Using Ultra High Frequency (UHF) for cattle electronic identification:

updated summary of ScotEID findings

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Contents

Using UHF for cattle electronic identification: updated summary of ScotEID findings

Following a Scottish Industry request UHF-EID for cattle has been trialled progressively in Scotland over the past decade. Testing under commercial conditions across farms, marts and abattoirs confirms that the technology is reliable and presents significant opportunities as well as advantages over the alternative of LF-EID

Introduction

1. ScotEID came into being in 2008 when SAOS was tasked with finding an acceptable way to implement electronic identification (EID) of sheep by 2010, as mandated by the European Union. At the time, the challenge looked daunting due to technical limitations and the nature of the Scottish sheep sector.

2. Nonetheless, mandatory sheep EID was successfully introduced in Scotland in 2010. This outcome represented the results of significant 'learning by doing' to discover practical solutions for different parts of the supply-chain, with ScotEID working closely with EID suppliers, government officials, industry stakeholders and academic experts.

3. ScotEID now has full responsibility for administering traceability systems for cattle, sheep and pigs in Scotland. This involves the design and maintenance of the core database to hold information (e.g. births, movements, deaths) plus supporting fast and accurate transmission of information to and from the database.

4. As part of this, ScotEID has been actively researching bovine EID for over a decade. This has, again involved co-design with many partners and has been shaped by the prior and ongoing experience of implementing sheep EID.

5. This report summarises the journey taken to reach current understanding of how bovine EID could be implemented successfully in Scotland. The Annexes contain additional supporting information.

Background to sheep EID

6. EID uses Radio Frequency Identification (RFID) technology whereby the identity of an object (e.g. an animal) is encoded onto a microchip attached via a device such as an ear tag or an injectable phial. The object's identity can then be retrieved wirelessly using electronic reading equipment. RFID is commonly used across the economy in various applications. For example, in logistics, retailing and security control.

7. RFID comes in different forms, varying in the radio frequency that is used to transmit information. For sheep EID, the EU mandated the use of Low Frequency (LF, 120 – 150 KHz) technology. This is a mature technology with a long history of being used with injectable

devices for companion animals (e.g. cats and dogs) and for voluntary farm management purposes.

8. Physics dictates that the distance over which LF microchips can be read is relatively short. For example, EU regulations accept a minimum reading distance of 12cm for an ear tag using battery-powered handheld equipment or 80cm if read using mains-powered stationary equipment. The need to get physically close to read an animal presents a health and safety risk to staff but also a welfare risk to animals, with risks being greater with animals unused to human handling and also with larger animals (and hence particularly high with extensively-reared beef cattle).

9. Moreover, LF technology lacks 'anti-collision' properties, meaning that reading equipment can only read one microchip at a time: due to collisions between their signals, if two or more microchips are presented at the same time to the same electronic reader, they will not all be read and/or false (ghost) reads may be registered.

10. The combination of a short reading distance requiring microchips to be read individually means that whilst LF is well suited to tasks involving single animals (e.g. identifying a dog at a vets or a sheep immobilised in a crush whilst being weighed) it is less suited to operations involving multiple animals moving at speed (e.g. loading onto transportation, running through a race).

11. Although the European Commission's Joint Research Centre (JRC) had published positive evaluations of LF EID for sheep, the applicability of the findings to the Scottish sheep sector was limited. In particular, the JRC's analysis did not extend explicitly to the stratified production system in Great Britain involving large volumes of movements through auction marts nor to sheep that were relatively unused to (and hence wary of) the close human contact needed to read LF microchips. For example, JRC case studies often focused on small milking flocks.

Implementing sheep EID

12. Scottish Government officials and industry stakeholders were aware of the technical constraints of LF-EID in 2008 and concerned that they would pose an unacceptable burden in terms of slowing the speed of commerce. Yet it was acknowledged that sheep EID had to be implemented to comply with EU regulations: a way had to be found.

13. Initial investigations by ScotEID confirmed the technical challenges faced. Moreover, these were amplified by revealed variation in the quality of LF equipment and by different suppliers pushing proprietary systems that were not necessarily compatible with each other. Consequently, early read rates were indeed unacceptably low at the speed of commerce demanded by users.

14. Nonetheless, working closely with Government, industry, and suppliers during 2008 and 2009, more reliable equipment and configurations to suit Scottish circumstances and achieve acceptable read rates were identified. This involved considerable learning-by-doing, both in controlled workshop conditions and (more importantly) in-situ across farms, marts, and abattoirs.

15. In particular, susceptibility to interference from surrounding metalwork and other electronic equipment meant that installations at marts and abattoirs were essentially bespoke. For example, in terms of the choice of equipment, its specific location and the use of multiple readers synchronised to allow the reading of multiple microchips.

16. As a result, average read rates above 90% were achieved routinely and the European Commission (EC) accepted that this was sufficient to deliver effective sheep traceability, given that batches of sheep are read at multiple points in the supply-chain. Moreover, the EC also accepted that the expense of readers to farmers was disproportionate given that reads at, for example, auction marts and abattoirs would suffice, which led to the agreement to use Critical Control Points. Mandatory sheep EID was subsequently introduced in 2010.

17. Incremental improvements since 2010 have raised average read rates to c.95%, achieved across multiple millions of sheep each year. This is somewhat higher than the equivalent read rates reportedly achieved in other parts of Great Britain (GB).

Implications of sheep EID experience for bovine EID

18. Shortly after overseeing the introduction of mandatory EID for sheep, ScotEID began work on trying to understand how LF might be used with cattle. This involved building on experience with sheep and exploring how LF was already used by a small number of cattle farms for management purposes. As with earlier research into sheep EID, testing was conducted under both controlled workshop conditions and in-situ across farms, marts, and abattoirs.

19. Although tolerable for sheep, 95% read rates will not be acceptable for cattle given that all cattle have individual lifetime IDs and cannot enter the food chain without one. Moreover, a reading distance of 12cm offers little advantage over visual reading of cattle tags and continues to expose stock handlers to health and safety risks, as well as cattle to stress. Scottish beef cattle are often unused to close human contact and risks of serious injury are not insignificant.

20. Attempts to achieve 100% read rates using LF for cattle not immobilised in crushes were unsuccessful. Reading multiple animals moving at speed through races or unloading from transport was particularly poor. Scottish stakeholders involved in these trials made it clear that they did not regard LF as fit-for-purpose in relation to cattle and therefore would prefer not to have to use the technology.

21. Dairy farms already using LF for parlour management face a particular additional problem. Specifically, the lack of anti-collision properties means that an official LF-EID tag will clash with the existing LF collar already in use. This will result in one or other or both LF devices failing to be read reliably.

22. Contact with experts in other countries where LF-EID is already mandated for use with cattle confirmed that these ScotEID findings were not unusual. For example, Michigan in the USA mandated LF-EID for cattle in 2008 as part of a programme to combat bovine tuberculosis. However, to comply with this, auction marts had to replace metal fencing and gates with wooden structures[1] to reduce interference and had to slow movements down by immobilising all animals individually in crushes. Similarly, Denmark mandated LF-EID for cattle in 2010, but Danish stakeholder contacts reported that much of the industry continues to rely on visual reading of ear tags since LF is not sufficiently reliable and offers no appreciable advantages given the shortness and slowness of reading. Irish stakeholder contacts have expressed similar concerns about the practicalities of recently mandated LF-EID for cattle in Ireland.

23. Australia mandated LF-EID for cattle in 2004 and contacts there report more positive experiences with LF. However, Australian cattle do not have individual lifetime IDs and animals are handled in mobs akin to how sheep are handled in batches in Scotland. More importantly, the permitted power of reading equipment is double that permitted in Europe,[2] thereby increasing the read range achievable. Reading multiple animals at a time is achieved through the use of synchronised multiple readers (as with sheep in Scotland), but it is not clear how reliably 100% read rates are achieved in practice since common practice appears to be to only read one animal in a group and to assume that the composition of the group remains constant during a given movement.

