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A.M. Bryant

B.B. Barnhardt

M.P. Epp

S.J. Glaenzer

See next page for additional authors

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Abstract

This study was conducted to evaluate the performance of ISO 11785 radio frequency identification (RFID) cattle ear tags and readers under ideal laboratory conditions. Tag and reader manufacturer identities are masked to prevent unintentional conclusions being drawn about any particular tag or reader at this stage of the U.S. National Animal Identification System (US-NAIS) proposed plan. Eight commercially available tag designs were evaluated, and included the half-duplex and full-duplex air interface technologies. Performance parameters of interest for tags were tensile strength, tampering evidence characteristics, as well as the average reading range. Three fixed-antenna stationary readers were used to determine the variability between reading ranges of each reader. Tensile strength parameters differed among tag designs. Only one tag design did not display tamper-evident characteristics. Average reading ranges differed among all eight tag designs, and there were significant differences in performance ranges among the three readers. Performance variation in tags and readers exists due to differences in material makeup (die and copper) and design characteristics. The results of this study support the need for minimum performance standards for ISO 11785 RFID technology as it applies to the US-NAIS.

Keywords

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Authors

A.M. Bryant, B.B. Barnhardt, M.P. Epp, S.J. Glaenzer, and Dale A. Blasi

VARIATION IN PERFORMANCE OF ELECTRONIC CATTLE EAR TAGS AND READERS

A. M. Bryant, D. A. Blasi, B. B. Barnhardt, M. P. Epp, and S. J. Glaenzer

Summary

This study was conducted to evaluate the performance of ISO 11785 radio frequency identification (RFID) cattle ear tags and readers under ideal laboratory conditions. Tag and reader manufacturer identities are masked to prevent unintentional conclusions being drawn about any particular tag or reader at this stage of the U.S. National Animal Identification System (US-NAIS) proposed plan. Eight commercially available tag designs were evaluated, and included the half-duplex and full-duplex air interface technologies. Performance parameters of interest for tags were tensile strength, tampering evidence characteristics, as well as the average reading range. Three fixed-antenna stationary readers were used to determine the variability between reading ranges of each reader. Tensile strength parameters differed among tag designs. Only one tag design did not display tamper-evident characteristics. Average reading ranges differed among all eight tag designs, and there were significant differences in performance ranges among the three readers. Performance variation in tags and readers exists due to differences in material makeup (die and copper) and design characteristics. The results of this study support the need for minimum performance standards for ISO 11785 RFID technology as it applies to the US-NAIS.

Introduction

The ability to individually identify beef cattle from farm of origin to harvest for health traceback purposes is the fundamental objective of the US-NAIS. The goal of the US NAIS is to have an identification health program in place that can trace any animal within 48 hours to its farm of origin and to identify all other animals that came in contact with the diseased animal. There currently are many programs that have their own procedures for identifying animals for one purpose or another, but there is not one nationally recognized program or technology that has the capability to accurately and efficiently identify all species of livestock in commerce, either individually or by group, from birth to harvest. The use of RFID is one of the automatic information and data-capture technologies being considered for use within the US-NAIS. The objective of our study was to determine if there were differences in performance characteristics among commercially available low-frequency RFID cattle-ear-tag designs and fixed-antenna stationary readers tested under an electromagnetically controlled laboratory environment where performance conditions were ideal.

Experimental Procedures

Tags and Readers. This study focused on eight commercially available low-frequency (134.2 KHz) cattle ear tags (n = 390; 40, 50, or 60 tags for each brand) that were purchased from various suppliers, and included both half-duplex and full-duplex technologies defined by ISO Standard 11785. The half-duplex designs were Tags B and E, and the full-duplex designs were Tags A, C, D, F, G, and H. Three fixed-antenna stationary readers were used to evaluate the average reading range of the tags; they included Reader X, with a 24×16×1 inch panel antenna; Reader Y, with a 23×18×1 inch panel antenna; and Reader Z, with a 31.5×24×1 inch panel antenna.

