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Using UHF for cattle electronic identification: summary of ScotEID findings **02/11/2015**

Using testing under both controlled and commercial field-trial conditions, ScotEID continues to assess UHF equipment for cattle EID. Findings to-date confirm that UHF offers performance advantages that are attractive to some users. A revealed problem with tag resilience has been addressed by replacing the physical connection between a tag antenna and its microchip with an inductive coupling connection immune to physical bending stress on the tag.

Introduction

1. Electronic Identification (EID) of animals has long been dominated by the use of Low Frequency (LF) technology. However, rapid technical developments over the past decade have led to the widespread adoption of Ultra High Frequency (UHF) technology across various other sectors, prompting re-consideration of UHF's suitability for livestock EID. Notably, UHF is already permitted for use with cattle in the USA where large-scale field trials are currently underway.

2. UHF has a number of attractions, including potentially lower costs, longer reading distances and faster reading speeds. However, relatively few livestock applications have been documented and performance under challenging environments has been questioned – particularly with respect to reading distances being reduced by wetness or blocking by animals' bodies.

3. To assess the potential for using UHF for cattle EID, ScotEID has been testing performance for several years under both controlled and commercial (field-trial) conditions. Prototype testing under controlled conditions has focused primarily on technical aspects, seeking to identify appropriate components and equipment for livestock applications – including the development of dual LF-UHF tags and readers.

4. By contrast, field-trials have focused primarily on user experiences of working with UHF under commercial conditions as cattle move between locations and/or are subject to routine on-site management such as milking or weighing, running though an auction ring or entering an abattoir line. Particular attention has been paid to ease of use and reliability plus the scope for EID to enhance or hinder current management practices. For example, the distance at which eartags can be read reliably, the time taken to read IDs (including any not read at the first time of trying), incidences of tag failure or loss and any behavioural response by cattle.

5. To-date, more than 9000 cattle have been tagged on 11 farms, with a further two marts and one abattoir also involved. Dual LF-UHF tags have been used in most cases, coloured pink for easy visual recognition. In response to formal requests from dairy farmers, full-duplex (FDX) LF has been used to avoid possible interference problems with existing half-duplex (HDX) LF management systems.

6. The main findings to-date from testing by ScotEID are summarised below for different aspects of performance. Field-trials rely mainly on self-reporting by users[1] and hence generate important qualitative insights, included here in the form of selected quotes alongside quantitative results.

Reading distance

7. An EID reader transmits a modulated radio frequency signal to an EID tag comprising an antenna and a microchip. The antenna draws power[2] from the signal, passing it to the chip which responds by modulating the backscattered signal to transmit back to the reader. For short-range reading applications, signals can be transmitted between the tag antenna and the reader antenna through the magnetic "near-field" component. Both LF and UHF have this capability. However, UHF also has an electric "far-field" capability which allows longer-range reading.

8. Prototype testing of UHF tags indicated that this far-field capability allows UHF tags to be read at distances significantly greater than can be achieved by near-field reading. Although reading distances are affected by tag design, quality of materials and reader power, distances of several metres are easily achieved and field-trial results have confirmed this (see Table 1).

9. Qualitative feedback supports this finding, as illustrated by these quotes from some users:

   "We can easily achieve 3-4m if we need to, so can read all cattle in a pen without having to get into the pen ourselves"

   "The [fixed] readers are arranged so that cattle have enough space around them but are read at about 1-2m distance"

   "I use the handheld at a distance comfortable for both me and the cattle, about 1-2m"

Signal blocking by body tissue

10. Electric signals are more susceptible than magnetic signals to blocking by dielectric materials, such as body tissue. Consequently longer reading distances may not be achieved if relying solely on electric signals which may be blocked by animals' bodies, either the animal's own or others'.

11. Testing revealed that signal blocking by an animal's own body really only arises if the reader is positioned underneath an animal on the opposite side to the EID tag – which seems unlikely to arise in practice, but suggests the technical solution is to position reading equipment above cattle head height to avoid any possibility of self-blocking. Positioning reading equipment (either handheld or fixed) at this height also reduces the scope for blocking by other animals. Given the shorter read range of LF, the advantages of positioning readers appropriately are not confined to UHF – although, unlike LF, UHF performance is further enhanced by signal reflection from nearby metal structures.

[1] The use of UHF has also been observed by ScotEID staff at each partner location, to confirm self-reported performance.

[2] Although it is possible for tags to have their own power source, such "active" tags are more expensive; "passive" tags drawing power from the reader's signal are more common.