UHF-EID

24. Whilst considering the implications of these international experiences, ScotEID became aware of developments in animal identification using a different form of RFID, Ultra High Frequency (UHF, 860 to 960 MHz) technology.

25. Whereas LF RFID applications are now largely confined to animal identification, UHF RFID is deployed widely across many sectors of the economy. For example, logistics, retail and security control. This reflects some technical advantages over LF. In particular, a longer reading range (e.g. up to several metres) and anti-collision properties, both of which greatly

[1] This poses significant biosecurity risks and would not be acceptable in Scotland.
[2] Regulatory power limits are imposed to reduce the likelihood of interference with, for example, aviation and military equipment, and vary internationally. UK limits are set by OFCOM and are lower than those in Australia.

increase convenience and reliability. UHF microchips also have some easier to implement security features which make it simpler to spot fraudulent copies.

26. In addition, innovation and competition mean that UHF equipment continues to evolve and prices to fall. This contrasts to LF where limited innovation and relatively high equipment prices is the norm.

27. Contact with existing proponents of UHF for animal identification in Europe, North America and New Zealand convinced ScotEID that UHF merited further investigation. This led to ScotEID hosting a successful international conference at Dingwall auction mart in 2012, at which the case for further research was made.[3]

28. Consequently, ScotEID embarked on an extended (and continuing) programme of UHF research and development. As with sheep EID, this involved working with partners across the Scottish industry and with external suppliers and academics.

29. Initially, UHF ear tags for cattle were sourced from a firm based in New Zealand. Some of these original ear tags are still in the ears of older breeding cattle on pilot farms, and still functioning – a demonstration of their durability.

30. Subsequently, ScotEID worked closely with international suppliers to co-develop a number of different ear tag designs. The suitability of these UHF tags for official traceability purposes has since been confirmed by current PAS44 approval.[4] UHF tags are essentially the same price as LF tags, c.£2.20 each.

31. As already shown by experience with non-EID cattle tags and both EID and non-EID sheep tags, although retention rates can be affected by poor design and/or poor manufacturing quality,[5] the main determinants of tag losses are whether tags have been inserted correctly and the prevalence of snagging risks around the farm. As such, tag loss is a generic issue across the board rather than one unique to EID tags or indeed UHF-EID tags. That is, the presence or absence of a transponder makes no material difference to the weight or size of a tag. ScotEID has been piloting different tags in different situations to identify how best to mitigate loss rates of all tags not just UHF ones.[6]

32. In parallel, ScotEID also worked closely with suppliers of reading equipment to source and configure different arrangements to suit different site circumstances. The availability of

[3] https://www.scoteid.com/Public/Documents/uhf_conference_report.pdf
[4] PAS44 is the domestic standard for cattle ear tags, revised in 2019 to prepare for the introduction of bovine EID using LF and/or UHF tags. ScotEID was represented on the drafting committee for PAS44:2019.
[5] Indeed, some early sheep EID tags were of very poor quality.
[6] Indeed SRUC are currently conducting research into tag losses https://www.sruc.ac.uk/all-news/new-survey-to-record-livestock-ear-tag-experiences/

'off-the-shelf' kit offers greater choice of equipment than for LF and has allowed flexibility in how items (e.g. antennae, readers, computers, software) have been combined.

33. For example, antennae used on forklift trucks in warehouses have proven ideal for withstanding the inevitable knocks received from cattle to fixed readers, and handheld readers utilising mobile phones are widely available.

34. Greater market competition also makes UHF equipment generally cheaper than LF equipment (e.g. £250 vs. £750[7] for a simple handheld reader). Moreover, at any given price point, UHF equipment typically offers greater functionality. Equally, like-for-like comparisons also need to account for ability of a single UHF fixed reader to automatically handle multiple antennae and simultaneous reading of multiple tags whereas LF requires multiple readers (at additional cost) carefully synchronised to do so.

35. Currently, 425 farms, 18 auction marts and 14 abattoirs in Scotland plus two port lairages are involved in testing UHF EID. This equates to around 150,000 cattle currently bearing UHF-EID tags, with around 112,000 recorded tag reads at marts and abattoirs during 2022 and over a million reads throughout the course of the pilot overall.

36. Farms include suckler producers, finishers, and dairy units, varying in size and management system. Equally, individual marts and abattoirs all have their own physical configurations and management processes. As with LF-EID for sheep, configuration of UHF fixed readers, antennae and accompanying software must be tailored to suit local requirements (eased by the wider choice and flexibility of off-the-shelf UHF equipment).

37. This volume of testing of under both controlled workshop and real-world conditions has confirmed that UHF offers performance advantages over LF. In particular, 100% read rates are feasible and the greater reading distance and speed of reading combine to offer greater convenience and safety. Importantly, the speed of commerce can be maintained.

38. Prior to long-term piloting of UHF, concerns were raised that it would not work well in wet conditions. No evidence for this problem was found during workshop testing or throughout a decade of prolonged real-world testing.

39. Similarly, concern was also expressed that interference from electrical equipment and metalwork would be problematic. Again, neither has proven problematic during workshop or real-world testing. Indeed, reflection of signals from metalwork has proven to enhance read rates by overcoming reliance solely on line-of-sight reading (shorter reading distance

[7] Cheaper LF handheld readers are available but are intended for use with companion animals rather than agricultural livestock. For example, they need to be physically brushed against an animal's skin and are not designed to withstand hostile environments. As such they are not suitable for farm, mart or abattoir applications. The conflation of companion animal and livestock applications is a persistent cause of confusion in EID debates.

and lack of anti-collision properties mean that LF does not benefit in the same way – indeed reflected signals actually cause problems because of the lack of anti-collision properties).

40. In principle, longer reading distances pose a risk of reading animals other than those intended. For example, the next animal in line to be weighed or animals in a neighbouring pen. In practice, this can be avoided through a combination of simple measures, all of which have been shown to work across a range of situations.

41. For example, reducing the power of reading equipment (very easily adjusted up or down by users, as required) to shorten the reading distance, focusing reading equipment in a particular direction (by positioning antennae) and using chicken wire to shield other animals from reader equipment.

42. Similarly, animals' ability (when not immobilised in a crush) to dip their heads and/or move behind other animals can potentially block line-of-sight reading. However, reading animals from above (e.g. placing fixed reader antennae above rather than alongside a race or pen, holding handhelds above head height) and utilisation of reflected signals means that body blocking is not a problem in practice. For example, auction marts of cows with calf-at-foot achieve 100% read rates with UHF.

<u>UHF-EID deployment</u>

43. Long-term demonstration of the relevance of UHF for bovine EID across the supply-chain by ScotEID has led to endorsement of it by many Scottish stakeholders and the project group[8] which was established by them to support the pilot. The project group is now calling for the Scottish Government to introduce mandatory UHF-EID for cattle.

44. Separately, in 2016, the USDA published findings from its own evaluations of UHF for animal identification. These are similar to ScotEID's results and led to the USDA approving UHF ear tags for use in the USA and to the formation of CattleTrace as a voluntary industry-led initiative to encourage the use of UHF EID for cattle (tagging for traceability is not mandatory in the USA).

