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AUTOMATED MONITORING OF VARIATIONS OF DRYING CONDITIONS IN A SEED DRYING FACILITY

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ABSTRACT The primary research focus is the development and demonstration of a wireless sensor system for the process control in agricultural biomass during storage. The secondary research focus is potential energy savings using imbedded sensors for optimisation of the drying process and for active feedback control based on on-line measurements by sensors within the grain storage. The overall objective of this research is to reduce energy consumption for seed and grain drying and at the same time ensure a high product quality. The approach builds on novel applications of traceability and the usage of ICT in the primary agricultural production as methods and technologies for enhancing the grain and seed production system. The reliable performance of the network confirmed the correct choice of network characteristics (i.e., frequency range of 433 MHz, a handshaking communication protocol, and 10 mW transmission power). The results of this study indicate that the designed wireless sensor system could be used for effective process control and improving the storage and the processing facility.

Keywords: Wireless Sensor Network, Storage, Processing, Quality optimization, Energy savings**.**

INTRODUCTION Storage drying facilities are primarily being used on farms and research has shown that the energy consumption is approx. 4.5 MJ per kg of evaporated water (Kristensen, 2004). Continuous flow dryers will have a energy consumption in the range of 5 MJ per kg evaporated water (Høj, 1995). The demand for drying varies very much from year to year. It is assumed that on average one third of the cereals needs drying. With a drying need of 2 percent points, this process would equal 340 TJ for 3 mill. ton. There is a large optimization potential, while the heat of vaporization for water is about 2.3 MJ per kg and thereby being much lower then what is actual used in the current drying process.

An essential parameter for an optimised drying process is that the moisture content is sufficiently low throughout the storage bin. Lack of control of this process can in some cases result in over drying, with a waste of energy as a result. Also, material that has not been dried sufficiently can result in lower quality. By assuming an optimized drying process in relation to temperature- and moisture, it is estimated that the energy consumption can be reduced by as much as 10-20 % and at the same time it is possible to ensure the quality of the cereals. Therefor, it would be beneficial to know the differences between drying ocnditions within the storage bin on a real-time basis using site specific information and thereby allowing for a site specific drying process to ensure optimal conditions anywhere in the storage bin. This solution would be possible using on-line wireless sensor distributed in the stored material.

Wireless sensors have been used for different applications within agricultural measuring, monitoring and control (Wang et al., 2006), such as precision irrigation, environmental field data collection systems, automated fertilizer applicators, and animal behaviour monitoring (Damas et al., 2001; Kim et al., 2006; Nadimi et al., 2008; Schumann et al., 2006; Vivoni and Camilli, 2003). It is the aim of this study to design wireless monitoring systems that is applied to measure parameters in biomass process facilities by placing networked wireless sensors throughout the storage area. The system will facilitate long-term data collection at scales and resolutions, which are better than those obtained using traditional methods. A wireless sensor's intimate connection with its immediate physical environment allows each sensor to provide detailed information, which is difficult to obtain through traditional instrumentation such as invasive electrodes or probes. In addition, sensor nodes have the ability to adapt their operation over time in response to changes in the environment. In the design of wireless nodes, communication reliability and low energy consumption are two important factors to be considered. System identification techniques have also been widely used for different applications in agriculture (Nadimi et al., 2009).

MATERIAL In order to design a wireless sensor system capable of measuring and transmitting data from remote locations in the open area, a two step system was designed involving a short distance communication between the sensor nodes and a transceiver box and a long distance communication system between the transceiver box and an internet server.

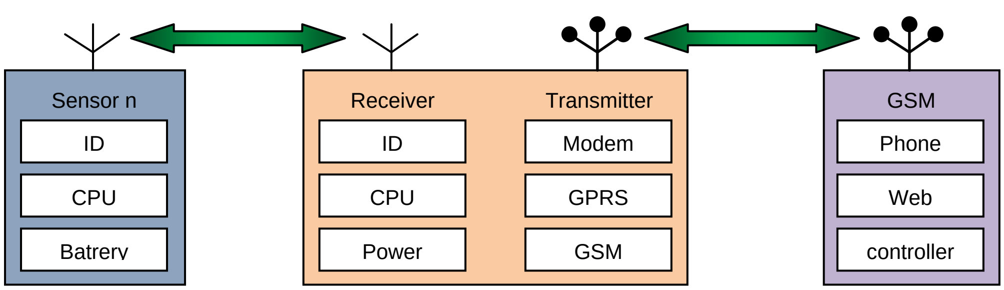

Figure 1 – Principle design of Wireless Sensor System for the two step communication.

Figure 1 describes the principle design of the wireless sensor system with a number of wireless sensor nodes communicating with a base station working as a receiver station and a transmitting station forwarding the collected data to an internet server or directly to a mobile unit as e.g. a mobile phone. This system design makes it possible to perform data mining in the data originating from the individual sensors to optimize the information transmitted. Also, in the base station it is possible to carry out a processing of the data, e.g. calculating mean or surveying for threshold values, so that alarm signals can be generated, if the received data exceeds a certain treshole.