Tensile Strength and Tampering Evidence. Twenty tags of each design (n = 160) were randomly selected to measure the tensile strength. Each tag was loaded into its designated tag applicator and the male 'pin' section and female 'receiving' section of the tag were locked together. Each locked tag was loaded into a custom attachment designed for use with the Instron Universal Testing Machine and was forcefully pulled apart. The measurements gathered by this test were peak height (inches), peak force (pounds of force), and peak energy (feet × pounds). Peak height referred to the greatest distance that a tag stretched before it tore apart or unlocked. Peak force was defined as the pounds of force reached in tearing apart or unlocking the tag. Peak energy was the amount of measurable energy required to tear a tag apart or unlock it. The ability of the tags to display evidence of tampering was evaluated. In the NAIS guidelines, tags can only be used one time; removal of the tag should prevent the tag from being used again, and must leave physical evidence that the tag had been tampered with.

Baseline Average Reading Range. The KSU Animal Identification Knowledge Laboratory presently does not have an anechoic chamber (a chamber that removes all radio frequency interferences); therefore, the laboratory was evaluated by the KSU Electronic Design Laboratory to measure any environmental interference at 134.2 ± 25 KHz that could interfere with the evaluation of reading ranges of low-frequency tags. Measurements taken with a spectrum analyzer (Hewlett Packard 4396B) revealed no measurable noises within the frequencies of interest.

A tag trolley (Figure 1) was designed and built to measure the average reading range. The baseline average reading range was the distance that a tag was from the antenna of the reader when it was successfully interrogated.

The center of the low-frequency ear tag in the cradle approached the center of the antenna at a rate of about 6 inches/second at an orientation parallel to the antenna. (i.e., the face of the tag approached the face of the antenna when being tested). An electric motor attached to one pulley was activated by the evaluator via a rheostat control, which moved the cradle and tag toward the antenna. The motor was switched off when the reader indicated a successful interrogation by an audible beeper, immediately stopping the cradle and tag, and the distance between the tag and the antenna was determined with a measuring tape that stretched on the floor from the reader's antenna to the beginning position of the cradle and tag. When each tag was interrogated, the 15-digit electronic identification number, as defined in ISO 11784, was automatically recorded into a spreadsheet. The sample of tags (n = 390) was measured in triplicate for each reader (1,170 data points per reader; 3,510 total).

Results and Discussion

Tensile Strength and Tampering Evidence. Table 1 contains the results from the tensile strength tests. There were significant differences ($P<0.05$) for all three variables (peak height, peak force, and peak energy) among all tags. Tags G and C had the largest measurements for each variable because these two tags were made from a strong, flexible plastic and had a sturdy locking mechanism that enabled the tag to stretch a longer distance and required greater force and energy to break the tag apart. Tag F had the smallest measurements for each of the three variables of interest because this tag design had a weaker plastic and a weaker locking mechanism that required less energy to unlock the tag. The tensile-strength performances differed in this study due to the differences in materials and design characteristics of the ear tags.

Table 1. Average tensile strength of low-frequency cattle ear tags

	Tensile Strength Variables			
Tag Design	Peak Height[1], inches	Peak Force[2], pounds of force	Peak Energy[2], feet × pounds	Tamper Evident[3]
A	1.88	69.5	7604	Yes
B	2.15	74.6	9459	Yes
C	2.04	97.3	11676	Yes
D	1.94	61.0	7244	Yes
E	1.77	62.9	6840	Yes
F	1.19	44.8	3446	No
G	2.24	99.7	13633	Yes
H	2.00	75.1	8768	Yes

[1]The distance a locked tag stretched before it broke apart or was unlocked.
[2]The measured pounds of force and energy required to break apart or unlock a locked tag.
[3]If the tag physically broke when it was pulled apart, then it revealed evidence of tampering. It did not reveal tamper evidence if it simply unlocked.

There were no tamper-evident characteristics for Tag F; when Tag F was pulled apart using the Instron Universal testing machine, the tag simply unlocked and could be locked back together, revealing no evidence that it had been tampered with. All other tags were designed with a locking system that did not allow the tags to be reused. When these tags broke apart, the tip of the 'male' pin section of the tag broke off inside the 'female' section of the tag, blocking the tag from being relocked with another pin. The only way to remove the pin tip would be to cut away the front of the female section, thereby revealing evidence of tampering.