45. Separately, although information is subject to commercial confidentiality constraints, positive outcomes are associated with the voluntary uptake of UHF EID for cattle in Brazil and in South Korea (using proprietary systems from a single supplier) reportedly covering

[8] The Scottish Bovine EID Stakeholder Group is chaired by NFUS and includes representatives from Institute of Auctioneers and Appraisers in Scotland, Quality Meat Scotland, Scottish Association of Meat Wholesalers, Scottish Beef Association, National Beef Association, Scottish Crofting Federation and the Scottish Dairy Cattle Association as well as Scottish Government, Food Standards Scotland and ScotEID.

several million animals in each country. Similarly, some Australian cattle exporters are reportedly using UHF.

46. In parallel, the potential of UHF-EID for pigs and for farmed deer has been demonstrated through various (non-ScotEID) research projects and at least one tag manufacturer is currently trialling UHF sheep tags.[9]

UHF-EID regulatory status

47. UHF has long been subject to international technical standards (e.g. ISO18000-6c) relating to performance, for example, how microchips should behave and interact with other electronics. However, the International Standards Organisation (ISO) recently agreed to also introduce a standard (ISO6881) for encoding UHF microchips for animal identification purposes, to mirror existing arrangements (ISO11784) for LF animal identification.[10]

48. This step signals formal acceptance by the relevant international community that UHF is an appropriate and viable technology for animal identification. ISO6881 is expected to be published by the end of 2023.

UHF-EID encoding

49. A major reason why LF-EID has not already been introduced in the UK for bovine EID is that regulations stipulate that encoding must comply with ISO11784 and replicate the visual ID printed on the outside of the ear tag as What-You-See-Is-What-You-Get (WYSIWYG).[11]

50. Unfortunately, existing visual cattle IDs in the UK are incompatible with ISO11784. This is because their numerical value is too large to fit into the allocated space on the microchip.[12] Altering the numbering system for cattle to comply with ISO11784 is possible, but has

[9] Earlier EU-funded research into UHF EID for sheep was not pursued further once LF-EID was made mandatory for sheep – although some interest remains, particularly in relation to slaughter tags for lambs where the regulatory requirements are less binding.

[10] A member of ScotEID sits on the relevant ISO working group, in a personal capacity.

[11] Non-WYSIWYG is also possible from a technical perspective, with the electronic number being different to printed visual number, but requires a cross-referencing lookup between the two which adds complexity and is not favoured by users.

[12] Cattle IDs comprise the UK country code followed by a six-digit herd mark followed by a checkdigit followed by a five-digit serial number for animals within a given herd mark. Although the last three components form a 12-digit animal number and ISO11784 was designed to hold 12-digit animal numbers, the maximum numerical value that can be stored is 274877906944. Yet all 12-digit Scottish cattle numbers begin with a 5, and hence are not ISO-compatible.

implications for compatibility with legacy databases designed around the existing numbering format.

51. The existing numbering system will need to be retained unless the Cattle Tracing System (CTS) is upgraded or replaced. As a relatively recent creation, ScotEID was designed to accommodate both the existing cattle numbering system and future possibilities and could accommodate a new numbering system now.[13] However, cross-border moves between Scotland and other parts of GB mean that Scotland cannot adopt a new cattle numbering system until other administrations have developed their own systems and moved away from CTS.

52. The advent of ISO6881 unfortunately replicates the numbering constraints of ISO11784, meaning that it too would require a change of UK cattle numbering. Again, whilst Scotland and ScotEID could accommodate this, adoption would have to be delayed until CTS has been replaced.

53. Moreover, even if cattle numbering is altered to comply with ISO requirements, this will apply only to newborn animals from some future date. Any existing animals (the 'historic herd') will necessarily remain incompatible since they will have to retain their lifetime ID.[14]

54. This is problematic given that maximising on-farm and supply-chain efficiencies depends on all animals being EID-tagged. For example, the ability to link dams and calves is enhanced if both are EID-tagged and mart sales will be smoother if all animals in a group are EID-tagged. Moreover, the breeding lifespan of cattle can be over ten years, meaning that the problem of mixed EID and non-EID animals would persist for some time. The market sector are keen to ensure that all animals being processed by them are fully electronically identified.

55. This problem could be avoided by using a different encoding standard to that prescribed by ISO. As an analogue analogy, a number can be written using Roman or Arabic numerals - the same information is presented, just encoded differently and easily interpreted provided that the reader is aware of the different encoding forms. Over the course of the Bovine EID pilot, ScotEID has experimented with different alternative encoding methods.

[13] Future ISO-compliant cattle IDs in Scotland will comprise a "2" followed by the herdmark followed by the serial number within that herdmark. Proposals for other parts of GB are that future numbers will comprise a "0" followed by the herd mark and serial number, with serial numbering shared between sheep and cattle.

[14] Renumbering an existing animal would require replacement of one or more ear tags but also cross-referencing in all databases to create and maintain a link between old and new IDs – something that is technically possible but expensive and difficult in a practical sense.

56. Helpfully, in 2016, the USDA issued an encoding standard specifically for animal identification using UHF-EID in the USA.[15] This offers an extremely flexible form of encoding, capable of accommodating a wide range of animal ID formats – including the current UK cattle format.

57. This has allowed participating animals to retain existing ID numbers. The pilot has demonstrated that the use of the USDA standard may be an appropriate method of identifying the historic herd in future and would have no impact in terms of the lifetime traceability of an animal and equally as importantly, have no impact on the existing CTS or other I.T. systems used in other parts of GB.

58. As-and-when CTS is replaced, UHF encoding for newborns could continue to use the USDA standard or switch to ISO6881. The latter would add some additional complexity in terms of readers needing to recognise more than one encoding standard, but is feasible since UHF reading equipment can be configured remotely (i.e. via automatic upgrades) to correctly interpret different encoding forms[16] (ala Roman and Arabic numerals, as above), to accommodate both the historic and newborn herd.

UHF disadvantages

59. UHF-EID offers some compelling technical advantages, as described above. However, as a new technology competing with an existing form of EID it suffers from two disadvantages. First, UHF-EID has yet to gain the institutional recognition already held by LF-EID. For example, EU regulations make no mention of UHF. This causes uncertainty about the status of UHF for official traceability purposes, particularly for animals moving between domestic and/or international jurisdictions.

60. Second, because LF-EID is the assumed default, adoption of UHF-EID implies duplication of costs for tags and reading equipment. For example, existing LF reading equipment would need to be supplemented by UHF reading equipment and cattle would need to bear both LF and UHF ear tags (either in separate ears or as dual-technology ear tags).

61. Acceptance by the ISO of UHF as a legitimate EID technology may help to gain wider institutional recognition. More fundamentally, a focus on the underlying motivation for current EID regulations rather than their specifics would also be helpful: ignoring the

[15] See https://www.aphis.usda.gov/traceability/downloads/uhf-interim-tag-data-standard.pdf

[16] LF-EID offers a precedent for this in that its ISO-encoding actually comes in two forms, HDX and FDX, which differ somewhat but are both automatically catered for by LF reading equipment.

potential of UHF risks lock-in, shackling the industry to an outdated technology, forgoing enhanced traceability and other potential benefits.[17]

62. Institutional acceptance may be helped by the fact that UHF-EID has no negative effects on either existing visual identification methods or LF-EID. This means that recipients of UHF-tagged cattle can still read the visual tag or any LF-EID tag present in the same way as for cattle without UHF-EID (and hence there is no practical reason for requiring tags to be removed from animals crossing borders).

63. Duplication of costs is a legitimate concern. However, assumptions that existing LF reading equipment for sheep can simply be also deployed for cattle are optimistic, particularly for fixed readers. For example, cattle are physically larger than sheep and hence readers will need to be configured differently – which essentially means having separate readers for sheep and cattle anyway.

64. Nonetheless, adoption of UHF-EID alongside LF-EID will inevitably impose additional costs. Of course, such duplication could be avoided if UHF-EID was adopted instead of rather than as well as LF-EID. ScotEID's view is that the worst outcome for the Scottish cattle industry would be prohibition of UHF-EID but mandatory imposition of LF-EID, incurring significant costs whilst forgoing more significant benefits.

