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Comparison of different ultra-high-frequency transponder ear tags for simultaneous detection of cattle and pigs

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Electronic animal identification is an important technology in modern animal husbandry providing great benefits. Low-frequency applications are state-of-the-art within the radio frequency identification of animals. Quasi-simultaneous detection of several animals and reading of the transponders over longer distances is impossible with low-frequency systems. Ultra-high-frequency (UHF) applications are suitable for this purpose. However, UHF systems have disadvantages through their susceptibility to metallic surfaces and liquids. Thus, the reflection and absorption of electromagnetic radiation in the animals' environment is often problematic. Consequently, an adjustment of the transponder ear tags regarding mechanical stability and functionality close to water (ear tissue) is necessary. In this project, targeted adjustments and a further development of UHF transponder ear tags concerning the resonance frequency were made. Three trials with cattle and two trials with pigs were performed in this study. Cattle were driven through a reader gate for ten rounds and six different types of transponder ear tags designed in-house were tested. The influence of the environment (indoor vs. outdoor), reader orientation at the gate (sideways vs. above) and output power of the readers (1.0 vs. 0.5 W) were tested in two experiments. The average number of readings per round and the reading rates of the transponder ear tag types were taken as target variables. In the trials with pigs, three transponder ear tag types were compared. The animals were driven through the gate for five rounds per repetition, but neither the reader output power nor the reader orientation were varied. The pig experiments were performed indoors.

The results of the cattle experiments showed that the average number of readings per round and the reading rates were significantly higher indoors compared to outdoors. The reader output power of 1.0 W achieved significantly better results compared to 0.5 W. The same applied to the reader orientation 'above' compared to 'sideways'. It could also be shown that an improvement of the transponder and, thus, an adjustment to the animal's ear could be achieved during transponder ear tag type development. A maximum reading rate of 100% was reached with the cattle transponder types finally developed (B3-4, B4-4 and B5).

In addition, an average reading rate of 100% was achieved for one pig transponder ear tag type (C2). However, these experiments have to be treated with caution due to a very low sample size.

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1. Introduction

Electronic animal identification is an important technology in modern animal husbandry. It can provide great benefits regarding process control on farms, animal or disease monitoring, animal and meat traceability, and improvement in the entire farm management (Artmann, 1999; Babot et al., 2013; Geers, 1994).

Radio waves are one option for individual electronic animal identification (radio frequency identification, RFID). In addition to the standard low-frequency band (LF, 120–135 kHz) used, high-frequency (HF, 13.56 MHz) and ultra-high-frequency (UHF, 868 MHz, 915 MHz) bands have become more popular and have been tested increasingly in research (Hessel and Van den Weghe, 2013; Hogewerf et al., 2013; Maselyne et al., 2014; Reiners et al., 2009; Stekeler et al., 2011a; Umstatter et al., 2014). Low-frequency RFID systems cannot identify several animals simultaneously and a separation of the animals is unavoidable (Barge et al., 2013; Ribó et al., 2001; Stekeler et al., 2011b). Even when an anti-collision technique is used, the reading rates are not sufficient (Burose, 2010). Additionally, LF and HF systems have a reading range of 1.0 respectively 1.5 m, which requires a small distance between reader and animal (Bauer et al., 2011; Caja et al., 2005; Thurner and Wendl, 2007). However, UHF-RFID benefits from a greater

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read range, the possibility of quasi-simultaneous reading by using anti-collision systems and a higher data transfer rate (Chawla and Ha, 2007). Ultra-high-frequency systems achieve a read range above 3.0 m with passive transponders (Baadsgaard, 2012; Clasen, 2007; Finkenzeller, 2012; Ruiz-Garcia and Lunadei, 2011; Umstatter et al., 2012). This results in a good suitability of UHF systems for animal husbandry by allowing simultaneous detection of larger groups of animal and the possible greater distance between reader and animal. Ultra-high-frequency systems should also be in a position to assume the application areas of LF and HF systems with shorter read ranges by reducing the reader output power. Ultra-high-frequency systems were previously considered as unsuitable for animal identification because of the high absorption potential of water in the UHF band, however, there have been further developments in terms of performance and robustness over time which partly bypass this problem (Adrion et al., 2015; Catarinucci et al., 2012; Finkenzeller, 2012; Stekeler et al., 2011b).

The farmer generally has many choices where to attach a transponder on an animal for on-farm identification. Passive systems are predominantly used in animal husbandry because of size and costs. Due to the light weight of the transponders, they are compatible with all mounting options. A collar is often used with dairy cattle. However, the collar is not a realistic option for pigs and fattening cattle, mainly because of the high costs and the risk of ingrowth with quickly growing animals. The use here of either an encapsulation for implantation or a transponder attached to an ear tag is more reasonable (Caja et al., 2005).

