# The use of RFID technology in drying and other thermal processes of wood.

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High temperatures (>50$^{o}$ C) are applied in a lot of processes in wood industry and monitoring of temperatures is a critical point, in order to follow the process properly. The most common method in practice to transfer the information is the use of cables, which connect sensors to data loggers. The accuracy of the method depends of course on the quality of the equipment, on the quality of the cables and on distance between sensor and signal receiver. For traceability reasons it is also essential many times to record temperatures achieved inside a chamber or –much better – inside wood core and recall them long time after the process has finished. Nowadays this can be achieved using RFID technology, without any need of cables, whenever and wherever you wish. In present paper a series of experiments are presented, where this technology was applied and the accuracy of the sensors was examined. Traceability is possible, as well, verifying temperature and time data.

Key words**: Wood drying, Data recording, RFID, semi-passive, battery assisted, temperature sensor, condition monitoring.**

## Introduction

RFID is the key technology for the Internet of Things. The Internet of Things refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. The great advance in embedded systems and web technologies offers new technological solutions for new services and re-engineering of existing products.

Radio Frequency IDentification (RFID) represents a modern identification technology and is able to change the identification and tracking of assets. The RFID infrastructure and the worldwide established standards (EPCglobal) give a unique opportunity to develop software applications to represent the position and condition of an item at real-time and worldwide. Each item or asset must carry (be tagged) a RFID label or tag and RFID embedded devices uses radio waves to identify items at each reading point (in the workplace, at a warehouse Dock door, on a Forklift, in a drying kiln or in a heat treatment chamber).

RFID technology was developed over several decades, as reviewed in the works of Landt (2001), Lahiri (2005), Dew (2006). There is a growing body of literature on operations management in service firms that is relevant to RFID adoption in service operations. Ngai et al. (2008a, b) presented a literature review of 85 academic journal papers that were published on RFID between 1995 and 2005, organized into four main categories: technological issues, applications areas, policy and security issues, and miscellaneous. Since then, several other academic studies have been written about the benefits (and costs) of adopting RFID. Doerr et al. (2006), Niederman et al. (2007), De Kok et al. (2008), Rekik et al. (2008), Szmerekovsky and Zhang (2008), Veeramani et al. (2008) and Kim et al. (2008) studied the use of RFID to improve supply chain and inventory operations

Modern information systems offers modules to support data collected from RFID infrastructures. A RFID infrastructure is based on hardware embedded devices like RFID tags and readers, special middleware – software modules based on the EPCglobal standards, and protocols for intelligent assignment of RFID data with business data. A modern RFID system consists of the following four parts:

- One or more smart labels – EPC code (UHF RFID tags or combined barcode and tag).
- One or more readers (RFID readers or interrogators).
- One or more antennas (RFID antennas).
- Advanced Information Systems for data collection, filtering and exchange.


Figure 1. UHF RFID Tag Passive, special purpose and battery assisted.

RFID tags could be as is or combined with a barcode printed on the paper face. This combination is a smart label which could be indentified from a barcode system and an RFID system. In our work we focus on the UHF RFID tags (850 - 950 MHz) and the EPC global infrastructure. The types of tags (Fig.1) are: (a) passive (No Battery – harvests energy for the radio waves and send back the unique code), (b) special purpose tags (Many companies design tags for special or robust environments – The Confidex Pino Tag for wooden pallets) and semi-passive (battery assisted tags with embedded sensors – The CAEN BAP RFID Tag for temperature logging).

Based on the EPC global standards each UHF RFID tag holds an Electronic Product Code (EPC) which is the most significant advance of the technology compared to Barcode. The EPC number offers a unique, serial code for each item or asset, not only a class/product code as barcode. The electronic product code is a number that is used together with the RFID technology to improve the management of the supply chain and to eliminate costs. This code provides us with detailed information about the product and a smart label carries a unique number which embed also the barcode (Fig. 2). This code has the following sub parts:

a) Header with 8-bits and gives the length of the UPC.
b) EPC manager and gives the producer of the product.
c) Object Class and gives the certain type of the item with the same way as the Stock Keeping Unit (SKU).
d) Serial number and gives the unique number of the certain item.