12. Reported field-trial findings confirm that blocking by body tissue is not a practical problem, provided that reading equipment is positioned appropriately and consideration is given to how and why blocking might occur. That is, few users have raised it as an issue and those that did related it to particular circumstances that can be easily avoided – as illustrated by these selected quotes:

    "If the next animal in the race is following very close behind with its head down, the [fixed] reader can miss it – but this rarely happens."

    "Having the [fixed reader] antennae arranged above and to the sides means that we can read simultaneously from different angles and catch any animal shielded in one direction by other animals."

    "I can't say that this has ever been a problem when using the handheld – you just do each animal in turn at the head end!"

    Signal blocking by wet conditions

13. Water can also potentially have an adverse dielectric effect on electric signals, reducing the effective read range. However, ultimately, even if far-field signals were to be completely negated by wetness, the magnetic near-field signal would still be operational, with a typical range of 0.5m (the same is true for blocking by body tissue, see above but also section on injectables and boluses below). Given the Scottish climate, EID tags and readers will often be exposed to wet conditions and hence there is a need to test performance under both wet and dry conditions.

14. During the field-trials, users reported no practical reduction in reading ranges under wet conditions, as these illustrative quotes reveal:

    "No, I've not noticed any difference reading in the wet or the dry."

    "Although we read indoors, cattle are still wet on a rainy day – but we've not seen any difference to reading on a dry day."

    "We've had no problems reading wet or mucky tags, unlike if doing them by eye."

    Reading wrong animal

15. The long reading distances achievable with UHF mean that there is some potential for reading a tag other than the one intended if other cattle are within range. In some cases, such as wishing to read all animals in a pen or as they are off-loaded from a trailer, this is not a problem, but in others, such as weighing individual animals, it could be.

16. However, the power of UHF reading equipment can be varied automatically or manually such that the reading range can be reduced if a user wishes to read one animal at a time or increased if multiple animals are to be read together. Moreover, the signal is also directional – meaning that the width of the interrogation field can be narrowed to direct the antenna signal at a given target, to further reduce the scope for reading tags other than the one intended.

17. Testing under controlled conditions confirmed the ability of variable power settings to reduce UHF reading distances. For example, cutting the range in steps from 4.5m to 0.5m (see Table 2). Similarly, configuration of reader antenna to route signals in a particular direction was also shown to avoid unintended reading of other tags.

18. Users report no issues with reading the wrong animal in the field-trials, varying the reader power whilst positioning the reader appropriately in combination with careful stock management to keep other animals out of range – as illustrated by these selected quotes:

    "We have a sliding door in the race and have tuned the [fixed] reader to read no further than that, so we don't read the next animal waiting by mistake."

    "I don't recall ever reading the wrong animal when reading one-at-a-time using a handheld in the crush."

    "I can see how that might happen in a pen, but not otherwise when you know which animal you're pointing at."

    Speed and reliability of reading

19. Speed of reading a tag is primarily determined by the frequency at which information is transmitted and the amount of information held on the tag. Lower frequencies transmit more slowly than high frequencies, so LF will take longer to read a given amount of information than UHF and any tag will take longer to read if it holds more information.

20. However, effective practical reading speeds will be reduced if reading fails at the first attempt and has to be repeated because it is attempted at too great a distance and/or if transmission signals suffer interference and/or if signal responsiveness is sensitive to how an animal is oriented/presented to a reader. In addition, unless anti-collision technology is used, if multiple tags are present at the same time within a reader's interrogation field, some or all of them will fail to read due to collisions between their signals. UHF and Advanced LF both have anti-collision capabilities, standard LF does not.[3]

21. Controlled testing confirmed that UHF can typically read in excess of 100 cattle tags per minute, standard LF less than 20 tags per minute and that UHF reading speeds were unaffected by the presence of multiple tags. This difference equates to the difference between an eartag (and thus an animal) having to remain within a single reader's interrogation field for a fraction of a second or a few seconds – a small difference, but one that is significant when attempting to read moving or even restrained animals.

22. Field-trial results suggest that the combination of faster reading and longer reading distances offers greater reliability of first-time reading and translates into higher effective reading speeds for UHF. The time-differences per animal may be small, but cumulatively the time-savings offered by UHF are significant. Moreover, some users report a significant reduction in the number of staff required for

[3] Although the lack of anti-collision capability can be worked-around to some extent by installing multiple readers, as currently deployed for standard LF-reading of sheep at marts, but this adds significantly to costs.

certain operations since the need for lengthy physical restraint is avoided. This is reflected in the following selected quotes:

"Compared to manual reading and recording, much less hassle and greater confidence that no errors have been made – we've saved a lot of time"

"Even though we were moving animals through the crush in both cases, LF still took longer than UHF – each animal needed to hold still for a little longer and we didn't always get it read first time, whereas with UHF it was all much smoother"

"UHF can cope better with animals moving several abreast whereas with LF they had to be in single file which caused bunching and slowed things down a lot."

