Application of RFID (Radio Frequency Identification) in the Timber Supply Chain

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Abstract – Nacrtak

This paper deals with the use of Radio Frequency Identification (RFID) in the timber supply chain. A distinction is made between the use in motor-manual and highly mechanised timber supply chains. A technical specifications profile is elaborated for both types.

As a result it can be summarised that the use of RFID in the timber supply chain is technically feasible. In motor-manual harvesting, it was possible to mark the logs with RFID tags manually. Several tag types could be read out at all stations between the forest and timber industry.

A RFID tag-fixing device for harvester heads was developed for the use in highly mechanised timber harvesting. Thus it was possible to attach RFID tags automatically to the logs. Automatic reading of tags during loading processes for skidding and transportation could also be realised.

The tag-fixing device and the antennas that were developed are preliminary models. For the practical use of RFID technology in the timber supply chain, further research is necessary for the development tag design and fixing and reading methods.

***Keywords**: timber supply chain, logistics, RFID, tag-fixing device, log identification, technical requirements*

1. Introduction – *Uvod*

In Germany a large number of mainly small and medium sized enterprises take part in the process of timber supply. Consequently, the timber supply chain from the forest to the timber industry is characterised by several fractions between these individual process participants, which results in a high disintegration of material and information flows. However, it is impossible to supervise or control timber logistic processes without knowing how much timber is where at a particular time. Long delivery times and related quality losses become inevitable. Attempts to compensate for information deficits by multiple measurements and inventory of round wood at individual points of the supply chain are costly and often produce errors when entering, assessing and passing on data. As the timber industry often lacks precise knowledge of the actual status of timber supply it holds large stocks of round wood as an intermediary buffer. This buffer ensures the current production but it also creates important costs. For supplies from small-scale private forests, in particular, accounting by manufacturer is very expensive because separate storing of timber by individual owner is often required.

In Germany, the supervision and control of product and information flows across businesses in the sense of Supply Chain Management (SCM) has recently been considered to have the highest potential for improving the entire supply chain from the forest to the timber industry (Bodelschwingh 2005, Friemel 2005, Holzmann et al. 2006). SCM aims at developing material, information and value flows across interfaces in the best time and at optimum cost. Automatic identification systems can be used in this context to clearly identify the products in the supply chain and, thus, make an essential contribution to the supervision and even control of the product flows. This produces a clear picture as to which products or quantities of products are at a specific place at a particular time. Thus rotation cycles in the timber supply chain can be shortened and quality losses can be reduced. In addition, an overview of the flow of products allows the clients to keep smaller stocks, which results in financial advantages due to reduced capital commitment. Clear identification of the forest owner at the saw mill allows, besides the accurate accounting of mixed loads from small private forest owners, a proof of origin in line with the Chain of Custody.

At present, the logistics sector is paying increasing attention to Radio frequency Identification (RFID) technology, which enters into competition with established systems like barcoding. RFID is less susceptible to dirt and, in addition, it is suited for simultaneous recording of several units (bulk reading). This is what makes its application in forestry particularly interesting.

Dykstra et al. (2003) discussed the strengths and weaknesses of various identification technologies for wood tracking. RFID was described as one of the most promising technologies of the future. The LINESET EU research project examined, among other things, the potential use of RFID technology in the timber supply chain, and first tests were carried out (Uusijärvi 2003). Another research project at the FVA Freiburg focussed on the use of RFID tags in motor-manual timber harvesting. Emphasis was placed on the development of a special fixing method to allow an automatic recovery of the tags at the saw mill (Holzmann et al. 2006). The forest consulting enterprise *Cambium Forstbetriebe* developed a log tracking system for improving internal logistic processes based on the identification of timber logs by means of RFID tags (Friemel 2005).

So far it has not been examined whether and under which conditions the application of RFID technology is technically feasible in the entire logistic process. Only a few tags have been tested. That is why there are no concrete specifications for using RFID in the timber supply chain. The following explanations attempt to close this gap.