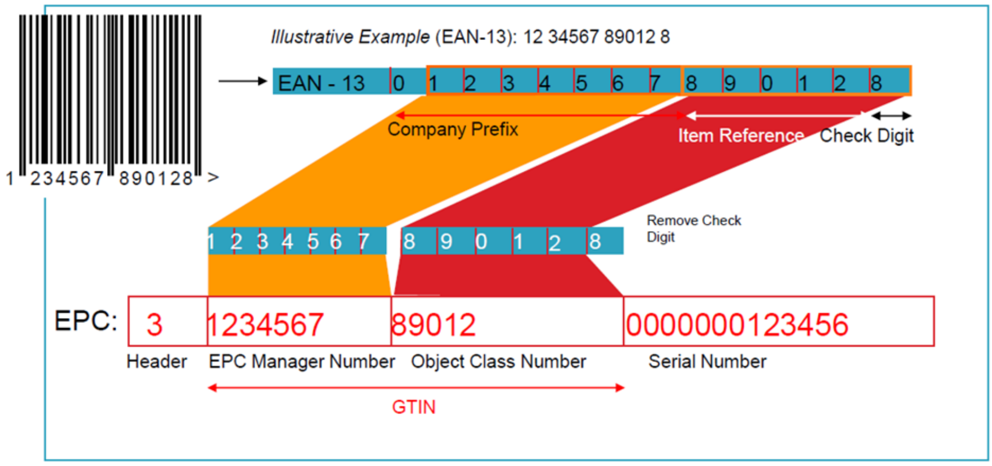



Figure 2. An example of a EPC number and how embeds the barcode.

The RFID reader uses antennas to transmit radio signals in order to activate the tag and also can read or write data on it. The antennas transmit the signals for the communication between the tag and the transmitter – receiver, which controls the communication of the data also. Usually, the antenna is packed together with the transmitter and receiver in order to become a reader which can be portable or not. If reader has embedded also the middleware software is called a “smart reader”. An RFID reader obtains object information from its RFID tags. The reader transmits radio waves in a distance between 3 cm up to 30 m or more, depending on the output power and the radiofrequency.

The UHF RFID reader is an embedded system which has significant resources, run Linux operating system, has multiple GPIO ports (able to handle sensors, and actuators like lights, alarms), has Ethernet interface or Wi-Fi and is able to power up to four (4) RFID antennas. In our research we observe the capabilities of such a device to upgrade the infrastructure of a typical heat treatment chamber which is designed not to capture digital data. The application of a reader (as a RFID Portal) in a chamber provides in real-time data all tagged items (and sensor data) entering the facility or abandon after treatment.

After identification stage, a middleware application filters and collects the codes based on a configuration. The ALE (Application Level Events) Server captures the data and the EPCIS (EPC Information System) requests data and combines them with business data (using a Core Business Vocabulary and Naming Service (ONS)). The unique codes are captured and combined with business data (A Forklift with EPC 51, carries in a Pallet with EPC 123, which contains 123 items with EPCs, and 10 semi-passive RFID temperature tags, at Chamber 10 and at 08:00 o’clock, the Forklift with EPC 23, carries out a Pallet with EPC 123, which contains 123 items with EPCs, and captured also the temperature data from 10 temperature tags, at Chamber 10 and at 11:00 o’clock). The unique temperature diagrams show the duration and the maximum treatment temperature for the unique 123 items. The RFID data could be valuable for companies and administration stuff. Last advances in RFID software offering access to EPC RFID data using RESTful web architectures

(RFID data for customer information using technologies like twitter and Google maps). An example is the Fosstrack (Open Source RFID Platform) and the EPCIS Webadapter, opening a huge range of web and mobile applications.

## EXPERIMENTAL FRAMEWORK AND METHODOLOGY

Our objective is to compare the two different systems of measuring the temperature in a drying chamber. For that purpose, an experimental framework, has been carefully designed in order to perform the experiments with the two different probes. One with an RFID with datalogger and thermosensitive probes and the other with the usual method by transferring the data from the thermo sensors with cables. The setup of the RFID devices is presented in Fig. 3.

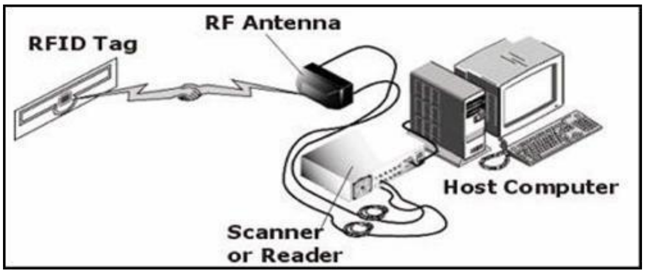



Figure 3. The basic system of RFID system

and includes the following items:

a) Antenna (Intermec): it emits the radio signals that initiate the communication and power up the tag. It also receives the signal transmitted by the tag.

b) RFID reader: it controls the whole system and implements the communication protocol. It processes the signal received from the tag in order to extract the information of the tag. It is connected to a computer to configure the temperature from the data logger and the time that we reach of the temperature values. We can also take the diagram of the temperature through the time.

