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Design, development and evaluation of a wireless system for the automatic identification of implements

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ABSTRACT

Monitoring operative conditions is one of the most important aspects of modern agricultural management. In order to improve data collection efficiency, it is necessary to develop an automated system that collects data on mechanised field operations and update the farm management information system (FMIS) database. Automation of operative monitoring is possible by adopting "field data loggers" (FDLs) installed in tractors working on farms. The present project is focused on the design, development and evaluation of a device based on wireless technology in order to identify the implements coupled to tractors. This allows automatic recognition of every mechanized operation carried out on the farm. The device consists of two main parts built with low cost commercial electronic components (hardware costs can be less than €100): (a) a RF radio transmitter fixed on an implement that, on the 868 MHz frequency, sends a univocal numeric code at predefined time intervals for every machine monitored; and (b) a receiver (integrated into the FDL), positioned on the tractor. The transmitter is triggered by a vibration sensor: so that the transmission of the machine code occurs only if the implement is in the working phase. This allows low electrical absorption (the life of the transmitter battery is estimated to be about 9 years transmitting two codes per minute). The device was implemented and evaluated in the field taking into consideration two different transmission power levels (PW 0 and PW 1) and three receiver positions: (i) on the left mudguard; (ii) at the top of the ROPS (Roll Over Protection Structure); and (iii) on the front of the engine's hood of two different tractors. This is done in order to determine the experimental horizontal 2D-beam patterns for every transmitter–receiver combination. Results show that, with the transmitter set at PW 1, all three receiver positions on the tractors can identify the rear and front coupled implements (2D beam patterns area ranges from 353.2 to 758.1 m^2, major axis ranges from 20 to 35 m and overlay index is equal to 100%) therefore, in order to protect the receiver device from incidental strokes, we selected the rear of the tractor cab as the best position to mount the receiver device.

1. Introduction

In order to improve data collection efficiency and optimize machinery field logistics, an automated data collection system is needed (Assirelli et al., 1998; Sorensen and Bochtis, 2010). Subsequent handling of the collected data, which is obtained via farm management information systems (FMISs), allows the farmer to process and store data using models and databases. It also allows the farmer to convert data into useful decisional making information (Nikkila et al., 2010). Mechanized real time operations monitoring has modernized traditional FMISs because it records the sequence of mechanised farm activities together with a set of attributes. The automation of operative monitoring is possible with the adoption of "field data loggers" (FDLs) (Mazzetto et al., 2007, 2009, 2010).

In general, a FDL consists of a "black box," installed in tractors working on farms, which allows automated monitoring of mechanised farm operations, providing detailed information related to field activity. The system is based on distance identification processes in which tractor and implement (IM) behave, respectively, as an identifying system (and data recording device) and object to be recognised. IM identification allows the recognition of mechanised farm activities.

A FDL includes the following components (Fig. 1):

(1) A central unit with data acquisition and data storage functions AU (Acquisition Unit) that usually include a GPS receiver with external antenna GPS-A, (GPS antenna).

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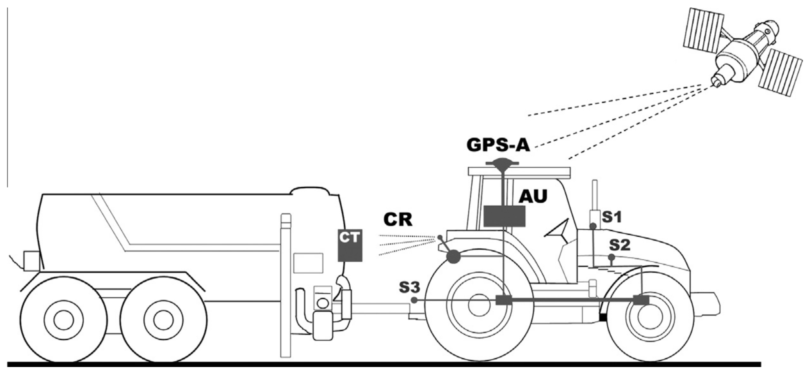

Fig. 1. Tractor equipped with the complete monitoring system.

(2) A CR (Code Receiver) system to receive the identifying code of the implement transmitted by the CT (Code Transmitter) device (Castelli and Mazzetto, 1996).
(3) A system of sensors (S) connected by a transmission bus with AU that measure principal operative parameters related to the tractor-implement system (i.e., S1: gas exhaust temperature, S2: engine rpm, S3: pto activation).