METHOD For testing and evaluating different data transmission and communication technologies, a setup consisting of two spears was mounted with different sensors and communication means and then inserted into different biomass storages.

The spears could be mowed (setup A) to test different transmission distances. Inside spear (B), a receiver was mounted and connected to a lab-top for data acquisition and mining. Spear (C) was mounted with the wireless sensor transmitting data continuously.

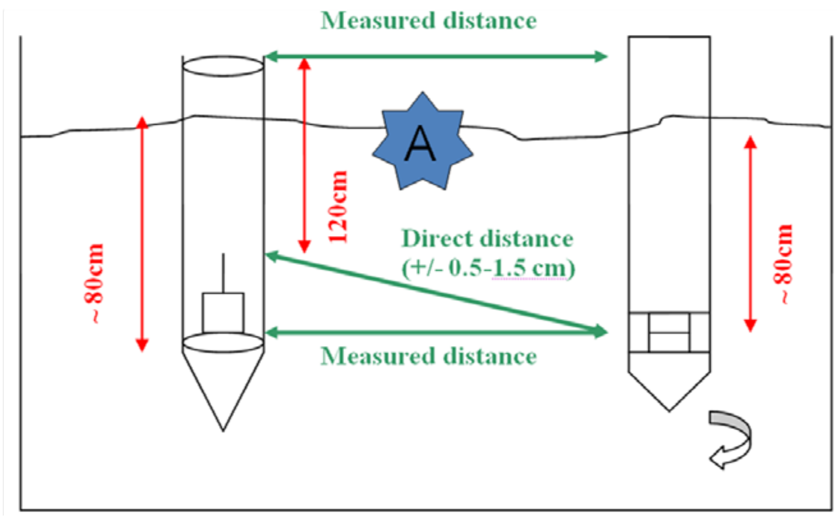

Figure 2. Setup for measuring signal transmission loss.

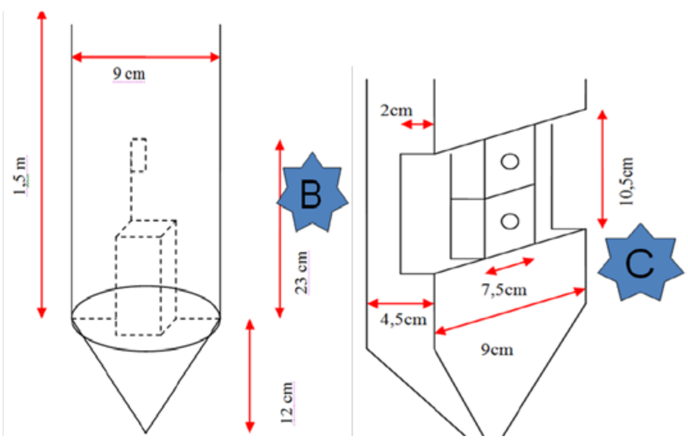

Figure 3. Design of equipment for measuring signal transmission loss.

A measuring system, consisting of 10 wireless sensors, measuring temperature and relative humidity, and that transmits to an external antenna and data acquisition system from a cereal drying process facility, were used for monitoring the variations within the drying facility.

RESULTS The readings from the developed sensor system monitoring variations of drying conditions over a period of 4 days are illustrated in Figure 4 and 5.

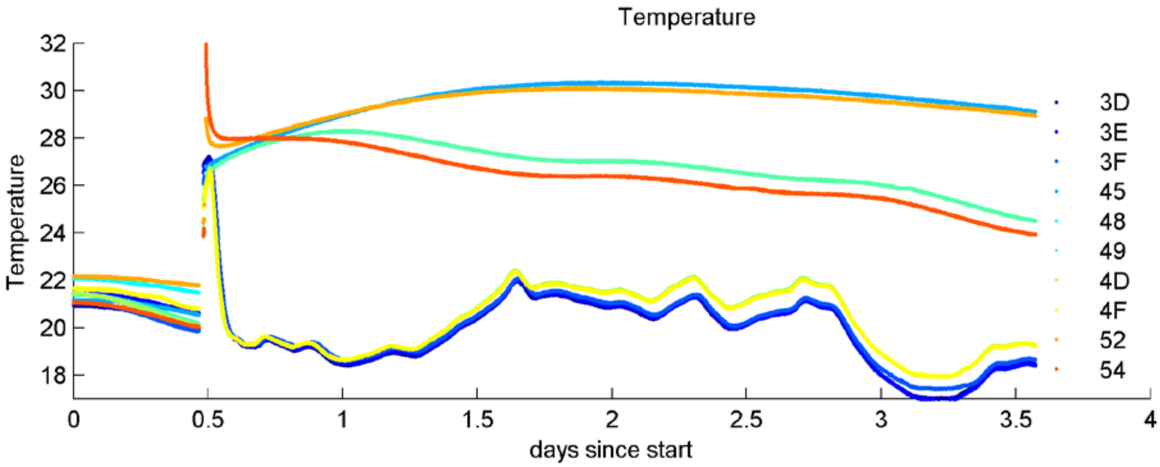

Figure 4. Temperature variations in the drying facility.