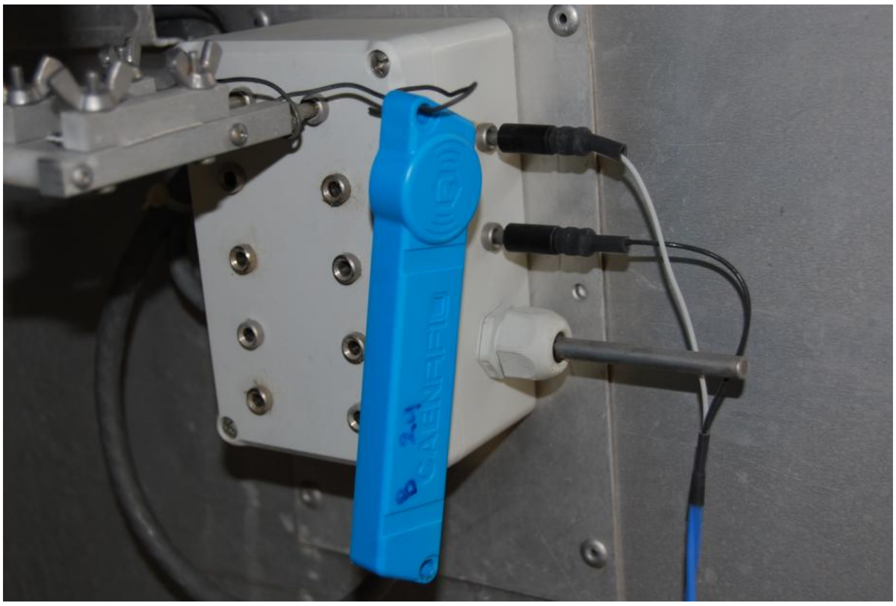
c) c) RFID: are placed ı) into the wood and ii) near the temperature sensor of the drying chamber. The selected tags are CAEN BAP RFID Tag for temperature logging.

d) Wooden pieces: The selected materials are from common wood species that are usually used for drying. One was from softwood *Pinus nigra* Arn. and the other one from hardwood *Fagus sylvatica* L.

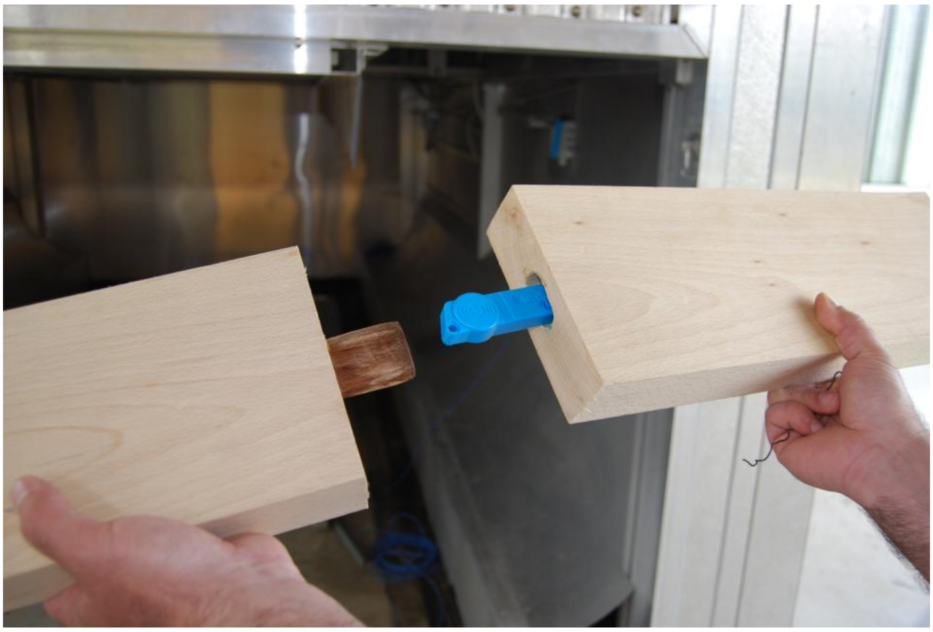
e) The air speed was also used as a parameter for the specific experiment, as air speed is one of the most important parameters for heat transferring. During the experiment two different air speeds were selected: 0,3 m/sec and 1,4 m/sec.

f) The last parameter was the Relative Humidity inside kiln. RH is usually not stable during a drying program and this is also something important for the different kind of sensors that were used. For our purpose the RH that used was 80% and the two different kinds of wood were tested.