Conclusions

65. Following a Scottish Industry request, UHF-EID for cattle has been trialled progressively in Scotland over the past decade. Testing under commercial conditions across farms, marts and abattoirs confirms that the technology is reliable and presents significant opportunities.

66. In particular, UHF offers several technical, safety and cost advantages over LF and has the potential for further development. UHF does, however, have some disadvantages in terms of having to overcome institutional caution and uncertainties.

67. Importantly, it has been demonstrated that UHF has no negative implications for users wishing to continue using visual IDs or LF-EIDs: their individual readability and contribution to traceability and management tasks is unaffected.

68. Table 1 below summarises the relative advantages and disadvantage of LF and UHF for EID.

[17] It is difficult to conceive of a parallel in other areas of agriculture where government would mandate the use of a 50-year old technology. An (imperfect) analogy would be obliging the use of candles for nighttime illumination rather than a modern LED flashlight with multiple brightness settings.

Table 1: Summary of relative advantages and disadvantages of LF and UHF for EID

Attribute	LF	UHF
Speed of reading	Slow, one at a time	Fast, multiples simultaneously
Max reading distance	Short, 12cm to 80cm	Long, several metres
Min reading distance	Touching	Touching
Health and safety	Poor – short reading range	Good – long reading range
Compatibility with pre-existing EID management systems	Low – collisions between multiple LF devices problematic (likely on dairy farms)	High – UHF does not interfere with LF devices nor other UHF devices
Compatibility with existing cattle numbering system	Low – regulatory obligation to follow ISO11784 means renumbering of cattle is required	Depends – high if USDA encoding standard adopted, low if ISO6881 adopted
Susceptibility to interference	High – adversely affected by nearby metal and electronic signals	Low – impairments can be avoided via reader configurations
Susceptibility to body blocking	Low – but only because short reading range already requires getting close to animals	Low – via longer reading range and antenna positioning
Scope for further innovation	None – mature technology restricted to niche applications	Lots – vibrant technology applied across economy
Costs	Relatively high, accounting for functionality	Lower, accounting for functionality
Suitability for management purposes	Medium – acceptable where immobilisation of animals occurs	High – with or without animal immobilisation, reader power can be varied
Suitability for traceability purposes	Low – slows speed of commerce at key points of supply-chain	High – works at speed of commerce across supply-chain
Institutional acceptance	High – default for official EID under EU regs	Low – yet to be widely recognised institutionally
Duplication of costs	Low – some scope for reusing sheep readers	High – but only if UHF is adopted alongside rather than instead of LF

Annex A: Specific aspects of UHF testing

Introduction

69. Given the issues with sheep EID implementation and ahead of the EU legislating for bovine EID, ScotEID has been researching the use of Ultra-High Frequency (UHF) Electronic Identification (EID) for cattle for over a decade. Initially, the focus was essentially experimental seeking to understand the technology under controlled workshop conditions. Gradually, the focus switched to exploring real-world applications of UHF-EID across the cattle supply-chain.

70. Today, UHF-EID is being actively trialled across 425 farms (see Table 2 for size and type distribution), 18 auction marts and 14 abattoirs in Scotland plus two port lairages. This equates to around 150,000 cattle currently bearing UHF-EID tags, with around 112,000 recorded tag reads at marts and abattoirs during 2022, with over a million reads throughout the course of the pilot overall.

Table 2: Size and Type distribution of participating pilot farms (count of farms)

	Number of cattle					
Type	1-19	20-49	50-99	100-199	200+	Total
Beef	48	69	97	80	33	327
Dairy	0	4	9	37	30	80
Finisher	1	1	0	1	15	18
Total	49	74	106	118	78	425

Beef = store producers and rearer-finishers predominantly reliant on own breeding herd
Dairy = farms with predominantly dairy rather than beef cows
Finishers = producers predominantly reliant on bought-in animals
Number of animals = breeding herd for beef and dairy farms, throughput for finishers

71. The gradual expansion of ScotEID UHF research to increasing numbers of supply-chain participants has allowed observation of interactions of the technology with different local conditions and business situations. For example, different farming systems, management procedures and environmental challenges.

72. This has allowed ScotEID, through learning-by-doing, to select, refine and configure UHF equipment to suit a variety of commercial circumstances. Demonstration of the reliability, convenience and management value of UHF-EID has led to increasing interest from industry on the ground, over and above the bovine EID stakeholder group.

73. Whereas livestock LF-EID has a relatively long history, UHF-EID does not. Hence, it was necessary to test UHF under real-world conditions to establish its suitability for bovine EID within Scotland. For example, to check tag suitability and the potential for interference from other electrical equipment and metalwork (e.g., gates and sheeting) or susceptibility to

wetness and blocking of signals by animals' bodies (e.g., of a calf-at-foot by its dam). No such problems have been encountered in practice.

74. Initial field-testing of UHF tags and reading equipment was relatively intensive and primarily conducted by ScotEID staff themselves. Over time, as the number of supply-chain participants has grown and confidence in the reliability of the technology has increased, testing became more routine with greater reliance on self-reporting by participants supplemented by visits from ScotEID staff.

Tag design and reliability

75. A decade ago, UHF ear tags were not widely available. However, ScotEID sourced tags already being trialled in New Zealand for testing. Pink was chosen as the colour for ear tags, to allow users to easily distinguish between EID and non-EID animals (see Annex E for some images).

76. Testing under controlled conditions by ScotEID and an external electronics laboratory confirmed that these tags could be read at a distance of several metres even with battery-powered handheld reading equipment and that anti-collision properties did indeed permit multiple tags to be read simultaneously. Moreover, no evidence of susceptibility to wetness or interference from electronic equipment or metalwork was apparent.

77. However, experience with sheep EID had shown that performance under real world conditions can differ markedly from performance under controlled conditions. Hence, several partner farms were recruited to test ear tags in cattle under a variety of management systems.

78. Again, prolonged observation under real-world conditions confirmed reading distances and speeds and the absence of any problems caused by interference from other electrical equipment or metalwork.

79. Tag durability and retention was generally comparable to similar non-EID tags. Specifically, retention rates for EID and non-EID tags are the same since EID tags and non-EID tags are essentially the same in terms of shape, size, and weight since the presence of a tiny microchip (plus antenna)[18] does not materially affect the external characteristics of an ear tag.

80. Experience with sheep EID had already indicated that retention of EID and non-EID tags is primarily driven by the external design of the tag, the quality of its manufacturing, the care used when inserting it into an animal's ear and the farm environment that it is exposed to.

81. For example, button tags are less susceptible to snagging than flag tags, cheaper plastics can degrade rapidly in the field, poorly inserted tags are prone to falling out, and snagging

[18] Confusingly, RFID terminology refers to a microchip and antenna (the latter required to actually send and receive signals) as a tag, whereas animal identification use this term to refer to the tag placed in an animal's ear.

hazards such as ryelock fencing can cause problems - but all apply equally to EID and non-EID tags alike.

82. EID tags do not just have to remain in an animal's ear, they also need to continue to function electronically. Reliability of the UHF ear tags from New Zealand was generally good. Indeed, some of the original tags are still present in breeding animals today and still functioning after a decade, indicating long durability.

83. However, over time, a few pilot farms started to report relatively high failure rates – the tags were still present, but not reading. This was restricted to only three farms, and the majority of farms reported no such problems.

84. Investigation revealed that only farms with vertical feed bars for administering feed to housed cattle were affected, and it was subsequently demonstrated that the movement of animals' heads through the feed bars was exposing the tags to repeated bending stress. This eventually led to internal breakage of the connection between the microchip and the antenna, leading to the tag no longer being able to be read electronically. Farms using horizontal feed bars were unaffected.