2. Main characteristics of RFID technology – *Glavne značajke RFID-a*

RFID-technology makes possible an exchange of data via radio between a data carrier (transponder; tag) and a data reader. A transponder is basically composed of a microchip for storing data and a coil used as antenna. If the transponder is in the electromagnetic field of a reader, data can be exchanged between the transponder and the reader. This alternation of transmitting and responding has led to the creation of the name transponder composed of *TRANSmitter* and *resPONDER* (Franke und Dangelmaier 2006, Finkenzeller 2002). With regard to energy supply, there is a distinction made between active and passive systems. Active transponders are equipped with an independent energy supply by an integrated battery. This battery provides the energy needed for data storing, data transmission and for other integrated elements such as sensors. Passive transponders use non-volatile data memories which do not need energy for storing data. For the transfer of data they receive the necessary energy without contact by means of an electromagnetic field (inductive coupling) established by the antenna of the reading device. The radio waves are used both for the energy supply and data transmission.

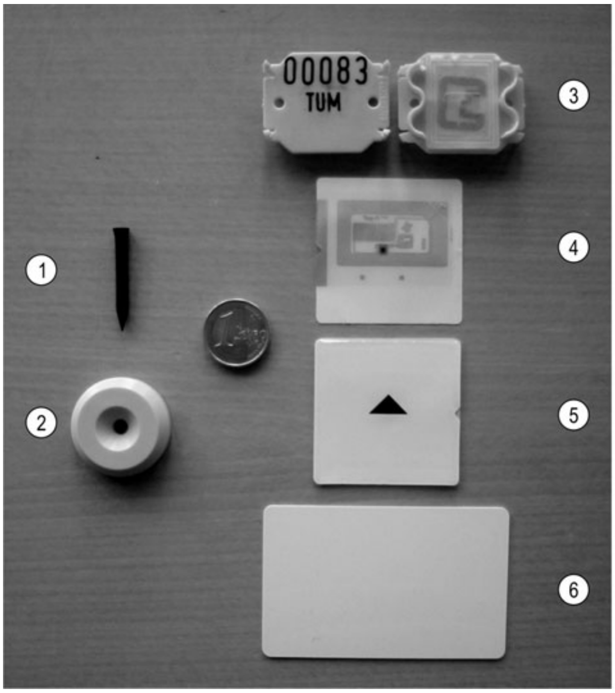
Passive transponders on which globally unique identification numbers are stored are often used for controlling logistic processes. By means of these numbers it is possible to clearly identify marked objects. This is mainly done in LF range (Low Frequency / e.g. 125 kHz transponder) with a reading range from a few centimetres to one metre, and in HF range (High Frequency / 13.56 MHz transponder) with a reading range of up to 1.5 metres. In the UHF range (Ultra High Frequency / e.g. 868 MHz transponder) the reading range may reach several metres.

Important characteristics for the practical application such as reading range, bulk reading capacity (simultaneous reading of several tags) or sensitivity to liquids and metals are determined decisively by the working frequency of the transponder. HF and UHF transponders allow bulk reading. So far LF transponders have not often been used for bulk reading despite technical feasibility because of the low reading range.

Since data transmission is done via electromagnetic waves, liquids and metals have a negative influence on the reading field and, hence also on the reading range of the system which increases with higher working frequency. Consequently, LF transponders are relatively resistant to metals and liquids. Whereas the sensitivity of HF transponders to liquids is low, they can be strongly influenced by a metallic environment. UHF transponder tags are usually strongly influenced by metals and liquids.

The full reading range can only be achieved by an optimal, parallel orientation of the tag antenna and the reader antenna. Deviating from the optimal orientation may significantly reduce the possible reading range.

In principle, transponder tags can be integrated into almost every case design type. However, depending on the work frequency there are minimum requirements for the dimensions and geometry of the transponder antenna. Round die-casting cases, the so called coins or discs, are frequently used for integrating transponders. Often transponder tag labels (»smart labels«) are made of paper or plastic films. Transponder cards are of a special design, where tags are incorporated into several layers of PVC films. The integration of transponders into glass capsules



Low Frequency – *Niskoferkvetni* (125 kHz)

1 Nail transponder – *Klinasti primopredajnik*
IC Unique, 35.5 x 4 mm in glass capsule, 12 x 12mm, Sokymat

2 Coil – *Dugmasta zavojnica*
EM V 4001/2, 30 mm O, Tectus

High Frequency – *Visokoferkvetni* (13,56 Mhz)