Encapsulation for implantation would not be the method of choice because of the potential high water absorption in the UHF band and the issue of fast removal from the carcass at the slaughter line (Merks and Lambooij, 1990). Using this operating frequency, an electronic ear tag seems to be the best choice for pig and cattle identification.

The legal foundation for pig and cattle identification in the European Union 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). Combining the official identification via an ear tag permitted already with the on-farm identification seems to be an obvious development.

1.1. Simultaneous individual animal identification with UHF-RFID

There have only been a few projects testing UHF ear tags for animal identification directly on the animals in practice. Cooke et al. (2010) used a UHF ear tag in their experiments for the simultaneous registration of deer, sheep and cattle on different farms. In the deer experiments, they achieved a reading rate between 75% and 100% with a gangway width of just above 2.0 m, depending on the reader position. The reading rate of the sheep experiments was between 94% and 100%, depending on the reader type, reader position and race width. They only obtained a reading rate of 72% in their cattle experiments at a race width of 2.6 m. However, an adjustment of the test conditions could not be performed here (Cooke et al., 2010). Further experiments with sheep were performed within a project called Rosei. Here, the authors achieved reading rates of 100% with a UHF transponder ear tag and two antennas in a metal race. They completed 2800 individual passes without a failure (European Commission, 2015). Stekeler et al. (2011b) attached a rigid UHF transponder to a pig ear tag and drove fattening pigs through a gate with two readers. They achieved a reading rate between 71.2% and 77.5%, while comparing different reader positions at a race width of 1.1 m. A UHF ear tag was developed for use in pigs in a project called “PigTracker”. A reading rate of $>95\%$ with a reading distance of 2.0 m was achieved in driving experiments with piglets (Baadsgaard, 2012; Swedberg, 2012). Hogewerf et al. (2013) carried out driving experiments with a button-type ear tag and five groups of pigs (10 or 11 pigs in each group) with a reader supplying four antennas. In a first trial in a 2.0 m broad hallway, they achieved a reading rate of 89.6% without a further adjustment of the experimental design. In conclusion, to the best of the authors' knowledge, the UHF technology has not been tested very often and a reading rate of 100% has seldom been reached.

1.2. Ear tag technology

There can be a general differentiation between rigid and flexible ear tags. The rigid ear tags are mostly button ear tags, and the transponder is inlaid into a round solid plastic ear tag. The surface available for the transponder antenna is very limited and the variability of the antenna structure of the transponder is restricted. Flexible ear tags, on the other hand, have a larger flat part where the transponder can be integrated. In general, the transponder has to be grouted into the ear tag to retain the size and not increase its weight. A professional grouting is very important to protect the transponder and to ensure durability.

The impedance of the transponder's antenna is changed depending on the material of the ear tag and its permittivity. This results in a shift of the transponder's resonance frequency. A reduction of the resonance frequency occurs usually (Rao et al., 2005). Consequently, the transponder must be adjusted to its surroundings (ear tag). The detuning of a transponder through the variation of its antenna length, label and antenna material, size and form are possibilities for a targeted adjustment and its successful use in animal husbandry (Adrion et al., 2015; Catarinucci et al., 2012; Lorenzo et al., 2011; Nikitin and Rao, 2006).

A few companies, for example, “definitive! business applications e.K., Münster, Germany”, “MS Schippers GmbH, Kerken, Germany” and “Simplum GmbH, Berlin, Germany”, currently sell rigid UHF ear tags for animals. Flexible UHF ear tags are also sold; “HANA micron Inc, Asan-si Chungnam, South Korea” can be mentioned here as an example.

1.3. Objectives

This study is part of a research project which is concerned with the development and testing of flexible UHF in-house developed ear tags for animal identification developed in-house. An optimal resonance frequency adjustment of the different transponder types developed to an animal's ear is the main aim. First systematic laboratory tests were carried out before testing the UHF ear tags in practice (Adrion et al., 2014, 2015; Hammer et al., 2013, 2014, 2015). According to the test bench results, different UHF ear tag types emerged as suitable for use in animal husbandry during the progress of the project.

Subsequently the test of these transponder ear tag types under practical conditions served the aim to identify the most suitable and durable one for simultaneous detection of cattle and pigs. Therefore, six different transponder ear tag types for cattle and three types for pigs were tested in driving experiments. The influence of the environment (indoors vs. outdoors), the reader orientation (sideways vs. above) and the reader output power (0.5 vs. 1.0 W) was also tested in the cattle experiments.

2. Materials and methods

2.1. Animals, UHF transponder ear tag types and UHF readers

All the experiments were conducted at the Agricultural Sciences Experimental Station of the University of Hohenheim. Unfortunately, it was not possible to test all transponder ear tag types

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