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Methodology of a dynamic test bench to test ultra-high-frequency transponder ear tags in motion

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A B S T R A C T

The electronic identification of sheep and goats has been obligatory in the European Union since 2010 by means of low-frequency radio-frequency identification systems. The identification of pigs and cattle is currently based on a visual ear tag, but electronic animal identification is gaining in importance. The European Union already offers the additional use of electronic identification systems for cattle in their council regulation. Besides the low-frequency radio-frequency identification, an ultra-high-frequency ear tag is a possibility for electronic animal identification. The benefits of the latter frequency band are the high range, the possibility of quasi-simultaneous reading and a high data transmission rate. First systematic laboratory tests were carried out before testing the ear tags in practice. Therefore, a dynamic test bench was built. The aim of the experiments presented in this study was to compare different ear tags under standardised conditions and select the most suitable for practical use. The influence of different parameters was tested and a standard test procedure to evaluate the quality of the transponder ear tag was developed.

The experiments showed that neither the transponder holder material (polyvinyl chloride vs. extruded polystyrene) nor the reader settings examined (triggered read vs. presence sensing) had a significant influence on the average of readings of the different transponder types. The parameter 'number of rounds' (10 vs. 15 vs. 20) did not show a significant effect either. However, significant differences between speed (1.5 m s^{-1}, 3.0 m s^{-1}), transponder orientation and the fourteen transponder types were found. The two most suitable transponder ear tags for cattle and pigs have been determined by comparison.

1. Introduction

Electronic animal identification in livestock farming has gained in importance over the last few years. The identification of individual animals using radio waves is one possibility of electronic animal identification and is known as radio-frequency identification (RFID). This technology provides great benefits not only regarding process control on farms, animal or disease monitoring, prevention of fraud, and registration of movements, but also for other administrative purposes (Artmann, 1999; Doluschitz et al., 2006; Geers, 1994). The RFID technology will be explained more precisely in the following.

1.1. RFID technology

RFID is regarded nowadays as a key technology which covers a wide spectrum of applications (Klindtworth, 2007). The technology behind this system is based on the communication between a transponder (attached to the animal) and a reader (mobile or static) via radio waves. Both transponder and reader contain an antenna for transmission and reception, and a chip for processing the radio signals. The communication between both units occurs remotely with coded radio waves, which are decoded by the respective electronic circuit (Finkenzeller, 2012; Kern, 2006). Distinctions are made between active RFID transponders, which generate their power from an integrated battery, and passive RFID transponders, with no battery. The passive transponders receive their power from the signal transmitted by the reader antenna (Jansen and Eradus, 1999; Zhu et al., 2012). Passive systems are predominantly in use in animal production. Three frequency bands are mainly usable in animal identification: low-frequency

Abbreviations: ARR, average of readings per round; ERP, effective radiated power; PS, presence sensing; PVC, polyvinyl chloride; TR, triggered read; XPS, extruded polystyrene.

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(120–135 kHz), high-frequency (13.56 MHz) and ultra-high-frequency (868 MHz, 915 MHz) (Kern, 2006).

1.2. Low-, high- and ultra-high-frequency RFID in animal husbandry

The electronic identification of sheep and goats has been obligatory in the European Union for all such animals born after 31/12/2009 (EC, 2004). The identification of pigs and cattle is currently based on a visual ear tag, but replacement of the latter with an electronic ear tag is already permitted for cattle (EC, 2000). Currently, systems working with low-frequency (LF) are state-of-the-art in animal husbandry (Fröhlich et al., 2007). The structure of the animal number and the functional principle are controlled by the ISO standards 11784 and 11785 (ISO 11785, 2008; ISO 11784, 2010). The combination of the country code (ISO 3166, 2013) and the national animal number ensures a unique number for an individual animal (Schwalm et al., 2009). Besides the unique number, which is obligatory for the legal regulations, free memory on the ear tag can be used for further management applications, such as the recording of animal characteristics (sex, size, weight) or medical treatments.

The farmer has many possibilities to attach the transponder to the animal. Starting with a rather expensive collar, a transponder integrated into a bolus or an encapsulation for implantation, and ending up with a transponder attached to an ear tag. There are many different agricultural applications on the market using LF systems. Low-frequency is mainly used in extensive husbandry conditions with sheep and goats to improve the traceability of individual animals and to reduce the risk of spreading diseases (Ribó et al., 2001). Low-frequency is very useful in sow keeping and dairy farms when combined with automatic feeding stations. An individual feeding schedule for each animal and stage can be implemented and food intake can be measured (Blair et al., 1994; Chapinal et al., 2008). This technique is offered by many companies for barn equipment. Junge et al. (2012) showed that the registration of drinking events and the calculation of a minimal walking distance for each sow is also feasible with LF technology (Junge et al., 2013). Using this information, as well as a preparation of the data by software, the health status of each individual animal could be monitored. The biggest benefit of this technology is the low susceptibility against shadowing by metal or liquids. Problems arise when reading many animals at the same time and over a greater distance (Caja et al., 2005; Thurner and Wendl, 2007), whereby some LF transponders with an anti-collision algorithm have already been tested by Burose et al. (2010). Even if the so-called anti-collision systems, where quasi-simultaneous reading of different transponders is possible, can be used with basically all RFID systems, the reading rate will be reduced (Burose et al., 2010).