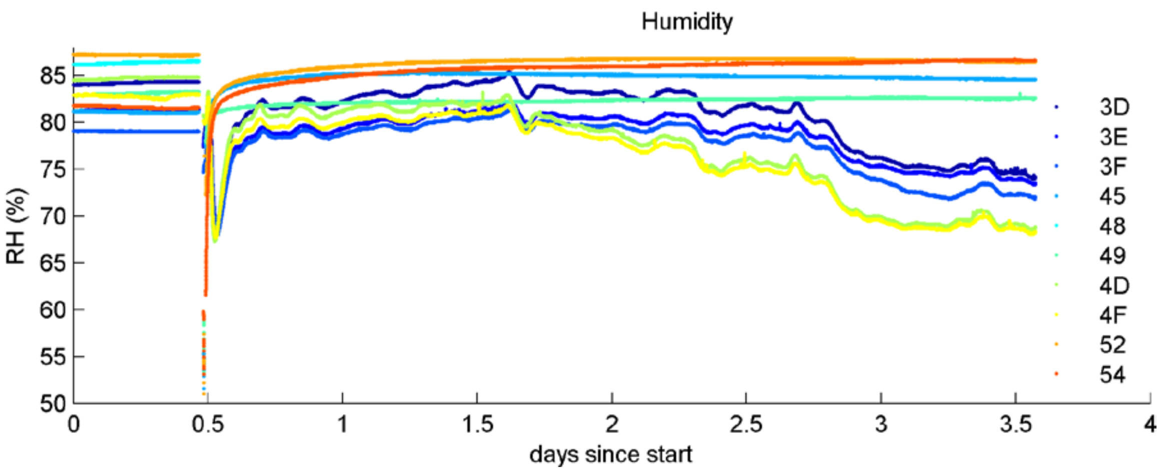

Figure 5. Relative humidity variations in the drying facility.

DISCUSSION Designing and developing of a wireless sensor network for monitoring cereal storage has two main challenges. The design and development of a positioning system and the optimal communication method between the sensors are both very important factors in order to create a sensor network that are able to work within a dynamic environment as a cereal drying storage.

A sensor system able to self positioning within the storage gives the possibility for on-line measurement inside cereal storage facilities that has stirring and/or continues flow. This kind of storage facilities are very difficult monitored with wired sensors, and therefore a wireless sensor system can be used for 3D modelling of the physical parameters.

The application of the storage area with numerous networked sensors can enable long-term data collection at scales and resolutions that are difficult to obtain using traditional methods. A sensor's intimate connection with its immediate physical environment allows each sensor to provide localized measurements and detailed information that is hard to obtain through traditional instrumentation such as invasive electrodes or probes. The integration of local processing and storage allows sensor nodes to perform filtering, data analysis as well as to apply application-specific aggregation and compression algorithms. The ability to communicate not only allows sensor data and control information to be communicated throughout the network of nodes, but nodes to cooperate in performing more complex tasks, such as statistical sampling and data aggregation. Low-power radios with well-designed protocol stacks allow generalized multi-hop communications among network nodes, rather than single-hop communication.

Novel localization techniques in wireless sensor networks have been among topics attracting lot of attention. Different methods such as angle of arrival (AOA), time difference of arrival (TDOA), time of arrival (TOA) or received signal strength indicator (RSSI) have been implemented for 3-D localization; however, none of these methods have been implemented to estimate the location of the sensors monitoring quality parameters in cereal storage. Consequently, novel low-power low-cost sensor nodes capable of monitoring quality parameters, communicating in a multi-hop fashion, transmitting their 3-D location are of great interest.

Non-invasive monitoring methods using wireless sensor networks have been implemented by Osman et al., (2002) and Lee et al., (2005). Single-hop connectivity was selected as the routing protocol leading not to achieve a reliable communication between sensor nodes and the gateway and consequently, having a poor packet delivery performance.

CONCLUSION In order to monitor variations of drying conditions in a seed drying facility to improve the efficacy of the system, novel non-invasive wireless nodes capable of measuring the temperature and relative humidity inside the processing facility have been designed and their performance evaluated in a full-scale drying facility.

The designed wireless nodes precisely monitored the temperature inside and reliably transmitted the measured data. The results of these experiments showed between 98.9%, 99.4%, and 99.3% of the packets disseminated from the tested sensor nodes were successfully delivered to the gateway.

The results of this study indicate that the designed wireless sensor nodes could potentially be used for other applications like detecting the occurrence of silage decomposition and for improving the efficacy of silage conservation systems.

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