Computers and Electronics in Agriculture 114 (2015) 261–268

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Quantifying detection performance of a passive low-frequency RFID system in an environmental preference chamber for laying hens

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ARTICLE INFO

Article history:
Received 6 February 2014
Received in revised form 12 March 2015
Accepted 15 March 2015
Available online 14 May 2015

Keywords:
Behavior
Poultry
Choice test
Radio frequency identification
Tracking
Validation

ABSTRACT

Radio Frequency Identification (RFID) systems are widely used in production livestock systems for identification, traceability assurance, and animal registration. An RFID system was implemented and evaluated for use in a four-compartment, two-tier, environmental preference chamber (EPC) to detect hens transiting between compartments. Eight RFID antennae were located near the passages between compartments and each hen wore an RFID tag on one of its legs. The RFID system's performance was assessed by determining detection ranges in a controlled test and by comparing the number of entries into and duration in each compartment as detected by the RFID system to manual assessment of recorded video. The RFID system detection range was revealed to cover a radius of approximately 29 cm from the antenna, excluding a portion of the compartment furthest from the antenna. During a choice-test study, successful detection rates based on duration of stay in compartments were 91.0 ± 2.6% (mean ± SD) for trials with groups of birds, and 85.8 ± 8.0% for trials with individual birds. Based on number of entries into compartments, successful detection rates were 62.6 ± 11.2% for trials with groups of four birds, and 51.3 ± 18.4% for trials with individual birds. Sources of entry misdetection included: (i) RFID tag being out of the detection range during sampling; (ii) conflicts caused by multiple RFID tags within the same detection zone; and (iii) visits of duration less than the RFID antenna scan interval. The delay between hen entry and RFID system detection averaged 42.3 ± 35.7 s and 6.4 ± 5.2 s in trials with individuals and with groups, respectively. Detection times were within the antenna scanning interval of 15 s (a hen entered a compartment and was immediately detected by the next antenna scan) in 60.3% of the events with individuals and 98.1% of the events with groups. Despite the difference between detected and actual entries ($P = 0.008$ [groups]; $P = 0.05$ [individuals]), no significant differences were found between total duration of compartment occupancy over a 24 h test period or average compartment visit duration, as calculated from RFID data and video observations. The RFID system was suitable for characterizing the amount of time birds spent in each EPC compartment, but not reliable for determining number of entries into a compartment.

1. Introduction

Radio frequency identification (RFID) technology in animal tracking has been utilized around the world (Voulodimos et al., 2010). With the increasing need for quality control and animal management, the demand for animal identification and traceability has increased. According to Eigenberg et al. (2005), system integrators such as Grow-Safe (www.growsafe.com), Insectec (www.insectec.com), and others have designed RFID systems for the production market. RFID technology could also be useful to track animal behavior in smaller studies with custom animal housing and specific data collection requirements, as there are limited options for monitoring movements and locations of small animals such as poultry.

RFID technology has been used in precision livestock farming and in supply chain management to: identify, trace, and register agricultural animals (Giametta et al., 2011; Geng et al., 2009; Zhao et al., 2009; Chansud et al., 2008; Tragas and Manolakos, 2010; Caja et al., 1999). RFID systems are comprised of a transceiver with a decoder to interpret data, scanning antennae, and transponders (RFID tags) previously programmed with unique identification information. RFID tags can be active or passive. Active tags have their own power source so their detection range

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http://dx.doi.org/10.1016/j.compag.2015.03.008
0168-1699/

can be amplified, although they have a limited life span. Passive tags are energized by the antenna, therefore have a virtually unlimited life span, but a more limited detection range. In the case of passive tags, upon being energized the tag sends its unique identity to the reader. Tags are worn by the animal being monitored, and may be located externally on the animal (such as an ear tag or leg band), implanted into tissues, or ingested.

RFID technology has been used for animal behavior and welfare research, to monitor and to obtain feedback on animal location and resource utilization. For instance, RFID tracking systems have been proven effective for monitoring animal feeding and/or drinking behavior (Fuller, 2006; Brown-Brandl and Eigenberg, 2011; Tu et al., 2011) and environmental preferences (Pereira and Nääs, 2005). Small temperature sensors with RFID capabilities have also been evaluated for measuring animal core temperature when injected intramuscularly in horses (Marsh, 2008; Marsh et al., 2008). Properly designed systems can generate accurate response measurements, for example, Brown-Brandl and Eigenberg (2011) reported a success rate of 98.3% when validating a specialized RFID system against independent video monitoring equipment in a cattle feeding system, and 98.7% in a swine feeding system.