The places that we put the RFID sensors and the usual sensors are shown ın Pictures 1 and 2:



Picture 1. RFID sensor close to kiln probe for temperature measuring air.



Picture 2. Placement of RFID sensor inside wood (Fagus sylvatica).

## EVALUATION AND RESULTS

The parameters that used and explained in previous section provide an experimental framework to compare the behavior of different ways of measuring temperature inside a dry kiln by using RFID and the common sensors. This section presents the obtained results, which are later discussed. This section lists the values of the measured temperatures that obtained in different conditions that were running into the drying kiln, using two different kinds of wood.

**Air speed:** The temperature was measured in three points. One with the usual sensor and two other measurements with RFID, one close to kiln sensor (2 cm distance) and the other inside the wood piece (softwood ). The results were the following:

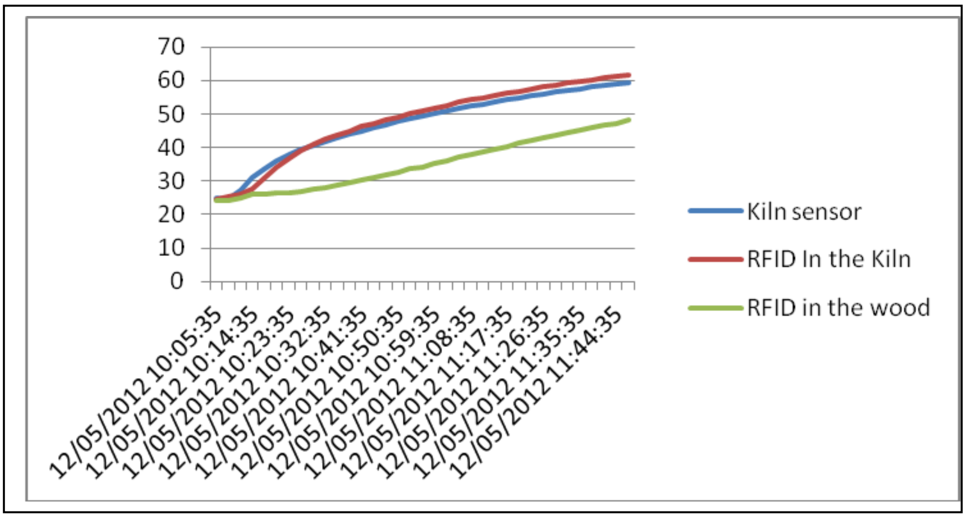



Figure 4. The data from the three different sensors with air speed 0,4 m/s (in a softwood).

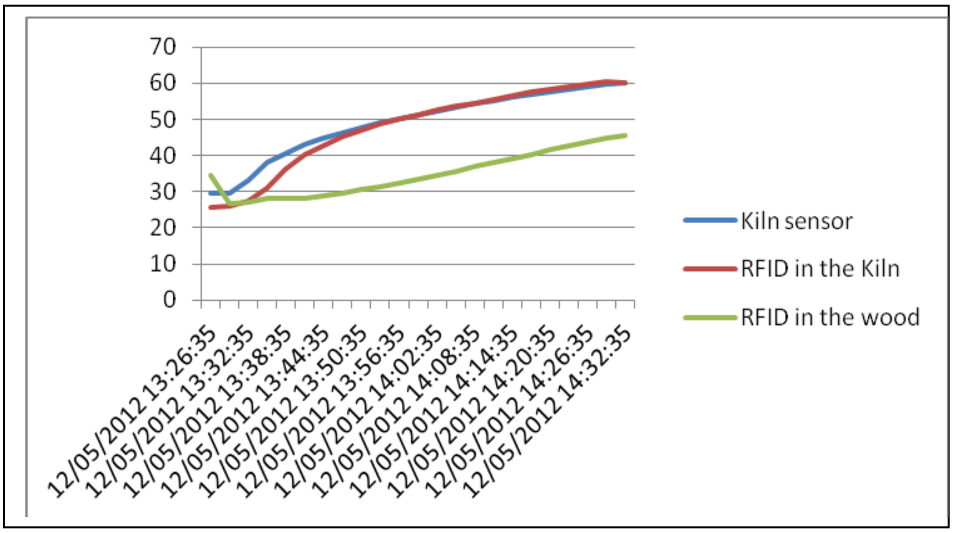



Figure 5. The data from the three different sensors with air speed 1,3 m/s (in a softwood).