Cattle behaviour

23. Handling cattle inevitably incurs some staff health and safety issues plus can affect animal welfare and growth rates through increased stress levels. Although dairy cattle typically become accustomed to regular handling, beef cattle – especially suckler herds – seldom do. Consequently, the act of reading eartags poses some risk. These are greatest if animals have to be physically restrained and/or have readers used in close proximity to their eyes. This can occur if a hand has to touch an eartag and/or a handheld reader has to be brought close to the head, but can be avoided if an ID can be read from a greater distance.

24. Observation of cattle behaviour whilst having eartags read under controlled conditions is not necessarily informative since the testing environment itself may affect behaviour – it is better to observe animals under field conditions. Hence field trial participants were asked to comment on how cattle reacted to having IDs read with UHF relative to other modes of reading.

25. In general, users report that dairy cattle behaviour is fairly consistent regardless of how IDs are being read. However, users noted less incidence of distress amongst beef cattle when read using UHF rather than with either manual recording or handheld LF (or barcode) readers. This is attributed to a combination of the reduced need for physical restraint and not having to get so close to an animal's head and eyes. In addition, users welcome the reduction in exposure to personal health and safety risks also delivered by these time and distance improvements.

"Handling beef cattle is dangerous and dirty, which is stressful for them and us – being able to read at a more comfortable distance is a real advantage."

"Our cows are not used to being handled and the old manual reading where you had to grab at heads and ears was definitely more stressful than using EID."

"Anything that helps to keep animals calmer is welcome, including avoiding close handling".

Tag and reader resilience

26. Although well-suited to testing reading distances and speeds, controlled testing is less suited to testing the durability or resilience of tags and readers under extended usage in varied and challenging

environments. Hence, whilst equipment that was obviously fragile was rejected at the prototyping stage, the resilience of tags and reading equipment can only really be assessed over time through the field-trials.

27. Field-trial results confirm that the chosen reading equipment is generally robust and capable of operating under a range of conditions, as illustrated by these selected quotes:

    "Since installation, the fixed reader has given us no problems"

    "The handheld has coped with the usual abuse inflicted on farm equipment."

    "The reader seems pretty robust, working despite a few knocks and low temperatures."

28. Field trial results also indicate that rates of tag loss are generally similar to those for non-EID flag tags, which is as expected since EID and non-EID flag tags are identical externally. Within this, some farms have seen very low loss rates, some much higher.

    "Retention has actually been pretty good, and I've seen some of my animals elsewhere still tagged – the pink makes them standout."

    "We've lost a few ear tags, but no more than normal I'd say"

    "We've had a disappointing time with tag losses, much higher than expected."

29. However, some users have reported particular problems with non-functioning EID tags. For example:

    "Even if the tag is still there, it may not be working – about 20% of ours have broken internally."

    "Stresses and strains seem to have taken their toll on a fair number of tags, stopping them working."

    "The flag UHF part has often broken off, leaving only the LF button part"

30. On inspection, non-functioning tags have been subject to bending stress which has broken the internal connection between the antenna and its chip. This appears to be more commonplace (up to 30% malfunctioning) on farms with vertical or angled bars on feeding stations than on farms with horizontal feeding bars (as low as 0% malfunctioning), implying that an animal backing-out from a feeding station is more prone to catching tags on vertical or angled bars than on horizontal ones. In addition, some animals appear to be harder on tags. For example, young beef bulls relative to adult dairy cows.

31. In response to the problem of non-functioning tags, ScotEID has redesigned the tags using novel technology developed for the laundry industry where tags sewn into linen (e.g. hotel and hospital bedding) are subject to regular and repeated bending stress through washing and drying. Specifically, the physical link between the antenna and the chip is replaced by an inductive coupling link that cannot be broken by bending.

32. Testing under controlled conditions has confirmed that this design retains the performance characteristics of previous ScotEID designs (as summarised above, but see Table 3 too), but is unaffected by bending stress. In response to the problem of tag loss, ScotEID is also exploring alternative, non-flag designs suitable for use as secondary tags. Volume production of the revised designs incorporating inductive coupling is underway and new tags will be issued to participating partners for field-trials in the near future.

