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Range measurements of a High Frequency Radio Frequency Identification (HF RFID) system for registering feeding patterns of growing–finishing pigs

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ABSTRACT

Monitoring the feeding pattern of a pig enables early detection of diseases and other problems. To monitor the individual feeding pattern of group-housed pigs, it has been suggested to equip the pigs with High Frequency Radio Frequency Identification (HF RFID) tags and the feeding trough with an antenna. The detection range of the HF RFID system is crucial to guarantee that all feeding pigs are detected without detecting the pigs located further from the feeder. The current study examines the factors that influence whether an antenna attached to a round feeding trough (such as those used in group housing of growing–finishing pigs) detects stationary HF RFID tags placed in various orientations and distances from the antenna. Four experiments were performed using a custom-built test set-up that allowed determining the RFID registrations for 70 tag positions, at seven distances from the antenna and for seven orientations of the tags in relation to the antenna. In the first experiment there was determined that which tag side is closest to the antenna had very little influence on the range of registration. The results of the second experiment revealed that all eight HF RFID antennas in the pig house performed similarly, with symmetry observed in their range of registration. In the third experiment the range of the HF RFID system was measured while accounting for tag, tag position and tag orientation, whilst the last experiment was designed to test the effect of interference between tags. Reproducibility between (the order of) the tags and the average agreement between five repetitions of all tests was very high. In total, the sensitivity was 51.0%, with a standard deviation of 43.1 percentage point (pp). The specificity was 87.1% with a standard deviation of 19.4 pp. It was concluded that the performance of the HF RFID system in terms of sensitivity and specificity of the range depends greatly on the height and orientation of the tags. This causes irregular gaps to appear between subsequent RFID registrations of a feeding pig. To improve the performance of the system in practice, it is suggested to adjust the height of the antenna to better match the size of the pigs and to develop algorithms and criteria to merge raw RFID registrations into relevant feeding variables for individual pigs.

1. Introduction

With increasing herd sizes in livestock farming and a decreasing labour time available per animal, adequate individual monitoring of animals becomes difficult. Therefore, automated monitoring of farm animals can be helpful and, in addition, might avoid economic losses (Frost et al., 1997; Pluym et al., 2013). Automatic control of the pigs' environment is already common practice, but behavioural measurements with the potential to improve production efficiency are still lacking (Wathes et al., 2008; Maertens et al., 2011). Problems with health, welfare and productivity in growing–finishing pigs are thought to be associated with alterations in feeding behaviour, possibly in an early stage of problem-development. Automatic registration of pigs' feeding patterns may therefore

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provide added value for farmers as well as researchers (Hart, 1988; Weary et al., 2009).

To measure the feeding pattern of an individual pig, the feeding pig must be both detected and identified while feeding. Video tracking or automated image analysis makes it possible to detect feeding pigs, but identification is very difficult (Lind et al., 2005; Ahrendt et al., 2011). Radio Frequency Identification (RFID), which includes a number of different techniques for wireless transfer of data between a data-carrying device (transponder or tag) and a reader by means of (electro)magnetic fields (Finkenzeller, 2010), can detect and identify an individual animal using one sensor (Artmann, 1999; Eradus and Jansen, 1999; Ruiz-Garcia and Lunadei, 2011). The use of RFID for animals is widespread and is typically limited to passive Low Frequency (LF) systems with an operating frequency of 134.2 kHz (ISO 11784 & 11785) (Artmann, 1999; Finkenzeller, 2010).

Computerised feeding stations using LF RFID have been used to measure pigs' feeding patterns in research since the early 1990s. For growing–finishing pigs electronic feed stations have been developed and used to log time and duration per feeding visit as well as the feed intake of the individual pig (Hyun et al., 1997; Bruininx et al., 2001a, 2001b; Hyun and Ellis, 2002). Electronic sow feeders have been used in research (Cornou et al., 2008) as well as in practice (pig farmers with group housing of gestating sows) (Tuyttens et al., 2011). However, these feeders only allow access to one pig at a time and mostly only one feeder is available per group. In most commercial growing–finishing pig houses multiple feeders with multiple feeding places are used.

Efforts have been made to integrate RFID systems into the commonly-used, commercially available feeders for group-housed pigs. Brown-Brandl and Eigenberg (2011) and Brown-Brandl et al. (2013) have achieved good results with LF RFID antennas in rectangular-shaped feeders. LF RFID currently does not provide the possibility to read multiple tags at the same time. For this reason, one LF antenna had to be installed per feeding place. RFID systems operating at higher frequencies exist. These systems allow multiple tags in the range to be read simultaneously, by integrating anti-collision algorithms. This makes it possible to use only one antenna per feeder with multiple feeding places, leading to a system which is more cost-effective and practical. Reiners et al. (2009) and Hessel and Van den Weghe (2011) have demonstrated the potential of a High Frequency (HF) RFID system with an operating frequency of 13.56 MHz for identifying piglets feeding at a round trough.