85. This problem had not previously been noted by the tag manufacturer nor by ScotEID laboratory testing and its discovery highlights the value of long-term field testing. ScotEID subsequently engaged with experts and tag manufacturers to address the problem, (for details see paragraph 89).

86. Unfortunately, the New Zealand supplier was bought-out by a larger, international company unwilling to further develop that particular ear tag. Moreover, the representative body for ear tag suppliers in the UK – ALIDMA (Approved Livestock Identification Manufacturers' Association) – indicated that it was unable to help ScotEID in sourcing UHF ear tags.

87. ScotEID subsequently reached-out to a number of alternative international suppliers outwith ALIDMA. These included companies already experienced in animal identification but also companies with knowledge of UHF applications other than animal identification.

88. These new relationships ultimately led to the development of a number of different UHF ear tags, now commercially available as approved official ear tags for traceability under PAS44. Co-design of these tags was an iterative process that considered different issues, including quality and thickness of the plastic, choice of microchip and antenna design, tuning of antenna to account for the effect of insertion into an ear (relative to a tag in freespace) and nature of the manufacturing process.

89. The specific (if rare) problem of internal breakage was addressed in two ways. First, an 'inductive coupling' design was used. This has no physical connection (only an inductive electrical one between two physically close but separate components) to break, and was an idea borrowed from the laundry sector where tags must withstand repeated mechanical washing and drying. Second, as an alternative, the physical connection was given additional protection using thicker materials. Both approaches have withstood long-term deployment on farms with vertical feed bars.

90. It is expected that more UHF ear tags will become commercially available over time, particularly now that ISO has signalled acceptance of UHF as an appropriate technology for animal identification. Indeed, some ALIDMA members are already stocking approved UHF tags co-developed by ScotEID.

Reading distance

91. Reading distance essentially depends upon radio frequency and the power of reading equipment, although the design and orientation of antennae also matters. Within legally permitted power ranges, LF tags are simply physically incapable of matching the reading distance of UHF tags. Indeed, this difference is acknowledged in the PAS44:2019 standard for UK cattle tags which states that the minimum acceptable read distance with a handheld reader is 12 cm for LF tags (also stated in EU 2021/520) but the equivalent for UHF is 100 cm, a difference with practical implications for convenience and safety.

92. Reading distances observed for UHF by participating supply-chain partners comfortably exceed the PAS44 threshold of 100 cm, stretching to several metres (see testimonials in Annex B). This confirms earlier workshop-based results which consistently showed reading distances of between 2 m and 7 m (see Annex C).

93. Some variation has been observed across different tag designs and readers. For example, button tags give shorter distances than flag tags, as would be expected given the smaller antenna size of a button tag. Equally, differences in antenna design and quality of plastic can lead to some minor variations in read distances. However, overall, the pattern of longer UHF reading distances compared to LF is clear. This avoids the need for close handling of animals required for reading LF or visual tags, offering advantages in terms of animal welfare plus human health and safety – points noted explicitly by pilot participants (see Annex B testimonials).

Reading of multiple animals/speed of reading

94. The short reading distance of LF tags means that animals essentially must be read by having readers physically close to their ear tags, which is typically achieved by momentarily immobilizing an individual animal in a crush. The longer reading distance of UHF tags avoids the need for immobilisation, offering faster read rates and improved health and safety benefits.

95. Moreover, UHF ‘anti-collision’ properties mean that multiple tags can be read simultaneously by the same reader, unlike LF tags which can only be read one-at-a-time. Again, this offers faster reading rates since cattle can be read as a group rather than individually, for example, in a pen or field, or moving on-and-off vehicles.

96. Workshop and in-situ testing demonstrates that the combination of longer reading distance and simultaneous reading of multiple tags offers considerable convenience relative to the use of LF. For example, not only can animals be read more quickly but also additional staff who would have been required to help immobilise individual animals are free to be spend time on other tasks (see Annex B testimonials, for farms and marts). This offers

opportunities to improve productivity and competitiveness, for example in terms of less time spent checking cattle passports and staff being freed-up from having to immobilise all animals.

Reliability of reading

97. 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 present but malfunctioning. Under controlled conditions, 100% read rates are easily achievable. However, read rates under commercial conditions are subject to more variable influences.

98. ScotEID observations and participants reporting identifies no instances of reading equipment not working and overall average reported read rates are over 99%. That is, 100% is commonplace but a few missed reads do occur. Where read rates fall below 100%, this is nearly always due to missing ear tags. However, as noted above, tag retention is a generic problem rather than an EID problem: EID and non-EID tags suffer similar rates of loss.[19]

Unintended reading of non-target animals

99. One concern raised about the long reading distance of UHF is that the wrong animal may be unintentionally read. For example, the next animal in line when cattle are being weighed individually on-farm or animals in neighbouring pens at an auction mart.

100. These are legitimate concerns. However, in practice they can be easily addressed. First, the power of UHF reading equipment can be adjusted downwards by users – it is merely a matter of turning a dial or pushing a slider on the reader's software App. This has the effect of reducing the read distance (see Annex C) and may be appropriate if animals need to be read individually. Ultimately, the read distance of a UHF tag can be shortened to that of an LF tag by this method (the reverse is not possible – LF reading distances cannot be increased to match UHF).

101. Secondly, the angle of reading can be set to wide or narrow, depending on how many animals need to be read together. Adjusting the directional focus of UHF reading equipment is more involved than changing the reading distance, but can be used if necessary, for example, with fixed readers in a mart to avoid reading animals in neighbouring pens.

102. Thirdly, if necessary, metalwork can be used to cover the area where animals are to be read. For example, chicken wire arches can be installed over a race. This has the effect of confining all RFID signals, making it impossible to read any tags out with the area. This approach has been highly effective for auction marts testing tags in the pilot. Moreover, the

[19] As an aside, whereas only one LF ear tag can be used per animal due to the lack of anti-collision properties, a n animal could be fitted with two UHF tags to maintain EID-readability in the event o flossing one tag.

use of chicken wire rather than solid metal sheeting allows light through to avoid spooking animals with shadowing and dark corners.

Wetness and body blocking

103. Non-immobilised animals can move their heads freely and/or move behind other animals, thereby potentially hampering the act of reading by obscuring line-of-sight reading. Controlled experiments did not reveal such 'body blocking' problems and nor have any been reported by pilot participants. Indeed, feedback highlights the convenience offered by UHF in terms of being able to rapidly read groups of animals, including dams with calf-at-foot (see Annex B testimonials).

104. This is partly a result of users operating reading equipment above animals rather than alongside them. For example, positioning antenna on an arch above a race or holding handheld readers above head height. It is also partly a result of UHF signals being reflected by surrounding metalwork. Consequently, body blocking has not been observed to be a problem.

105. Similarly, suggestions that UHF does not perform well under wet conditions have not been supported by experience. No farms, marts or abattoirs have reported problems due to the general dampness of their environments nor the specifics of animals and/or tags being wet or soiled with organic matter. This is consistent with workshop testing of simulated wet conditions which also failed to show any adverse effects on UHF performance, an important point given the weather conditions in Scotland.

Interference

106. Farms, marts, and abattoirs are hostile environments where other electrical equipment and metalwork might be expected to cause interference with RFID. Indeed, experience with sheep EID showed that LF was (despite manufacturers claims to the contrary) often susceptible to such interference.

107. By contrast, UHF has shown less susceptibility – provided that reading equipment is configured correctly, for example, grounded electrically, use of appropriate cabling and with antenna pointed appropriately. The wide availability of off-the-shelf UHF reading equipment and antennae allows flexibility in configuring set-ups to suit local circumstances. Choice of LF reading equipment and antennae is, by contrast, more limited.