Overall read-rates

33. The proportion of animal IDs that are read on a given occasion depends on whether reading equipment is functioning and used correctly, on whether any EID tags are missing and on whether any EID tags are malfunctioning. Under controlled conditions, 100% read rates are easily achievable, but read rates under commercial conditions are subject to more variable influences.

34. Field trial users report no instances of reading equipment not working. Moreover, 100% read rates are commonplace. Where read rates fall below 100%, this is typically due to missing eartags but in a few cases (as noted above) malfunctioning tags have lowered the overall read rate significantly.

"We generally achieve 100% read rates. When we don't, it's usually because an EID tag or two are missing."

"Most times we get 100%, but on occasion you'll find that a tag is missing or is not working for some reason."

"We've had a terrible time with around 20% of tags not reading even though they're still there. ScotEID staff confirmed that the tags were malfunctioning."

Co-existence of LF and UHF

35. Reflecting ScotEID's belief that the key to widespread adoption of EID is to allow users some flexibility in terms of how IDs are read, the majority of the tags used in field-trials have been dual LF-UHF tags. These allow the same ID to be read using LF or UHF reading equipment, or indeed to be recorded manually from the number printed externally.

36. Controlled testing confirms that dual tags perform at least as well as separate LF or UHF tags, with no interference between the two (see Table 4). This is as expected since LF and UHF operate at completely different parts of the frequency spectrum.

37. Field-trial results also confirm that the two technologies can co-exist, with no conflicts with existing LF-based systems on dairy farms being reported and dual tags being readable with LF, UHF or dual LF-UHF reading equipment. For example:

"Our existing LF readers work fine with the dual tags."

"We've checked and yes, the tags can be read with either our LF or UHF readers"

"We ran the same animals one-at-a-time through the race and read them first using LF and then using UHF, and got the same results both times."

UHF costs

38. The adoption of UHF by other sectors, notably logistics and retailing has seen unit costs for tags and reading equipment drop as R&D has improved designs and sales volumes have increased. Consequently, although prices vary with order size and quality, UHF tags and readers are cheaper than LF equivalents (see Table 5). Moreover, the ability of UHF to read multiple tags (due to anti-collision properties absent from standard LF) means that a single UHF reader is sufficient for high throughput situations such as at marts rather than then multiple readers required for LF, again offering a cost advantage. Unsurprisingly, users view lower costs favourably. For example:

"Cheaper equipment is a bonus."

"Lower costs are what we're after."

"If it is cheaper, that only adds to the pros for UHF"

UHF injectables and boluses

39. Although eartags are the predominant mode of livestock EID and the form most likely to be used for cattle in Scotland, LF is also available as injectables (e.g. as permitted for use in goats and horses) and boluses (e.g. as permitted for use in goats and sheep). However, as yet, UHF has not been available in similar ways and the European Commission views this as a drawback.

40. In response, ScotEID has been working with some international researchers to develop UHF injectables and boluses. This work is still at an early stage, but preliminary testing confirms that there are no technical barriers to using UHF in this way. However, reliance will be placed on near-field rather than far-field capability since signal blocking by body tissue will be unavoidable, meaning that reading distances will be similar to those of LF if users chose to adopt this form of EID.

Cattle numbering

41. As yet, it still remains unclear as to whether adoption of bovine EID will require cattle in Great Britain to be renumbered to comply with international EID numbering standards.[4] However, although ScotEID remains involved in national and international negotiations regarding numbering formats, the choice of which numbering standard to use is completely separate from the choice of transmission technology.

42. That is, LF and UHF are both ways to transmit information and can be used with any numbering format. Hence ScotEID currently uses the same standard (ISO11784) for encoding both the LF and UHF components of dual tags and will do the same for whatever numbering format is finally agreed.

[4] See previous ScotEID paper on this: https://www.scoteid.com/Public/Documents/Bovine_EID_numbering.pdf

43. The choice between Roman numerals (i, ii, iii etc) vs. Arabic numerals (1, 2, 3 etc) offers an analogy. Either can be used to represent the same number but the choice of which to use is different from a decision as to whether to use a pen and a piece of paper or a chisel and a stone tablet to write with: the pros and cons of each number format are distinct from the pros and cons of how they are written, carried and read.

Conclusion

44. Using testing under both controlled and commercial conditions, ScotEID continues to assess UHF equipment for cattle EID. Findings to-date confirm that UHF offers performance advantages that are attractive to some users interested in the time-savings and health & safety gains offered by longer reading distances. Moreover, the possibility of co-existence with LF offers flexibility to suit different users' EID preferences.