When designing a HF RFID system to detect feeding pigs in a commercial pig house, the range of registration is crucial. The pigs grow quickly (which changes the height of the tag), the pens are crowded, and the pigs jostle each other around the feeder as they compete for food. To detect only the feeding pigs, the HF RFID system's range should provide good coverage of the area above the feeding trough but should not detect tags outside of that area. The range of a HF RFID system depends on numerous factors: the operating frequency, the type of tags used, the type of reader used, the size of tags and antenna, environmental influences, etc. (Finkenzeller, 2010; D'hoe et al., 2011). The theoretical range of an RFID system as measured by the manufacturer (often in optimal circumstances) can differ substantially from the achieved range in a real-life situation (Ciudad et al., 2010). Extensive range measurements *in situ* could provide valuable information on where and when feeding pigs will be registered by the HF RFID system, and whether this range is sufficiently accurate to discriminate feeding pigs from pigs moving close to the trough but who are not feeding. Well-designed experiments can also provide insight into which factors influence the range of the HF RFID antenna. Although the presented HF RFID system and other RFID systems used to measure animal feeding behaviour were validated online (using feeding animals) (DeVries et al., 2003; Brown-Brandl and Eigenberg, 2011; Maselyne et al., 2014), we could not find any well-designed experiments to measure the range of an RFID system in practice and to determine the factors that influence that range. These measurements could provide more insight into the functioning and limitations of RFID systems however.

To investigate the factors influencing the detection range of a HF RFID system for the monitoring of pig feeding patterns, we have performed various range tests. The objectives of the study were (1) to determine the effect of antenna, antenna quadrant, tag side (up or down), tag, tag position and tag orientation on the RFID registrations, and (2) to calculate sensitivity, specificity, reproducibility and repeatability for the range of the HF RFID system in this application.

2. Materials and methods

2.1. Materials

2.1.1. Pig house and HF RFID system

The tests were performed in a pig house at the experimental farm of the Institute for Agricultural and Fisheries Research (ILVO, Melle, Belgium). The pig house was divided in four pens with eight feeders in total (Swing MIDI, Big Dutchman Pig Equipment GmbH, Vechta, Germany) (feeder positioning illustrated in Fig. 1). The feeders had a round metal trough with a diameter of 450 mm and an edge with height of 110 mm from the ground. To register transponders near the feeder, a round High Frequency (HF) RFID antenna (custom-made by DTE Automation GmbH, Enger, Germany) was attached to the feeders above the trough (Fig. 2a). The diameter of the antenna was 390 mm, the internal diameter of the plastic housing was 350 mm, and the external diameter was 430 mm. The underside of each antenna was 50 cm from the ground. The antennas were tuned on-site to achieve the correct resonance frequency of 13.56 MHz. This is necessary to adjust the system to any fixed environmental influences on the resonance frequency (for example metal or electromagnetic fields in the environment). A tuning board (i.e. a connector between antenna loop and data cable used to tune the antenna to the correct resonance frequency before installation) can be seen on one side of the antennas (Fig. 2a). This was named the 'tuning side' of the antenna, in contrast to the here-after called 'other side' of the antenna. Also, a 'left side' and a 'right side' were assigned. Conventions for these

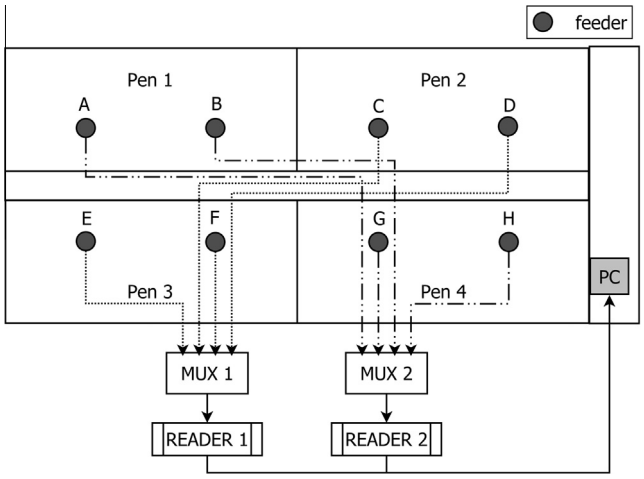

Fig. 1. Floor plan of the pig house indicating the position of the feeders in the pens and the connections of the RFID antennas to the two multiplexers (MUX 1 and MUX 2) and the readers (READER 1 and READER 2). Both readers are connected to a PC in the control room next to the pig house.