per second, longer read ranges, smaller antenna, collision management 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[1]. In recent years UHF technologies have become a focus point for innovation and continuous technology improvement.

A 2009 project undertaken by Rezare Systems on behalf of Deer New Zealand, NZTE, the Meat Industry Association, ANZCO Foods, GS1, and the RFID Pathfinder Group[2] demonstrated that the first generation of commercial UHF animal tags can be used to record animals "at least as well as well-tuned LF technology", and has additional advantages for handling groups of animals and for supply chain integration.

That report recommended 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; and
- Quantification of the benefits of UHF animal identification technology both on farm and across the entire value chain.

In May 2010 a follow up project evaluated the use of UHF radio-frequency identification for livestock, following animals from farm through transport to a meat processing plant. Funded by New Zealand Trade and Enterprise and ANZCO Foods, the team from Rezare Systems and GS1 New Zealand focused on the performance and use of UHF tags in reading individuals and groups of

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[1] Detailed in ISO/IEC 18000-6:2004 (www.iso.org)
[2] Use of UHF Tags in Deer, Cattle, and Sheep – NZTE Project Report; Cooke A, Diprose B, Brier B; February 2010.

animals, up to the stun box. Follow-on work carried out by GS1 New Zealand traced the identified carcasses through to boning, packing, and shipment and delivery of the resulting cartons[3].

2 Cattle Trial

A small group of cattle were tagged at a nearby farm. We tracked these animals from farm to plant, recording them onto the truck and off the truck. The same animals were then followed to the stun box, where they were individually recorded at slaughter. The GS1 New Zealand team then followed product from these animals through the plant and to point of sale.

2.1 Recording on Farm

The farm manager pre-tagged these animals using the supplied Invengo CTF-8605 tags and Allflex males (the Allflex male tags have a more rubbery plastic that is less prone to break and a metal tip). However, we needed to programme each tag with the correct manufacturer and item identification for the trial, and a unique serial number. In practice this would be done during the manufacture and distribution process, and the unique code would be locked into the tag with password protection to avoid tampering.

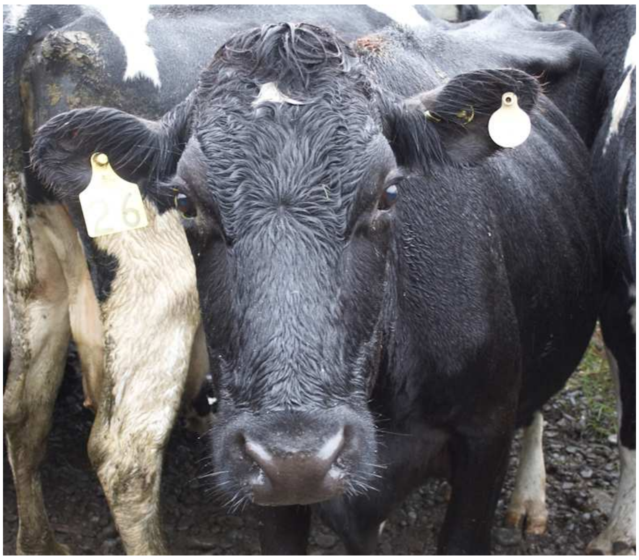

Figure 1: Cattle tagged with UHF tags (the rounded flag tag).

We programmed the tags using a Tracient Padl-R reader[4], connected via USB cable to a laptop with the programming software. This demonstrated the importance of ergonomics and practical on-farm equipment design. Leaning over the heads of cattle in the rain with a small reader and USB cable is far from a recommended procedure. Again, in the normal course this task would not have been necessary as tags would have been purchased pre-programmed.

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[3] GS1 EPC-IS Proof of Concept for Livestock Processing; Hartley G, Sundermann E; 2010.
[4] Tracient Padl-R UF (http://www.tracient.com/)

After programming the tasks, we ran the animals through the race a number of times using the Intermec IV7 battery powered reader and two Intermec IA36 antenna in different configurations. This simulated on-farm activities such as weighing, drenching, or handling animals. Data from the reader was captured by Racewell PDA software[5] running on an M3 industrial PDA. This reflects how livestock data would be captured in the field. The Racewell software is capable of running with industry standard weigh scales and drafting units for animal management.

Reading cattle on-farm was relatively reliable with the Intermec equipment. However, it is important that at least one send-receive antenna should be side mounted to provide coverage relatively close to the ground. Cattle are very likely to put their heads down when being moved by people. We had best results with one IA36 antenna about 30-40 centimetres from the ground, while hanging the other antenna just above the animals' head height.

2.2 Transport

The truck arrived early the next morning to collect the cattle for delivery to the ANZCO processing plant. We used the Intermec IV7 reader on battery power, with a pair of IA36 antenna mounted on the wooden sides of the loading ramp. Loading cattle into a truck is a relatively sedate process (at least for the reading equipment) so there were no missed reads. As with on-farm reading, we placed one antenna just above animal head height, and one closer to the ground.