**Wood materials:** In order to find how the density and different material influences the RFID sensors, two different kinds of wood were used. A hardwood and a softwood. The results for this type of material with different tags are:

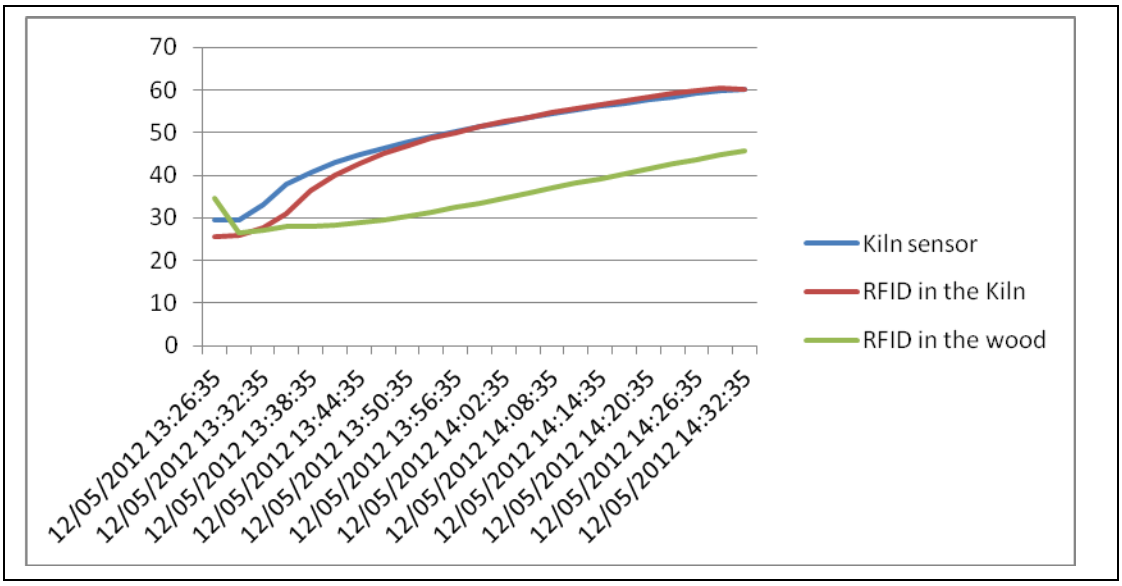



Figure 6. The data from the three different sensors. The wood used was a softwood.

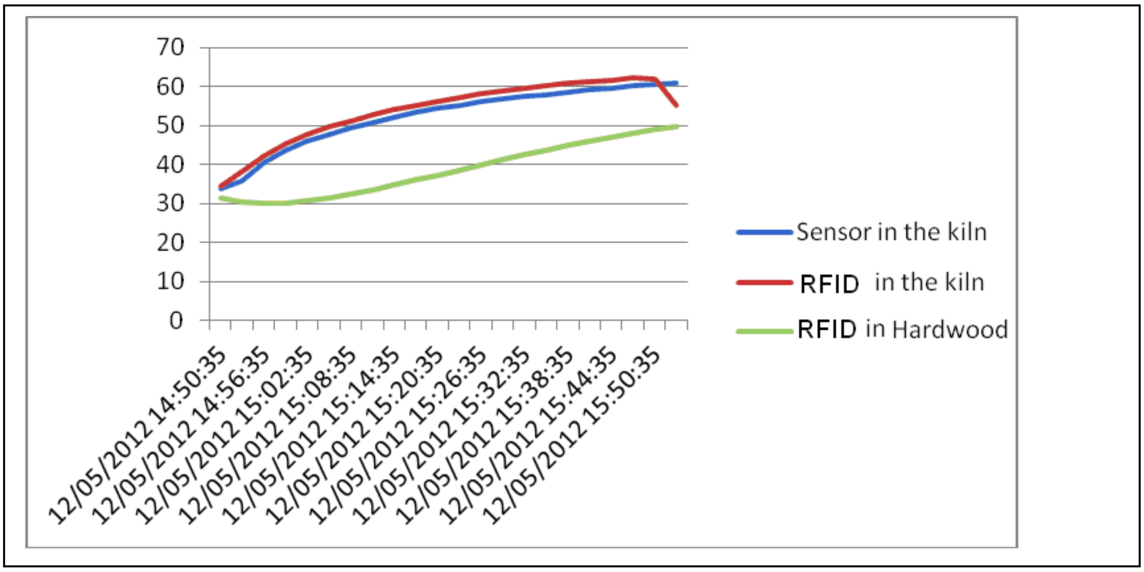



Figure 7. The data from the three different sensors. The wood used was a hardwood.