108. Moreover, reflected signals from metalwork actually enhance overall read rates by avoiding complete reliance on line-of-sight reading. This is only possible because of the longer reading distance of UHF (LF does not benefit in the same way and indeed reflected signals cause problems for LF due to its lack of anti-collision properties).

Costs

109. Prices for LF and UHF tags are essentially identical, and more dependent on manufacturing and distribution costs plus supplier profit margins than on the cost of electronic components.

110. Prices for reading equipment are more variable (Table 3), with LF equipment generally being more expensive for any given level of functionality. As noted above, this largely reflects greater market competition for UHF which is deployed more widely across the economy rather than being largely restricted to animal identification (see Annex D for examples of UHF readers and antennae).

Table 3: Indicative unit costs

	LF	UHF
Tags	£2.20 to farmer	£2.20 to farmer
Handheld readers	£250-£750[20]	£250-£1500
Fixed readers	£1200-£1500	£250-£1250

NB. For any given price point, UHF readers offer greater functionality than LF readers.

111. Importantly, if multiple animals need to be read simultaneously, the installation costs for LF are greater relative to UHF. This is because whereas a single UHF reader can be deployed multiple LF readers need to be and then synchronised to get around the problem of lack of anti-collision properties. For example, four fixed LF readers might be needed instead of a single UHF reader, which means increased cost per installation.

[20] As noted previously, cheaper LF handheld readers are available but are intended for use with companion animals rather than agricultural livestock. For example, they need to be physically brushed against an animal's skin and are not designed to withstand hostile environments. As such they are not suitable for farm, mart or abattoir applications.

Annex B: Testimonials

The technical performance and cost advantages of UHF are clear. However, personal testimonials of participants in the pilot can offer additional insight into practical experiences of using UHF. Names of individual farmers have been redacted.

Some additional commentary can be viewed in video form at the following links:

https://www.dropbox.com/s/nytx4dm4kcil4cr/ScotEID%20for%20RHS_video%20only_v03.mov?dl=0

https://www.dropbox.com/s/f07m17840og4uut/ScotEID%20RHS%202022%20Loop%20Film.mp4?dl=0

Farm #1:

We have tagged around 700 animals with UHF tags this includes all our breeding stock on the first year of the pilot and all subsequent calves born since.

The UHF tags have become an essential part of our management system since we have started using them. One of the main features that make them so valuable to our system is the extra safety when working with cattle, the fact that we can read the cows/calves ear tag without physically entering the pen with a newly calved cow to read her tag if we cannot visually read it, which also allows for less handling and stress on the cows as before having the UHF tags if we could not read a tag due to hair in the ear covering it or dirt covering it we would have to pull the animal from there pen and put it up the race and into a cattle squeeze to allow us to safely clear the obstruction from the ear tag to read it which would put added stress on to the cow whereas now we can stand at a distance and use the chainway reader to get the number without the animal realizing we have done anything.

The second value they have added to our business is saving time on record keeping and allowing us to keep more accurate records and track cattle health and efficiencies easier.

We work with beef cattle and sell the calves store at a year old thus requiring us to wean calves in November and house and feed them until roughly the end of March. Using the UHF tags, the chainway reader and our Farm Matters software package one person can weigh all the store calves in roughly 90 min where it would take us rough 3 hours doing it manually.

This allows us to keep track of growth rates more regularly and that data can alert us to underlying health problems of calves which are not reaching target gains also allows us to track their feed intake against growth rates so as we can track that they are on the most efficient diets as possible which provides the best growth rates and least waste.

The UHF tags also reduce stress on the cattle when it comes to selling them as well, previous to using UHF tags we would have to run them all through the cattle squeeze individually and read their tags visually whereas now they can be kept in a group in a pen and be read in an instance before loading them and prevents any tags being misread visually.

I cannot stress to you enough how much these tags have improved the efficiency and accuracy of the records as they are all done at the time of administration now and not noted in a note book and then entered into the farm records at a later date which adds extra chance for errors by misreading notes of mistyping numbers in when sitting down to do it late at night after working with cattle all day.

I appreciate having had the chance to be in the pilot scheme to allow me to see the benefits of the UHF tags and we need to keep pushing to get these tags out onto all farms to allow everyone to see the advantages to using them.

Farm #2:

Covering 1800 acres, currently running 80 Angus x and blue grey cows, 3 bulls, just shy of 1000 ewes growing 80 to 100 acres of Malt barley.

I had been looking at adding electronic tags to the cows for a while and decided end of 2019 we'd aim to tag 2020 calves with them, just for weighing calves in order to get better at not keeping cows that's calves weren't performing.

In the process of looking for electronic I'd heard that UHF may be coming and was put in contact with David Kerr of ScotEID, I then decided to go down that route, being part of a pilot scheme, so from there I decided to tag the whole herd with them, which we did,

I've not looked back since then.

Read range is tremendous, having spoken to a few farmers using low frequency they are having to be quite close to the tag to read them, with the UHF there's no need to even go in with the cows, making things safer, especially with myself being a one-man band with the cow side of the farm.

Calving time I can tag a calf, read the tag, read the mothers tag and upload to the computer later on where I then register the birth through Farm matters software.

At last year's calf sale once we'd sorted the calves at the market I walked on the outside of the pen reading all the tags of each lot in seconds, with no need to get in amongst then, then uploaded to farm matters adding the sale details to each batch, simple and effective.

Tagging the herd with UHF has been a tremendous decision, making things more efficient with the management of the cows and more importantly making the management of them safer which is hugely important nowadays when more and more stockmen/women are working alone with the cattle I'd recommend them to anyone going forward.

Farm #3:

Report on practical use and experience of EID tag (UHF) in cattle.

Having now been using the above tags and readers etc for a period of time we would report that the system works very well.

We were part of the PAS44 trials for one of the button tags and at that point continued to tag all breeding cattle with eid tags. We will have used the tags in some 90 breeding cattle and 150 store cattle to be sold on.

The cattle we raise are native bred beef breeds and as such it is immensely critical that we have total control of performance and growth at all times. To this end we monitor weights of cattle regularly and chart daily gains. The use of the tag reader and linked weigh head has cut the time taken to carry out this task by at least 75%. Add to this the animal welfare and health and safety of the job it has become very streamlined indeed. With information easily available from the software on the weigh head we can react quicker to change feed ration balances as required thus getting greater conversion efficiency.

When sorting cattle in groups the system also lends itself easily to reading numbers, from a comfortable distance, thus making handling safer and more comfortable for people and cattle alike.

Overall, the EID tag and reader combination has indeed been of great benefit to the farm business. We have gained better efficiencies and increased ease of working.

We would anticipate if the scheme was fully rolled out to all marts and abattoirs that the efficiency of the system would increase a great deal indeed and errors would be far fewer.

Farm #4:

I run a herd of 40 suckler cows including a small herd of pedigree beef shorthorns. I also rear about 50 dairy cross bred calves and run a flock of 320 Lleyn ewes. The farm extends to about 300 acres and is run as a part time unit, alongside a full-time job as an agricultural consultant.

My EID journey started in 2010 when I first bought sheep, these were EID tagged with low frequency tags, for me the potential for using EID for management purposes in sheep was very limited and I only used it for compliance purposes. However, the potential of EID in cattle was clear to me. We regularly weigh cattle to monitor performance, this process would be massively more efficient if only cattle were EID tagged. For this reason, I jumped at the opportunity to be part of the ScotEID pilot for UHF EID. We received tags for all cattle on the farm, this along with a new EID reader which would connect by Bluetooth to our weigh head meant that we were up and running and the rest is history. We are now able to simply monitor live weigh gains, with no paper, on person can weigh all youngstock on the farm in less than an hour. If something is easy it gets done. We were part of the beef efficiency scheme but found the process of weighing to be a cumbersome chore, the task is now a pleasure and the only change in the system is a UHF chip in each tag and a basic reader. In short UHF EID has revolutionised our system and made us better farmers and we have only scratched the surface, the opportunities are endless.