Figure 2: Loading cattle onto the truck - the upper antenna attached with twine is visible on the left

[5] Racewell Limited – www.racewell.co.nz

2.3 Unloading at Plant

On receipt at the plant, we used a Motorola XR-450[6] reader with separate Motorola AN200 send and receive antennas mounted 2.6m above the steel-sided, 2.4m wide loading ramp. In practice, this is too great a distance to read a mob of cattle exiting from a truck. The animals walked quickly past, three abreast and with heads down, so the RFID tags were often up to 2.4m from the antenna and partly blocked by the body mass of adjacent animals. Our results were very poor.

Figure 3: A single send and receive pair of antenna mounted above cattle at 2.6m height

We moved the antenna to the side of the unloading race and achieved an 80% read rate. Interestingly, in one of these tests we placed the reader right beside a large water pump. There was no reduction in read performance – the reader is quite immune to the sort of radio frequency interference caused by pumps.

[6] http://www.motorola.com/Business/US-EN/Business+Product+and+Services/RFID

Figure 4: Moving the send-receive antenna pair to the side improved results; in practice send/receive antennas above and beside animals would perform better.

We consider that we would have had better results by using the two combined send/receive antennas (such as the Motorola AN400 or Intermec IA36) positioned one above the animals (at 2.4m or less height) and one beside the animals. This maximises the coverage field. We will revisit these tests in future trials, but our earlier work indicates that antenna positioning and performance is critical for reading mobs of moving cattle and deer.

2.4 At the Stun Box

We used an integrated reader from Convergence Systems[7] to capture the tags of cattle as they entered the stun box. The CS203ETHER Integrated Reader contains a UHF reader and circularly polarised antenna in a single IP68 ruggedised unit, with an Ethernet interface that supports Power-over-Ethernet (PoE). We consider that this sort of simple, ruggedised equipment is ideal for challenging environments such as processing plants.

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[7] Convergence Systems - http://convergence.com.hk/

Figure 5: Reading individual cattle with an integrated reader at the stun box.

For the trial, the reader was positioned at the entry to the stun box, using a camera tripod for a temporary mount (see Figure 5). We turned down the power of the device to ensure that we only read tags from the animal entering the stun box. The reader correctly read the tags of all animals and transmitted these to the computer.

Although pumps, stun equipment, chain and other electrical and motor equipment were in very close proximity, there were no detectable interference issues. If anything, the equipment performed too well and the output power needed to be decreased to achieve an appropriate field.

3 Sheep Trial

3.1 Recording on Farm

A small mob of sheep were tagged on farm and their IDs were read using a battery-powered Intermec IV7 reader and antenna, talking through a Bluetooth serial adapter to a ruggedised PDA. This simulates the sort of on-farm environment that the equipment will need to support. In remote yards a quad bike or utility vehicle battery is likely to be used to supply power, and robust portable devices gather data.

3.2 Transport

Sheep were loaded onto a stock truck using a 2.2m wide race with a ramp from the truck. Utilising the battery operated reader again, two combined send-receive antennas (Intermec IA36) were used – one on each side of the race, just above the sheep and angled slightly down toward the animals. This produced the best results – 100% read performance with the animals moving at speed.

3.3 Unloading at Plant

Sheep were unloaded at the plant, although we did not follow these animals through the remainder of processing. The truck backed up to a 1.8m loading race, shown in Figure 6. Animals were unloaded quickly and passed at speed through to the pens.

Figure 6: Unloading facilities at the sheep plant.

Figure 7 shows how animal tags were read in this situation. We lacked mounting brackets of the correct height and position for the trial, so used a person on each side of the race to hold an Intermec IA36 antenna. The antennas are above and to the side of the animals, turned slightly to face the direction of movement of the animals.

Figure 7: Unloading sheep - two people are used as temporary holders for the antennas.

We were successful in achieving repeatable 100% reads of the sheep when unloading at the plant. There were no obvious signs of interference or changed performance from proximity with plant equipment, but we did not test reading sheep on the processing line itself.

4 Integration with Traceability Systems

In practice reading tags at point locations is not enough. For a traceability system to be effective, data about the animals and their location must be transmitted to a central location and able to be accessed when needed – for instance to confirm the status of an animal prior to slaughter .

We demonstrated two methods of managing this data:

1. LivestockOne, a software system designed for traceability from farm to plant for livestock; and
2. The GS1 EPCglobal Network is a standards-based network that uses EPC Information Services (EPC-IS – web services architecture), digital certificates and authentication to allow supply chain partners to exchange detail information related to events through the supply chain.

