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Technical note: A novel approach to the detection of estrus in dairy cows using ultra-wideband technology

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ABSTRACT

Detection of estrus is a key determinant of profitability of dairy herds, but estrus is increasingly difficult to observe in the modern dairy cow with shorter duration and less-intense estrus. Concurrent with the unfavorable correlation between milk yield and fertility, estrus-detection rates have declined to less than 50%. We tested ultra-wideband (UWB) radio technology (Thales Research & Technology Ltd., Reading, UK) for proof of concept that estrus could be detected in dairy cows (two 1-wk-long trials; n = 16 cows, 8 in each test). The 3-dimensional positions of 12 cows with synchronized estrous cycles and 4 pregnant control cows were monitored continuously using UWB mobile units operating within a network of 8 base units for a period of 7 d. In the study, 10 cows exhibited estrus as confirmed by visual observation, activity monitoring, and milk progesterone concentrations. Automated software was developed for analysis of UWB data to detect cows in estrus and report the onset of estrus in real time. The UWB technology accurately detected 9 out of 10 cows in estrus. In addition, UWB technology accurately confirmed all 6 cows not in estrus. In conclusion, UWB technology can accurately detect estrus and hence we have demonstrated proof of concept for a novel technology that has significant potential to improve estrus-detection rates.
Key words: estrus, estrus detection, ultra-wideband technology, dairy cow

Technical Note

Poor estrus detection is a major contributor to reduced fertility in dairy cows. Traditionally, estrus detection was performed by visual observation for signs of mounting behavior, which is accurate, but larger herd sizes and less labor per cow reduce opportunities for visual observation, and detection is often below 50% (Van Eerdenburg et al., 2002; Roelofs et al., 2006). Automated technologies have been developed to obviate the need for visual observation. Pedometers and accelerometers are used to monitor increases in physical activity at estrus, with detection rates often 80 to 90% (Firk et al., 2002), some even achieving 100% (At-Taras and Spahr, 2001). However, the error rate is variable and reported to range between 17 and 55% (Firk et al., 2002). Mounting behavior can be monitored automatically by detection devices such as HeatWatch (CowChips LLC, Manalapan, NJ), which uses digital radio transmitters incorporating a pressure switch that are glued onto the tailhead and have a reported accuracy of 87.5% (Rorie et al., 2002). The most definitive indicator of estrus is a cow standing to be mounted. We hypothesized that this indicator might be detected by measuring the relative position of cows in 3 dimensions with advanced techniques, such as real-time ubiquitous positioning.

Ubiquitous positioning focuses on integrating global navigation satellite systems, including the global positioning system, which are capable of 3-dimensional positioning with other location technologies. The accuracy of these positioning systems ranges from a few millimeters to tens of meters, depending on the techniques and algorithms used, but they have poor accuracy and reliability indoors or in obstructed environments (Meng et al., 2007). Ultra-wideband (**UWB**) radio technology developed by Thales Research & Technology Ltd. (Reading, UK), however, has proven accurate in harsh environments such as those subject to high multipath error and many obstructions (Ingram, 2006; Harmer et al., 2008) and can achieve positioning with centimeter accuracy in the horizontal and less than 30 cm in the vertical dimension (Ingram, 2006), which is the most difficult plane in which to achieve high accuracy. Therefore, UWB technology has potential for monitoring cows mounting and standing to be mounted using the specific interactions that occur at estrus and moni-