Baseline Average Reading Ranges. There were significant differences for reading ranges among tags, as well as among readers (Table 2). The average reading range for each low-frequency tag design was significantly different for each reader. This outcome may be linked to the fact that the manufacturers of Reader X and Y each manufacture two tag designs that we tested, and their readers may have been tuned to optimally read their tags. The manufacturer of Reader Z does not manufacture any commercially available low-frequency cattle ear tags; therefore, this reader may be tuned for optimal reading of as many tag designs as possible.

For Reader X, the greatest average reading range was for Tag B, followed closely by Tags A, C, and G (Table 2). The average reading ranges for Tags D and E were similar, with intermediate reading ranges. All other tag combinations were significantly different (Table 2 and Figure 2).

Table 2. Average reading ranges for eight low-frequency cattle ear tag designs

	Average Reading Ranges[1], inches		
Tag Design	Reader X	Reader Y	Reader Z
A	26.5	16.3	22.6
B	31.6	14.6	29.7
C	26.4	16.8	37.5
D	24.2	14.0	34.3
E	24.7	10.1	20.5
F	20.5	12.4	28.6
G	26.6	17.2	37.7
H	19.4	11.4	26.6

[1]The distance a radio frequency tag was from the antenna of a reader when it was first successfully interrogated.

For Reader Y, the average reading ranges were greatest for Tags A, G, and C, and were intermediate for Tags B and D (Table 2 and Figure 2).

Tags C and G had the greatest average reading ranges when Reader Z was used (Table 2). All other tags had average reading ranges that were significantly different (Figure 2).

In conclusion, variation in performance of tags and readers exists due to differences in materials and design characteristics. Minimum performance standards should be established for current radio-frequency technology designated for livestock identification. Appropriate regulatory authorities should address the issue of technology performance in any further development of a National Animal Identification Program.

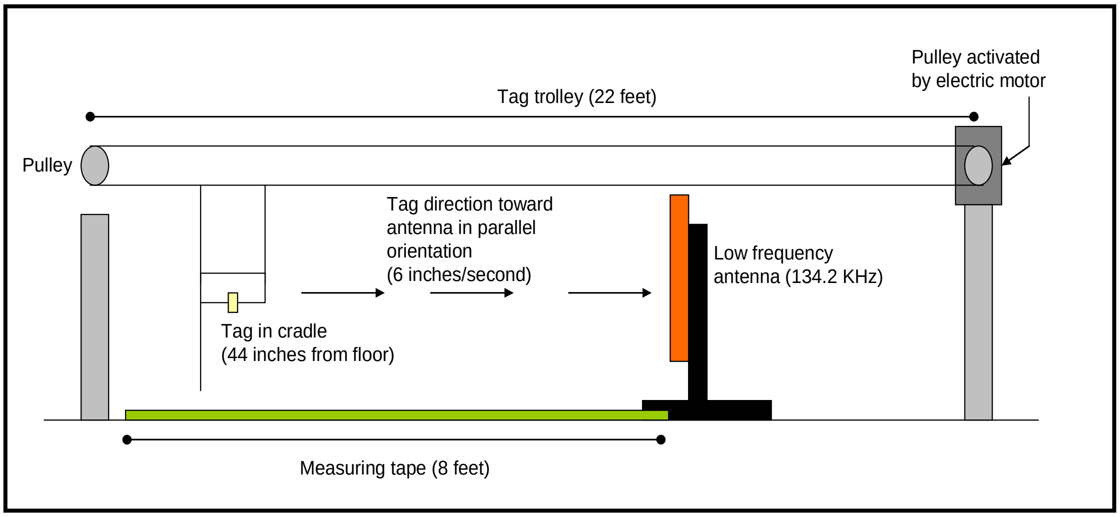

Figure 1. Tag trolley design used to measure reading ranges of low-frequency cattle ear tags.