Others carried out monitoring systems for tractors research (Auernhammer, 2001; Rothmund et al., 2003; Speckmann and Jahns, 1999; Steinberger et al., 2009; Wang et al., 2006). In these studies, the identification of the implement coupled to the tractor was created through a wire connection based on ISOBus protocol normally used for the real-time operative control of the IM. We believe that this solution is hardly viable at the moment for the following reasons: (a) the adaptation of ISObus systems on tractors available at the farm is generally expensive and difficult, and (b) in Italy most tractors and implements now in use are not provided with ISOBus devices, thus requiring alternative retrofit solutions. The approach proposed here is based on wireless systems because connections by wire are commonly subject to breakage and to accidental or intentional forgetfulness by the farmer. During the preliminary design phase, we excluded ZigBee immediately. As is known, ZigBee is a high level communication protocol based on an IEEE 802.15 used to create low bit rate PAN (Person Area Network). Though low-powered, ZigBee devices can transmit data over longer distances using intermediate devices to reach more distant ones. In this way a mesh network is created, i.e. a network with no centralized control able to reach all networked devices. So the use of ZigBee to create direct connections point to point between single transmitters and receivers (i.e. between tractors and IM) is more vulnerable to interference or blockage (AA.VV., 2006). For these reasons, we have designed, developed and evaluated an innovative RF (radio-frequency) transmitter with triggering controlled by a vibration sensor, capable of generating a univocal numeric code for the automatic identification of each implement coupled to the tractor. In this case, the numerical code is transmitted only when the machine is coupled to a tractor in work phase. The advantages of this simplified system are twofold: a non-coupled implement cannot transmit codes (the possibility of receiving unknown codes is thus drastically reduced); consequently, electrical absorptions are minimised. Finally, transmitter cost is less than other types of connections e.g., transponders (Sugahara et al., 2008; Voulodimos et al., 2010).

The aim of this work is to present the behaviour results of these new simplified transmitters, when installed on coupled IMs (both mounted or trailed) with the receiving antenna mounted on tractors. We detected their transmission range by measuring the related useful broadcasting field in terms of horizontal 2D-beam pattern. To achieve this, we decided to carry out static fix trials as described below to better focus on the results in terms of the relative positions between receiver/transmitter.

2. Materials and methods

2.1. Field data logger

The identifying code transmitter, fixed on every implement, operates on the 868–870 MHz frequency band (7 channels in the 868 MHz license free band) and uses the FSK (frequency-shift keying) modulation technique. FSK allows greater protection against electric noise compared to other types of RF modulations.The electronic circuit of the transmitter can be divided into two parts (Fig. 2):

(i) Microprocessor (Philips P87LPC762BN, Philips, The Netherlands) with functions of:

(a) Timer, once a pulse on the vibration sensor is detected, the microprocessor, via a monostable stage, switches the circuit on for a pre-established time. Power is supplied by a lithium battery (3.6 V, 2200 mAh).
(b) Code generator, the microprocessor is generated via a time programmable radio frequency serial line ASCII code made up of 21 alpha-numerical characters. This preset univocal code for each specific implement – is generated by the microprocessor triggered by the vibration sensor at a pre-defined frequency (commonly 1 code every 30 s). The bit rate is set at 34,800 bps. At the same time the code is generated, the transmitter is activated only during transmission. This is another solution to minimise electric power absorption.

Signalled by the last vibration, the microprocessor sends further data for a pre-defined length of time, then goes into sleep mode (consumption: 20 μA). In this phase, no data are transmitted and the microprocessor waits for a new vibration to start another transmission cycle.

(ii) Transmission module.

The RF transmission module (Aurel XTR-7020A-8, Aurel, Italy) is a device based on TTL-RS232 logic (bit rate ranges from 9600 to 115200 bps), and data transmission is realised by the "store and forward" technique: input data are stored in a buffer memory and transmitted at the end of reception. In the reception phase, the bytes are stored and transferred to the serial port only after the checksum validation. In case of transmission failure, all bytes received are rejected (in other words, the radio message must be completely transmitted). The maximum length of the transmissible data packet is 240 bytes. By sending "AT" type commands