**Relative Humidity:** Data obtained from the two different systems of sensors when Relative Humidity was in a high level (80%) are the following:

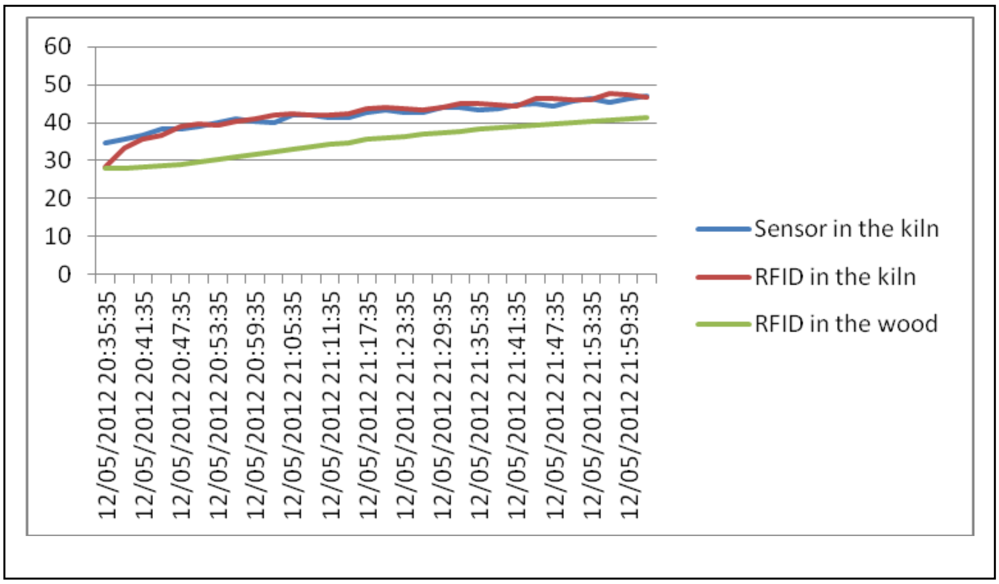



Figure 8. The data from the three different sensors with RH 80%. One RFID sensor is inside a hardwood.

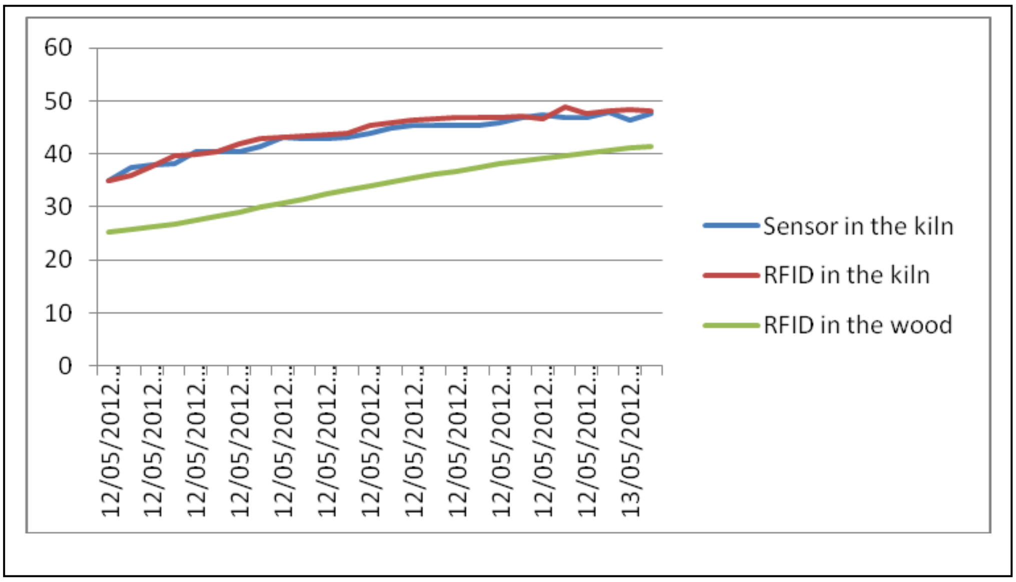



Figure 9. The data from the three different sensors with RH 80%. One RFID.sensor is inside a softwood.

## Discussion

The objective of present paper is to compare the behavior of two different temperature measuring systems, which can be used in a drying process or in a heat treatment installation. To achieve this objective, results are compared between RFID sensors and a usual sensor that a normal champer uses and, finally, the results are compared in a global way to get an overview for the difference that these two sensors system provides in their data in different conditions in the champer (air speed, humidity, kind of wood) .