4.1 LivestockOne

Rezare Systems created the first version of LivestockOne in 2005 to assess the feasibility of tracing livestock from farm to farm and eventually to processor, using mobile readers. From 2006 to 2008 the LivestockOne XML transfer, database and web technology was used to record 40,000 sheep in an innovative cross-farm tracing trial with a major New Zealand sheep breeder.

Together with Racewell Limited, Rezare Systems developed the front end technology for LivestockOne into a software tool that runs on Windows Mobile devices such as ruggedised PDAs. These devices can be configured to transmit sessions of animal data and events to the central LivestockOne database server.

For the UHF trials, the PDA software was modified to expect a GS1 SGTIN (serialised global trade item number) rather than a traditional low-frequency ISO 11784 identifier. The software was placed on a ruggedised PDA and communicated with an Intermec IV7 reader over a Bluetooth serial connection.

Transactions were recorded when cattle were first identified, and when they were loaded for transport. For the sheep trial, transactions were recorded at identification, then at loading, and finally when animals were unloaded at the plant.

4.2 EPC Global Network

The EPC Global network architecture defines a number of layers of functionality with clearly defined published protocols for communication between each layer. These are illustrated (in a simplified form) in Figure 8.

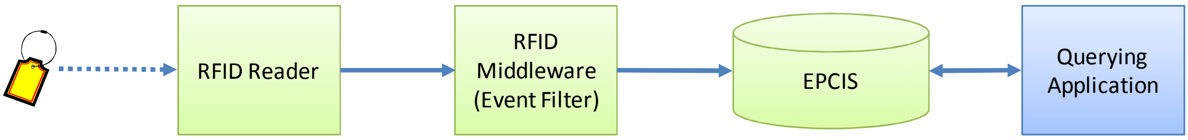

Figure 8: Conceptual architecture showing layers in the EPC Global Network

At each layer, open protocols allow the flow of data and substitution of hardware and software components. Examples of these protocols are TDS (Tag Data Standards, which define tag memory), the Gen2 UHF Air Interface protocol, the Reader protocol, or the Filtering and Collection (ALE – Application Level Events) Interface.

An EPCIS repository is used to store the resulting detail information and event information about every item, and this repository can be queried by external applications (for instance, a purchaser's system). A global object naming service helps external applications to find the repository that they should access to find information about a given item.

In our trials, data from the Motorola XR-450 reader was captured by RFID middleware, and associated with relevant events for submission to the repository:

- When animals were first identified, a **commissioning** event was recorded, and the animals were considered active;
- When animals were loaded onto the truck, a **loading** event was recorded, and the animals were considered in-transit;

- When animals were received at the plant, a **receiving** event was recorded, and the animals were considered active again;
- At the stun box, a **transforming** event was recorded as the live animals are transformed to another product – a carcass.

In situations where the XR-450 reader was not used, we took the files of tags and timestamps (for instance, from the PDA) and manually loaded these into the RFID middleware for transmission through the EPC Global network.

5 Conclusion and Recommendations

UHF tag and reader technologies generally function well when used to trace animals from farms to processor and into the downstream supply chain. This was clearly the case for sheep were animals could be handled in groups and at speed with very good read performance and reliability. In the case of cattle it is clear that body mass, ear tag placement, and the relative position of antenna and tag have significant impact on read performance.

We recommend that those considering implementing UHF RFID with cattle or large animals should pay particular attention to antenna selection and configuration in order to maximise coverage of the reading field and minimise "shadows" caused by other animals.

It proved straightforward to modify existing animal recording software designed for use with low-frequency radio identification to work well with UHF systems, and we demonstrated that we can collect and store data that will be necessary to meet legislative requirements for animal movements. In addition, the EPC Global Network was demonstrated as a method for tracking item data (including animals and carcasses) right through the supply chain.

The actions demonstrated in our project were standard events defined in the EPC IS schema. Extension fields allow linking between events, which is necessary for the following stages of processing (for instance, linking carcass back to animal or linking cuts back to the carcass).

We noted that UHF RFID equipment performs very well in the challenging environment of the processor. Importantly, UHF equipment showed no sign of decreased read performance or interference from proximity to electrical and mechanical equipment. This has been a significant challenge for RFID and communications equipment operating at low frequency.

Additionally, "off the shelf" reader and antenna equipment is now available with IP68 waterproof and ruggedised packaging and with single Power over Ethernet connection which should enable ready integration with existing plant systems.

Widespread use of low frequency RFID tags and readers in existing cattle and dairy operations, and legislative requirements for New Zealand's National Animal Identification and Tracing system

(NAIT[8]) are likely to mean the continuation of low frequency RFID use for cattle. However, UHF RFID may be a viable option for other animal species, particularly where premium product and end purchaser demand justifies the end to end supply chain integration that will be feasible with EPC Global information systems.

6 Acknowledgements

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[8] www.nait.org.nz