45. Although the revealed tag resilience problems are disappointing, their discovery highlights the worth of field-trials involving large numbers of animals under different conditions over extended periods of time: the resilience problems were not revealed by more limited testing under controlled conditions and have not occurred everywhere. Revised tag designs to address the retention and malfunction issues have been identified and will be subject to field-trial testing in the near future.

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Annex A: Tables

Table 1: UHF reading distances (m)

Tag Design	Tag orientation						Overall		
	1	2	3	4	5	6	Avg	Max	Min
A	3.2	3.3	3.6	5.2	5.0	2.8	3.9	5.2	2.8
B	4.4	3.4	5.0	2.3	3.9	4.3	3.9	5.0	2.3
C	5.4	4.3	4.4	4.8	5.4	3.9	4.7	5.4	3.9
D	5.4	4.8	3.7	5.4	5.4	3.5	4.7	5.4	3.5
E	6.6	4.2	6.7	4.5	5.5	4.7	5.4	6.7	4.2
F	5.2	3.7	3.7	5.2	5.8	3.5	4.5	5.8	3.5
G	7.5	3.7	7.0	4.7	6.0	4.2	5.5	7.5	3.7
H	6.7	4.6	5.1	6.0	5.7	3.8	5.3	6.7	3.8

Designs vary in terms of: antenna type, length and width; chip set; and external tag size.
All tags read with Deister UDL 500 2 Watts ERP, with tag moved progressively nearer to the antenna to determine limit to reading range.

Tag orientation key

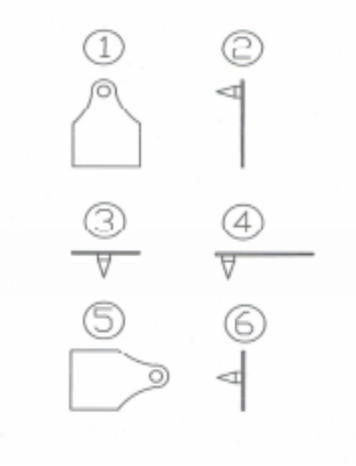


Table 2: Effect of varying reader power on reading distances (m) under workshop conditions

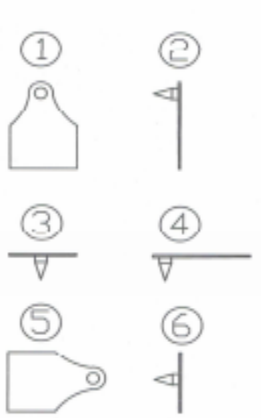
Reader type	Power	Distance
Handheld	100%	3.00
	75%	2.50
	50%	1.00
	25%	0.25
Fixed	100%	4.50
	75%	2.00
	50%	0.50
	25%	0.25

Handheld readers were ATID 870; Fixed readers were Impinj Speedway 420.

Table 3: UHF reading distances for inductively coupled UHF tags

Tag Design	Tag orientation						Overall		
	1	2	3	4	5	6	Avg	Max	Min
A	6.0	3.0	5.0	4.0	4.0	4.0	4.3	6.0	3.0
B	6.5	4.0	6.0	3.5	5.0	5.0	5.0	6.5	3.5
C	8.0	4.0	6.5	4.0	5.0	6.0	5.6	8.0	4.0
D	6.0	3.0	5.0	3.0	4.0	3.5	4.1	6.0	3.0
E	5.0	2.0	5.0	4.0	4.0	3.0	3.8	5.0	2.0
F	6.0	3.0	5.5	3.0	3.5	3.5	4.1	6.0	3.0
G	6.0	3.5	6.0	3.5	4.0	4.5	4.6	6.0	3.5
H	7.0	4.0	6.5	4.0	5.0	4.5	5.2	7.0	4.0

Tag orientation key



Designs vary in terms of antenna type, length and width. All tags read with Deister UDL 500 2 Watts ERP, with tag moved progressively nearer to the antenna to determine limit to reading range.

Table 4: LF, UHF and dual LF-UHF reading distances (cm) under controlled conditions

Tag type	Reader type	Max	Min
LF	LF	67	21
	Dual	68	22
UHF	UHF	5500	3000
	Dual	5000	3500

Readers are all handheld, an Agrident AWR10 for LF and an ATID870 for UHF plus the dual LF-UHF reader.

Table 5: Indicative unit costs

	LF	UHF	LF-UHF
Tags	X	X	X
Handheld readers	£200+	£800+	£800+
Fixed readers	£1000+	£700+	n/a
Mart installation	£8000+	£1000	n/a

Note: LF mart installation assumes multiple readers, to work-around lack of anti-collision capability. Dual fixed readers not currently available.