Speaking to fellow farmers, there is huge confusion, uncertainty, and frustration about the future of EID in cattle. Farmers are keen to rise to the climate change challenge, EID and technology hold the key to herd efficiency. The sooner it is here, the sooner we can revolutionise our beef systems and ensure a bright future for our beef farmers and associated industries.

Farm #5:

We have been working with UHF ear tags for approximately three and a half years within our beef finishing system. We buy store and sell finished around 300 cattle each year and the opportunity to use the UHF ear tags has been great as it allows us to collect data easily and safely with an ear tag reader fitted to our handling system. Primarily the data we collect from our cattle is daily liveweight gains and this information is easily recorded and then downloaded to a spreadsheet for analysis, checking the cattle are performing how we expect. By working with technology in this way it also reduces stress on our cattle as data recording is instant and time spent handling cattle is minimal.

Farm #6:

Thought this interesting. We moved 35 cattle to a shed off the farm for wintering and when I went to register the move discovered that 1 of the tags had been read twice on the sheet of paper so only 34 of 35 numbers that we needed. This was done manually as the reader had a flat battery. We charged the battery and went down to the shed and the reader picked up all 35 numbers straight away. What was interesting was that 2 other numbers were written down incorrectly. In one case a 9 was written for an 8 and another a 6 for an 8. It just shows the value of the UHF WYSIWYG system, it is so easy to read batches or indeed cattle at a feed barrier, down the race or even in the field if you can get within reading distance. I can't understand why it has not moved forward when it makes the job of tag checking so safe and simple.

Farm #7:

I Started using UHF tags on the calves 3 years and after speaking to David Kerr at ScotEID, I got a loan of an EID reader to use in conjunction with the tags. I have found the reader very easy to use - it connects via Bluetooth to my weigh scales and phone, making it quick and easy to record data and monitor the performance of the calves. I've found it a great piece of equipment that will allow me to continue to improve efficiency within my beef herd.

Farm #8:

We have been using EID tags for nearly 10 years with the help of ScotEID.

In the summer of 2013 we started tagging purchased stots, quickly followed by our own calves. By late summer, after ironing out some initial problems, we had tagged our in-calf heifers and remaining fattening stots and heifers. Since this time all our fattening herd and own calves have been EID tagged which is about 550 every year.

While ScotEID initially provided a very good system for recording tag numbers and incorporating weights into a downloadable file, from the start it was obvious there was room for improvement, and they made numerous refinements to the software to get a system that really worked well for us and did all the tasks we needed easily.

The other issue that became obvious very quickly was that despite the immediate and obvious advantages of UHF tags, the tags themselves were not robust enough, both physically and from an electronic point of view. Trialling different tags quickly brought improvements and by 2015 we felt tags had improved to the point they were worth fitting to the rest of our 180 cows (our youngest cows having been tagged as heifers) Since this point all our stock have been tagged.

The benefits quickly became apparent every time we handled cattle – increased speed, accuracy, and ease, and effectively reducing the personnel needed by one. An increased level of data available immediately at weighing times enables better decision making, which directly improves financial returns. The longer term build-up of information on individual cows is frequently useful too. After handling it's very easy to transfer data to our PC where we can analyse it using excel or import it into our management software in a few simple steps, and all without the errors that characterise manual data entry. It made submitting data for the beef efficiency scheme quick, easy and error free.

To summarise the benefits is easy, everything is quicker, easier, and more accurate with EID tags. You can handle cattle in less time and with less people. Data transfer is improved, and errors are eliminated. There are no downsides except a tiny increase in cost which is inconsequential.

We would never want to go back to the old way and are excited to be moving forward to the future where all cattle are tagged which will reduce work further. I can only imagine how much this will benefit the wider industry, for example auction marts, who handle cattle with even more frequency.

Farm #9:

We farm 750 acres and have around 140 suckler cows. All followers are finished on the farm, and we buy in approximately 150 cattle to finish per year.

We have used UHF successfully over the last 3 years using almost 400 tags. The technology has made weighing cattle and monitoring individual weight gains much easier using our TRU-TEST weighing equipment. This ensures we keep within specification and enables system changes to be readily implemented and monitored.

The scanner is set-up in a fixed position, at the front of the crush, it does not need to be very close so does not impede work on the animal. The EID and weight are captured automatically. If animal has been weighed before, the weigh head automatically displays the average daily gain so performance can be seen instantly.

What was a cumbersome process is now effortless. In addition to data analysis, we also use the data gathered on the weigh head to produce a list of animals treated and this has significantly reduced time to create medicine records and eliminated paperwork.

Farm #10:

We have been using UHF tags in our cattle since 2012. We have 300+ cattle on farm at any time with UHF management tags in the beginning and now official tags. 140 cattle were read twice a day through our milking parlour. The technology was invaluable for identifying which cattle had entered the parlour. We then used the reads to update Calving and medicine records. With members of the team having dyslexia, accurate number recording was a struggle before the technology was used and quite often mistakes were made which proved to be costly on time and money.

We also use EID to record daily weight gains on our Bull beef enterprise. The speed and ease of recording this information makes the job safe and quick therefore reducing stress on the animals and staff. Which in turn allows for more occasions to weigh and judge the efficiency of the fattening animals. The accurate reads help to draw the passports easily before a batch is moved off the holding.

The UHF readers and tags work fantastically in a cattle float without the need to run cattle through a race just to read the ear tag. All the cattle in the float can be read from the rear door without entering the danger zone.

Without doubt using EID has improved health and safety and efficiencies on our farm which is always welcome with an ageing workforce and constant pressures from retailers to reduce the value of our product.

Farm #11:

Had tags in cows and calves for 2 years. He has 140 cows so total tags would be roughly 560.

One cow tag lost but replaced. Not a drastic amount but more than he would like.

He has a reader and likes what it does for accuracy. He'd like a weigh set up in the future to link to his reader to make it even better.

Farm #12:

Tags in cows and calves for 3 years. Total tags fitted to date is approximately 280.

Early tags were breaking but he has heifers he kept for breeding that have all still got their tags fitted two years ago.

He has a reader but would get more value from it if his farm software could link to the reads. Currently he reads a calf and only gets the number, he would like to see ref to its mother and sire, which could come from the software.

Farm #13:

I have been using the ultra-high frequency (UHF) tags for 4 years now. Previously we were using standard tags and have found that since using UHF tags, we have significantly reduced the time spent reading tag numbers and reduced the number of errors in reading tag numbers to zero. As tags can be scanned from 5 meters, it means more difficult livestock can have tag numbers read easily without having to put ourselves at risk.

Retention rate for tags is the same as, if not better than standard tags.

Our time management has been greatly increased with regards to weighing cattle due to the efficiency of the communication between the tags, reader, and cattle management software.

ANM Group Ltd, #14:

ANM Group Ltd have been working with Scot EID over the last couple of years trialling the introduction of digital electronic real time recording of cattle throughout the production and marketing chain.

This required the creation of a new unique cattle digital recording system and a cloud-based database capture system using Ultra High Frequency (UHF) data ear tags. A unique electronic identifier for each beast will provide the method of tracking and traceability throughout the animals' life. Potentially doing away with paper passports. They will instead be digital.

ANM were keen to be part of this trial to ensure that the software and hardware worked in the challenging market conditions.

We have now got the hardware working consistently in the market and achieving consistent reads of 100%. As we use the technology more, we as a market can see real value in this for us.