Choice-tests used in animal behavior and welfare research may benefit from the use of RFID-based tracking methods. In such choice-tests, the animals are presented with several variants of a resource or different types of resources or situations between which they must choose. The choices made must be registered to determine animal preference, which necessitates identifying each animal, its location (choice made) and duration at that particular location; RFID-based tracking methods may offer a solution for gathering this sort of information. Animals subjected to choice-tests may be studied individually or in groups. When a single antenna communicates with a group of tagged animals, detection conflict or collision between tags will occur without anti-collision capability (Rohatgi, 2005). Low-frequency tags typically used in the animal industry do not normally have anti-collision technology, which creates a potential challenge to implementing this technology for monitoring small animals in a choice test. The objective of this study was to evaluate the performance of a low-frequency RFID system applied within a four-compartment environmental preference chamber for poultry. The following tasks were identified:

- Range mapping, which consisted of moving an RFID sensor through a mapping grid near the RFID antenna as the RFID system scanned the antennas.
- Hen navigation tracking, which consisted of collecting RFID readings of a hen navigating the EPC for six hours and comparing the RFID readings to video to identify potential RFID misdetections and their causes.
- Choice-test study positioning data validation, which consisted of collecting recorded RFID data and videos from a choice-test study with groups of birds as well as individuals, and comparing the detected events.

2. Materials and methods

2.1. Environmental preference chamber

An environmental preference chamber (EPC) comprised of four stainless steel compartments (1.2 m × 1.2 m × 1.2 m occupancy space, with conical subfloor and attic space) was located at the Environmental Research Laboratory of the University of Illinois at Urbana-Champaign, USA. Further details on the design, development, and operation of the EPC are provided by Sales (2012) and Sales et al. (2013).

All cages in each of the four EPC compartments were constructed of wire mesh on all sides with a plastic mesh floor. Compartments were interconnected by passageways, which allowed birds being tested to walk from a cage in one compartment to a cage in either of the adjacent ones. Cages in upper and lower levels of the compartments were not connected. An antenna was located within each cage in a corner between the two openings that gave access to the passageways (Fig. 1), and a video camera (CAM-5D-24DN-VP, Aventura Technologies, Inc., Hauppauge, NY) was mounted from each cage's ceiling above the bird area. The antenna placement within the test bird area was determined based on (a) its proximity to both passageway openings, where higher activity was expected, and (b) the placement with best in-cage sensor detection in preliminary testing.

Each compartment contained a top and bottom cage, for a total of eight areas to be monitored and eight RFID antennas within the chamber, two in each compartment. Within each cage, when testing individual birds, the test bird was restricted to the cage area nearest the antenna, while companion birds occupied the remainder of the cage but were not allowed to move among cages. When testing groups, the entire group of four birds had access to the entire cage and were free to move among cages on a single level. Hens could not move to a different level within the chamber. For the analysis presented in this paper, level within a compartment will not be distinguished and only detection of movement between compartments will be discussed.

2.2. Radio frequency identification system

An animal identification system based on RFID technology (RFID-AIS) was added to the EPC to electronically determine where each individual bird was located on a continuous basis. The RFID-AIS hardware and software used in this study was designed and developed at the USDA Roman L. Hruska Meat Animal Research Center (USMARC), Clay Center, NE (Brown-Brandl and Eigenberg, 2011) for feeding behavior studies with cattle and pigs, and modified to accommodate application to the EPC. The RFID-AIS was originally developed to record time spent eating in a group-penned environment using industry standard feeders/bunks, to be capable of operation in harsh environments, and to be constructed at a relatively low cost. The system was comprised of:

(1) a commercial RFID reader (Series 2000 High Performance Remote Antenna-Reader Frequency Module [RA-FM][RI-RFM-008B-00], Texas Instruments, Inc., Dallas, TX), with a control module (Series 2000 Control Module [RI-CTL-MB2A-02], Texas Instruments, Inc., Dallas, TX) connected to a host computer via serial communication;
(2) eight antennae designed and tuned based on design criteria (Texas Instrument, 2000). These antennas were designed and built for the feeder system and were selected for this study owing to the fact that they were readily available;
(3) a multiplexer (MPX), designed and built by engineers at USMARC, comprising eight relays;
(4) a TFX-11 microcontroller to sequence readings of all antennas with a single reader in the system;
(5) RFID tags (32 mm glass transponders [RI-TRP-WR2B-30], Texas Instruments, Inc., Dallas, TX);
(6) operational software: in-house developed using HT Basic® (HT Basic for Windows, Version 8.3. TransEra Corp., 375 East 800 South, Orem, UT 84097) that controlled timing and data collection.

The operational software used by the system was designed as two separate components. The first component was designed to run on the host computer and was responsible for timing, data