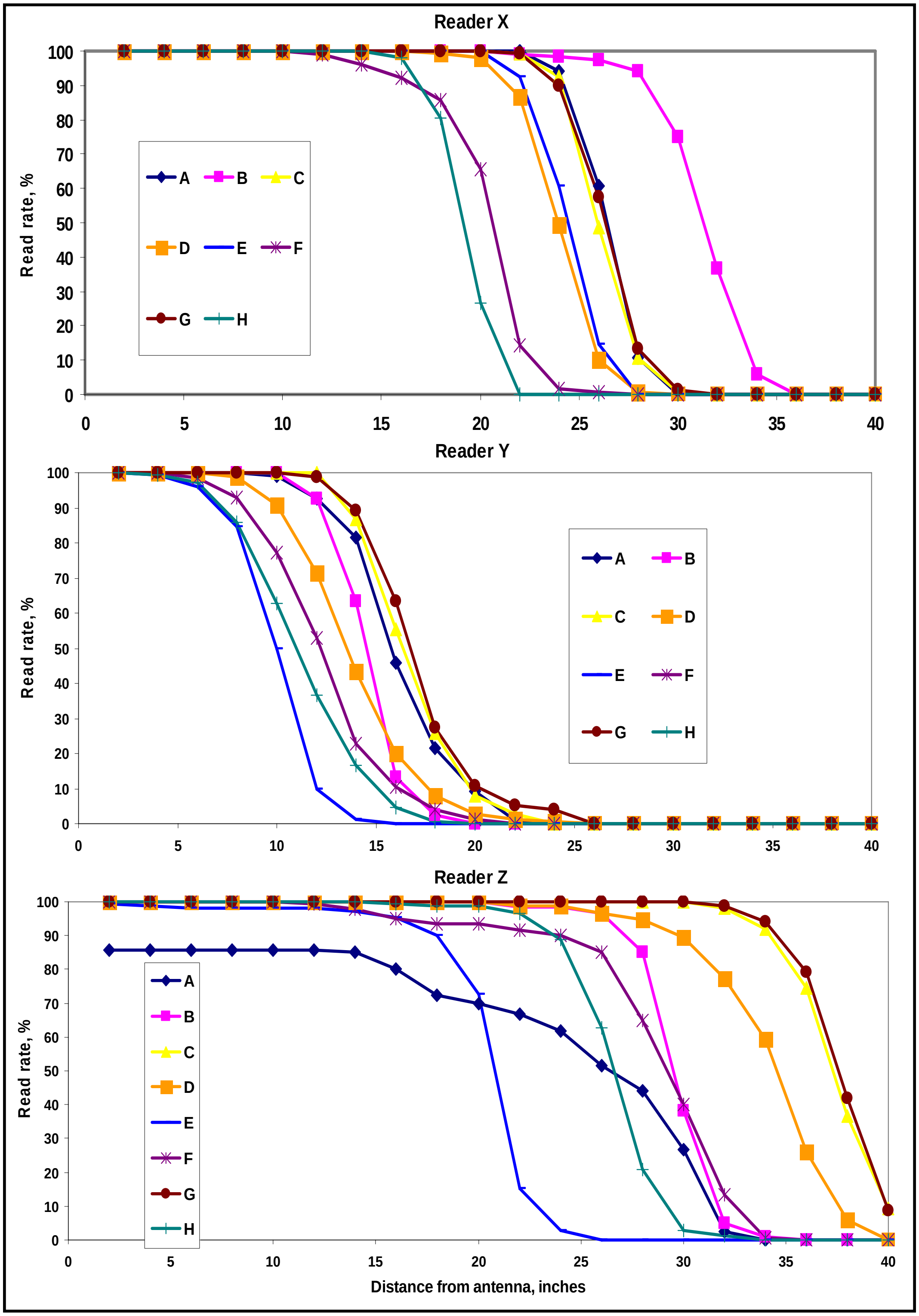

Figure 2. Reading rate versus distance from antenna for eight low-frequency cattle ear tags interrogated with three readers.