Our primary concern is always the safety of our employees who closely work the cattle some of which can be unpredictable. Using UHF to read tags electronically allows each animal to be read and the information displayed to the animal handler at a distance. Having better information earlier in our process means that our stock handlers have better information to draw stock. We want to make sure our staff are operating in a safe environment – also it may help attract younger workforce into livestock markets with digital technology and safer working environments.

It also allows each animal to be “read on and off” the market in real time and Scot EID notified. With readers at various points around the market we are more easily able to trace an animal when required.

It also means we don’t have to try and visually read tags that are dirty or a covered with hairy ears, removing the risk of tags being misread.

So why are ANM so heavily invested in this? SAOS of which Scot EID is part of and ANM's co-operative status meant it a good fit.

For us Sheep Tag readings are on average 95% accurate but 95% is not good enough for cattle. We wanted to ensure that the technology being proposed worked properly 100%. During 2021 over 350k cattle went through Scottish markets.

We also wanted to make sure that the hardware i.e., readers and antenna are robust enough and can work in a commercial market environment.

We want to make sure that our staff work in a safe environment and the technology offers opportunities to change practices that prevent our staff being in harm's way.

Scot EID have set up readers at most markets and abattoirs, however, I became involved 2 years ago to help them drive the project forward.

We can really see the day-to-day benefits of adopting this technology in terms of safety, accuracy, and efficiency. If we can make the process more efficient to handle cattle data, it allows opportunities for these savings to be passed onto our customers as a co-operative society or in these financially challenging times prevents additional costs to our customers. There will also be around £600k approx. savings when doing away with paper passports. Instead, all will be digital passports.

There has been significant investment from ANM in terms of my time working on this almost exclusively for 2 years. We have had significant support from ANM and attracted grant funding through Opportunity Northeast which has allowed us to purchase thousands of pink UHF tags to give away to our customers to trial on their cattle – so that they can be read coming through the market.

We believe in this technology and believe that this is the right way forward for us as an industry. It allows us to continue to implement improvements, efficiencies, and cost benefits.

Change is always difficult, but as change goes it is just a different type of tag from cattle that already have tags. But the benefits digitally with the additional information is huge. It is using technology that is widely used globally with similar applications.

Annex C: Illustrative reading distances

Table 4: Mean, minimum and maximum reading distances for different UHF tag designs.

Tag Design	Overall		
	Mean	Max	Min
A	3.8	5.3	2.7
B	3.9	5.0	2.4
C	4.7	5.5	3.9
D	4.7	5.4	3.5
E	5.4	6.7	3.6
F	4.5	5.8	3.6
G	5.5	7.4	3.7
H	5.3	6.6	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 at different orientations to tag.

Table 5: Effect of varying reader power on reading distances (m).

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.

Annex D: Example of off-the-shelf UHF equipment

Figure 1: Handheld UHF readers

Figure 2: Fixed UHF readers

Figure 3: UHF reader antennae

Annex E: Example cattle with UHF tags

Figure 4: Tags in a beef calf

Figure 5: Tags in a dairy calf

Glossary

ALIDMA: Approved Livestock Identification Manufacturers' Association. Umbrella body representing suppliers of ear tags (EID and non-EID) in the UK.

Anti-collision properties: The ability of multiple EID devices (e.g. ear tags) to be read simultaneously. LF-EID lack anti-collision properties, meaning that only one animal ear tag can be read at a time. If two or more LF-EID devices are present at the same time, reading becomes unreliable. UHF-EID devices possess anti-collision properties.

Cattle number: The unique lifetime identity issued to a registered bovine animal at its birth. The number currently comprises a country code (UK, now GB) followed by a 12-digit number with the first six digits being the herd mark of the farm where it was born and the last five being a serial number relating to its position within the sequence of all bovine births on that farm. The additional digit in the middle is a check-digit used for checking errors in the transcription of the full number.

CTS: Cattle Tracing System. The traceability database for cattle in Great Britain up until 2021, now restricted to England and Wales since ScotEID assumed full responsibility for cattle traceability in Scotland from October 2021. Replacement of CTS across Great Britain is a necessary precursor to the adoption of EID compliant with ISO encoding standards.

EID: Electronic Identification, the use of Radio Frequency Identification (RFID) for the identification of animals.

Ear tag: The required form of physical identification for UK cattle, with each animal bearing a tag in each ear. One tag must be of a flag design, the other may be either a flag or a button. All tags must bear the animal's unique lifetime identify printed externally. Tags may be EID (containing a transponder) or non-EID (not containing a transponder).

Encoding: The method by which information (e.g. an animal's number) is stored in binary form (zeroes and ones) on an EID device. Different methods are available – the use of Roman and Arabic numerals on a piece of paper offers an analogue analogy i.e. the same information can be represented in different ways but its correct interpretation requires an ability to recognise how it has been encoded.

FDX: Full Duplex, one of two versions of LF-EID.

HDX: Half Duplex, one of two versions of LF-EID.

ISO: The International Standards Organisation. ISO11784 is the standard for encoding animal identifiers using LF-EID. ISO6881 is the forthcoming standard for encoding animal identifiers using UHF-EID. Unfortunately, neither are compatible with the current system of cattle numbering used across the UK. By contrast, the USDA standard is compatible.

LF-EID: Low Frequency Electronic Identification, the use of Radio Frequency Identification (RFID) operating in the frequency range of 120 – 150 KHz for animal identification. LF comes in two flavours, FDX and HDX. LF-EID is the default form of animal identification, with its

origins in EID for companion animals (e.g. cats, dogs). LF-EID is a mature technology over 50 years old with limited current applications beyond animal identification.

PAS44: A Publicly Available Standard published by the British Standards Institute (BSI) relating to the physical and electronic properties of ear tags to be used for official EID in the UK. The most recent version (2019) includes specifications for both LF and UHF ear tags.

Read range (or distance): The distance over which an EID device can be read. UHF-EID typically offers read ranges of several metres whilst LF-EID offers 12c, to 80cm.

Read rate: The proportion of EID devices read when presented for reading. LF-EID with sheep achieves c.95% in Scotland. Bovine EID needs to achieve much closer to 100%

Reader: Equipment for reading information encoded onto an RFID transponder. Readers may be handheld or fixed.

Retention rate: The proportion of ear tags retained by animals over a given period, typically a year.

RFID: Radio Frequency Identification. A form of wireless communication utilising electromagnetic fields (radio waves) to automatically identify and track objects. An RFID system consists of a tiny radio transponder, a radio receiver and transmitter. When triggered by an electromagnetic interrogation pulse from a nearby reader device, the tag transmits digital data back to the reader.

Speed of commerce: The speed at which animals currently move through parts of the supply-chain. Embarking/disembarking from vehicles and moving through auction marts typically involve faster speeds, which are challenging for LF-EID.

Transponder: A microchip and antenna, used for RFID. For EID, transponders are most commonly embedded in ear tags but can also be in removable collars, internal boluses and injectable phials.

UHF-EID: Ultra High Frequency Electronic Identification, the use of Radio Frequency Identification (RFID) operating in the frequency range of 860 to 960 MHz for animal identification. UHF-EID is emerging as new form of EID for animal identification. UHF applications are commonplace in other sectors of the economy, such as logistics, retailing and transport.

USDA: The United States Department of Agriculture. In 2016, the USDA issued an encoding standard for animal identification using UHF-EID. The USDA standard is compatible with the current system of UK cattle numbering.

WYSIWYG: What-You-See-Is-What-You-Get, visual equivalence between how an encoded animal identify is displayed by reading equipment and how it is physically printed on the ear tag and passport. A requirement under EU regs but also the preference of industry stakeholders.