Another possibility for animal identification are high-frequency (HF) systems. The HF systems offer a higher data transfer rate than LF systems (Chawla and Ha, 2007). Thus, the identification of moving transponders is feasible even when using anti-collision algorithms. The HF systems are mainly used in access control systems, smart cards and different logistic areas (Thurner and Wendl, 2007). Fröhlich et al. (2007) think that the commitment of HF transponders in animal identification would have its benefits in the industry-wide movement of goods from the point of animal production right through to transportation and slaughter. Hessel et al. (2008) used a self-made circular HF antenna on top of two different feeding troughs to read ear tags in piglets. The reading rate of both feeding troughs was around 97%. The high activity of the piglets, the water content of their bodies, the material of the feeding station and the orientation of the transponder to the antenna of the reader are seen as reasons for missed reading events (Hessel et al., 2008; Reiners et al., 2009). Further experiments with a round feeder were performed by Maselyne et al. (2014). Eight antennas connected to a single reader using a multiplexer were installed above the troughs of the feeders. The RFID system was validated by video observation of 20 focal pigs (two HF ear tags each). Therefore, several time window sizes were tested and examined. A sensitivity of 88.58% and a specificity of 98.34% were achieved (Maselyne et al., 2014).

A third possibility of electronic animal identification are ultra-high-frequency (UHF) systems. The UHF systems are increasingly used in other industries, such as the pharmaceutical and retail industries (Desmons, 2006; Impinj, 2006; Umstatter et al., 2012), as well as for the identification of goods containing liquids or metal (Catarinucci et al., 2013). The clear benefits of this frequency band are the high range, the possibility of quasi-simultaneous reading (anti-collision system) and a high data transmission rate (Baadsgaard, 2012; Clasen, 2007; Finkenzeller, 2012; Umstatter et al., 2012). Such systems were considered as unsuitable for animal identification because of the high absorption potential of water in the UHF band; however, over time, there have been further developments in terms of performance and robustness (Catarinucci et al., 2012; Finkenzeller, 2012; Stekeler et al., 2011). There have only been a few projects testing UHF for animal identification in pigs, sheep, cattle and deer (Baadsgaard, 2012; Cooke et al., 2010; Hartley, 2013; Hogewerf et al., 2013; Swedberg, 2012; Taylor, 2013). In these projects, the UHF transponder was tagged to the animal in the form of a rigid or flexible ear tag. The material of the item to which the tag was attached or embedded, the size and stability, the orientation of the tag to the reader, and the environment in which the system operated were named as reasons for performance degradation and reliability problems (Baadsgaard, 2012; Chawla and Ha, 2007).

1.3. Test benches for RFID transponders

Test benches are well-suited to test transponders under controllable and comparable conditions. Burose et al. (2010), for instance, built a test bench to analyse LF transponders with an ISO standard and with an anti-collision algorithm. This test bench consisted of a plastic slide which was drawn by a wire rope hoist on two wooden tracks. Using this test bench, the following parameters could be varied: the distance to the ground, the velocity, the number of transponders and the orientation of the transponder to the reader (Burose et al., 2010). Barge et al. (2013) also used a test bench to move LF transponders (HDX, FDX) through a reader field under standardised conditions. This test bench consisted of a wooden trolley pulled by a rubber belt and driven by an electric motor, simulating a group of animals passing a reader gate. Different combinations of transponders and velocity could be varied (Barge et al., 2013). Thurner and Wendl (2007) designed a test bench for testing HF transponders and readers. In this case, up to four parallel running V-belts clamped to two bicycle rims and powered by an electric motor carried the transponders through the reading field. Six holders carrying up to five transponders each were attached to one V-belt. The height of the reader, orientation of the transponder, velocity and direction could be varied on this test bench (Fröhlich et al., 2007; Thurner and Wendl, 2007). Wehking et al. (2007) built a test bench to test UHF transponders for application in logistics. Their test bench consisted of a nine-metre haulage road with a conveyor speed of 0.5 ms^{-1}. Loading units up to a weight of 300 kg could be examined. There were two UHF antennae centred on top of both sides of the conveyor. Additionally, one LF antenna was centred on each long side of the conveyor. On this test bench, mainly the transponder orientations (two- and three-dimensional) and the content of small load carriers could be varied. Ten thousand cycles were performed for each test series (Wehking et al., 2007). McCarthy et al. (2009) developed a test