**Air speed:** The airspeed in the chamber seems to have an extremely low influence on the two different sensors, giving almost the same data with a speed of 0,4 m/s (Fig 10 ) and with speed of 1.3 m/s (Fig 11)

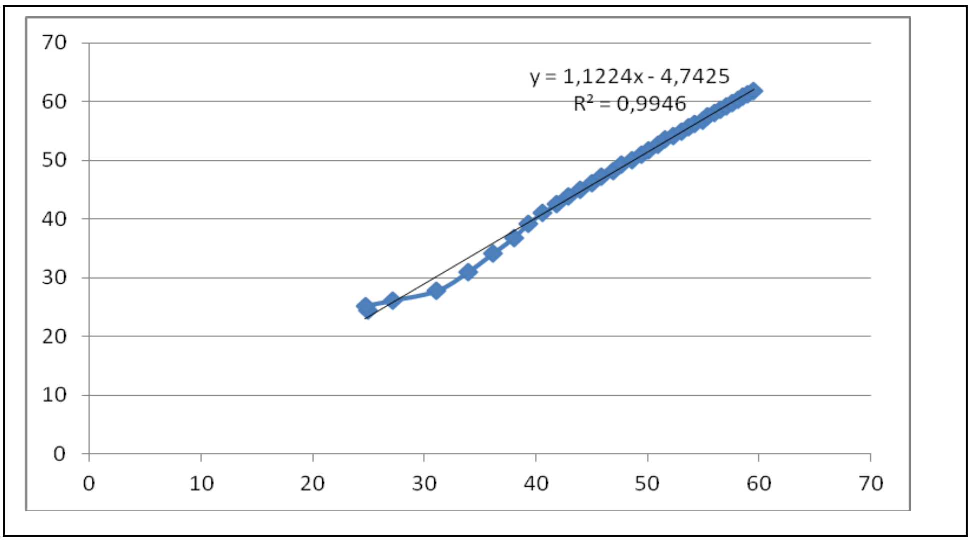



Figure 10. The correlation between data from the two different sensors with air speed 0,4 m/s.

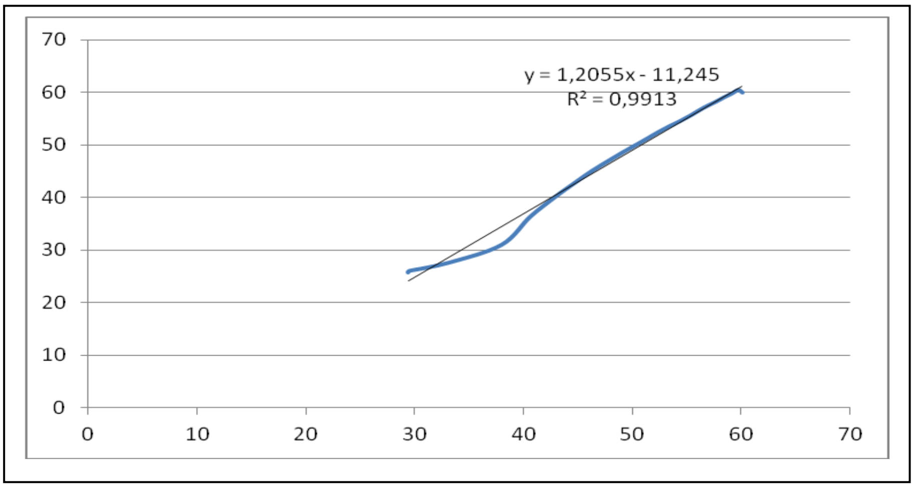



Figure 11. The correlation between data from the two different sensors with air speed 1,3 m/s.

**<u>Wood material</u>:** The two different types of wood that used (softwood and hardwood) showed a different speed of temperature increase in the core, with the softwood to be more difficult to increase temperature in the core of the wooden piece, even if they had the same dimensions. Finally, in softwood the temperature in the same time period was more than 4 degrees lower than the hardwood. But even with these problems, the two sensors provide us with the same data without any problem.