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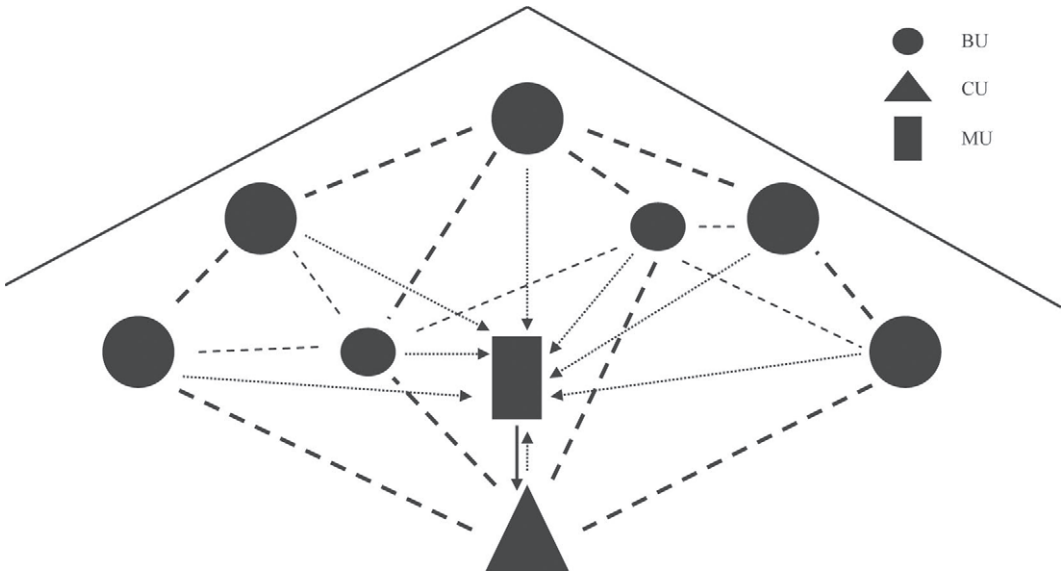

Figure 1. The 8 base units (BU) form a reference network between themselves (dashed line) in absolute positions that are known by the control unit (CU; also part of the BU network), connected to a computer. Each mobile unit (MU) within the BU network monitors broadcasts of BU positions (dotted arrows) and calculates its own position, which it reports to the CU (solid arrow), where position is stored in the computer.

toring changes in height. The objective of the current study was to investigate proof of concept that UWB technology could be used for accurate estrus detection.

Animal work was conducted under the authority of the UK Animal (Scientific Procedures) Act 1986, and approved by the University of Nottingham animal ethics committee. Animals used were 16 Holstein-Friesian dairy cows at Nottingham University Dairy Centre (Sutton Bonington, UK; average annual milk yield: 11,500 L/cow). Cows were housed in a freestall barn with 4 pens of approximately 40 cows. Cows were milked in automatic milking stations (Lely Astronaut A3; Lely UK Ltd., St. Neots, UK) between 2 and 5 times per day. All cows were fed the same silage-based diet, with concentrates fed at milking.

A reference network was established consisting of 8 base units (**BU**) in fixed locations (Figure 1). The BU network was set up with optimal geometry to cover the 2 pens used in this study and to provide accurate positioning for roaming mobile units (**MU**) attached to cows. Each BU broadcast its absolute position to all other units. This allowed each MU to calculate its own 3-dimensional position, which was transmitted back to a control unit (Figure 1) where data were stored. The MU were set to sample at a rate of 2 Hz. Each cow was equipped with 1 MU mounted in a backpack (Cassidy Covers Ltd., Dublin, Ireland) and connected to a battery pack (12 V 22 Amp h Tracer Lithium-Polymer Power Pack; Deben Group Industries Ltd., Suffolk, UK). Batteries were changed once per 24 h in the evening so as to minimize interference with the cows' normal behavior. Cows were trained with backpacks and equipment before each trial. All cows displayed normal feeding, lying, and ruminating behavior, and mounting behavior was not inhibited.

The behavior of 8 cows was recorded in each of two 1-wk-long trials, recording position by UWB 24 h per day for 7 d. In each trial, estrus of 6 cows (at least 40 DIM) was synchronized with controlled internal drug release (**CIDR**) devices (1.38 g of progesterone; InterAg, Hamilton, New Zealand), inserted into the vagina on d 0. Six days after CIDR insertion, 2.0 mL of Estrumate (cloprostenol sodium; synthetic analog of $PGF_{2\alpha}$) was injected intramuscularly, and on d 7, CIDR devices were removed.

At d 6, UWB recording commenced and continued until the morning of d 13. During this period, cows came into estrus and were visually observed for estrous behavior from d 7. Observations for signs of estrus were made for periods of 10 min at hourly intervals initially. More-frequent observations were made as cows began to show increased interest in herd mates, eventually resulting in continuous observation to record mounting and standing to be mounted. Four hours after the last episode of standing, estrus was deemed over.

Throughout the trial period from d 0 to 17 (5 d after UWB recording), 20-mL milk samples were collected via a Lely Shuttle Milk Sampler (Lely UK Ltd.) for progesterone analysis. Milk progesterone concentration was determined with a Ridgeway ELISA kit (Ridgeway Science Ltd., Gloucestershire, UK) following the manufacturer's protocol. Milk progesterone concentrations of