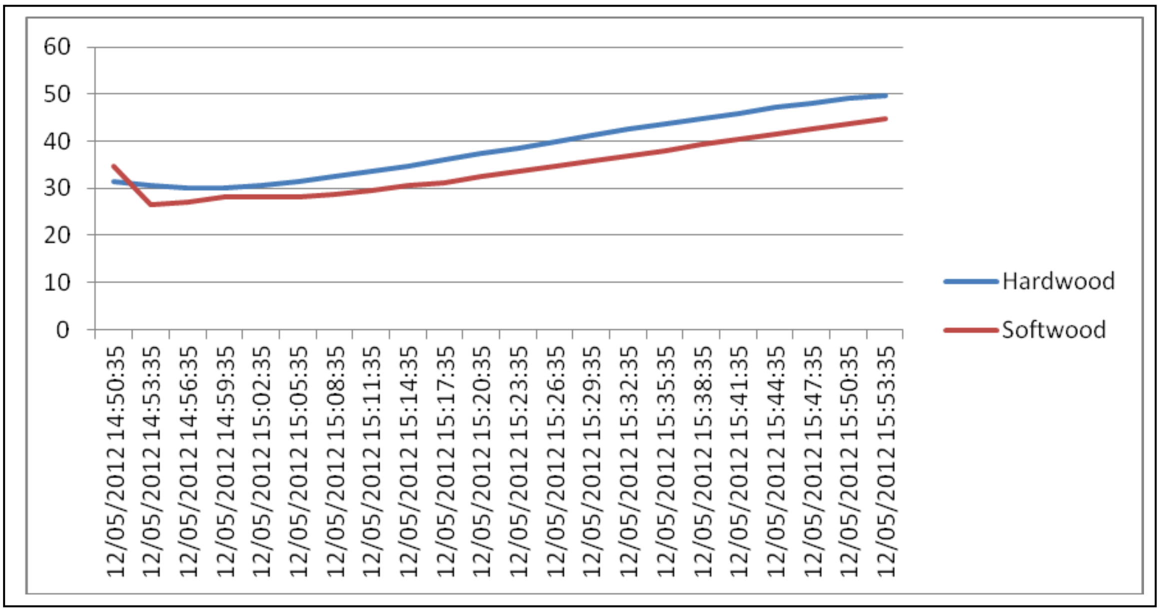



Figure 12. The temperature inside the core of softwood and hardwood.

**<u>Relative Humidity</u>:** The behavior of the two different systems when tried to measure temperature with high Relative Humidity environments had not the same performance as in lower RH. We can see the correlation between the two sensors in the following Fig 13.

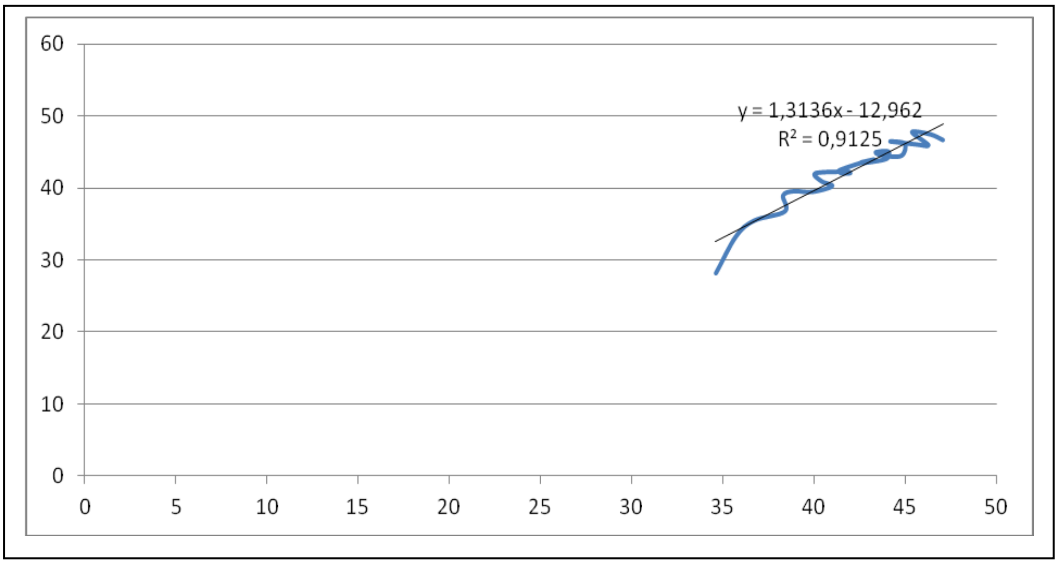



Figure 13. The data from the two different sensors with RH 80%.

It is important to note that the better performance of the RFID system was in the chamber with low RH and without any problems of the air speed.

## Conclusions and future works

After studying analyzing the obtained data, it can be concluded that the RFID system can be used without any problem inside a chamber in order to collect temperature data, which will be helpful for drying wood but also can be used inside the wood in order to have the necessary data for heat treatment of wood according ISPM 15. We can also keep these data in an archive in order to help the traceability of this treatment.

It should only be kept in mind the deviation of the two different systems, when the chamber is running with high Relative Humidity.

Ongoing work is focused on the active RFID tags but with higher air-velocity, in order to receive all the necessary data from a bigger distance and without need to use any cables. It will be a cheap solution for very old chambers without any data collecting systems and they can be improved and used for any kind of drying or heat treatment.

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