3 Number plates Signumat – *Brojčane pločice* Signumat
Philips I-Code, 35 x 43 mm with Inlet, 16 x 20 mm, Latschbacher

4 Adhesive label (square) – Ljepljiva etiketa (kvadrat)
TI HF-1 plus, 50x50 mm

5 Special adhesive label – *Posebna ljepljiva etiketa*
Plasto-Label TI HF-1 plus, 50 x 50 mm, Schreiner LogiData

6 ISO card – *ISO kartica*
Philips I-Code, 54 x 86 mm, X-Ident

Fig. 1 Tested RFID tags
Slika 1. *Testirane RFID pločice*

allows a particularly slender design. Such glass capsules, when incorporated into plastic nails, for example, can be driven into wood.

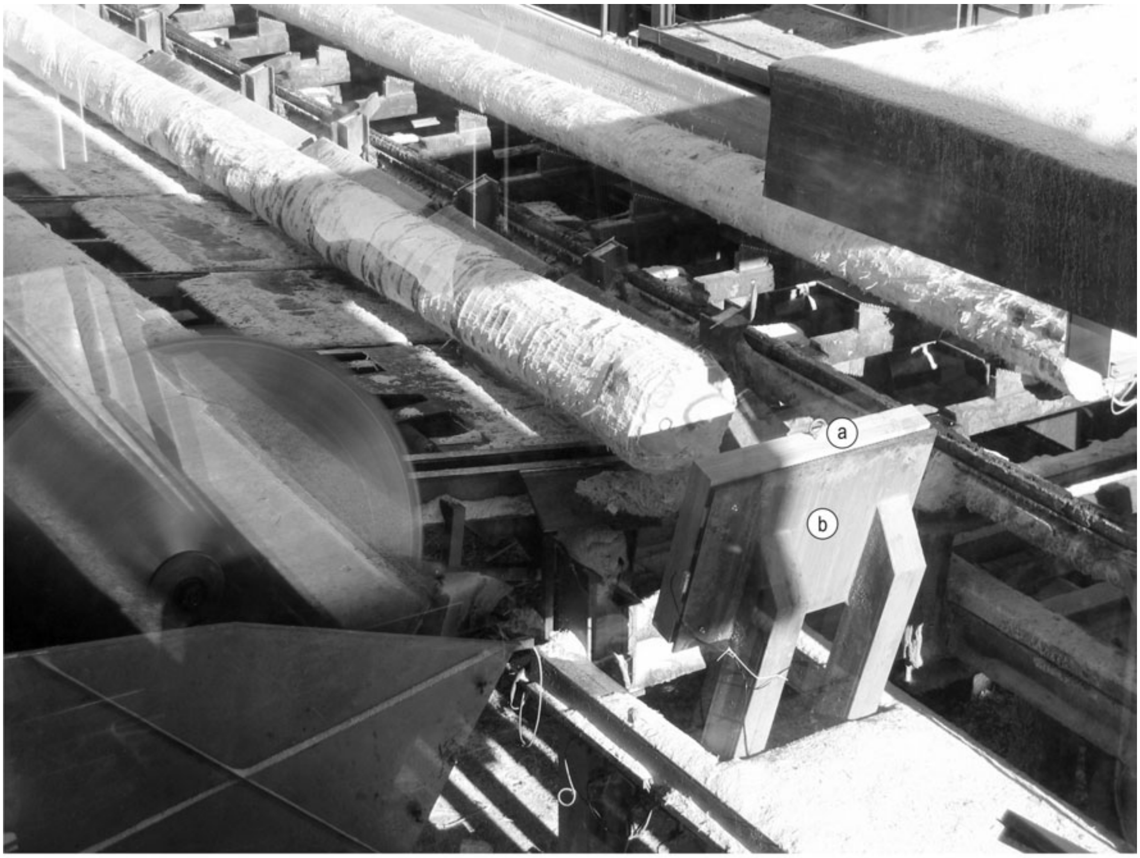
In comprehensive tests, potentially suitable LF and HF transponder tags of different design types were examined for their durability and weather resistance. Furthermore, some design types were submitted to load tests (Korten and Schneider 2006). Due to their high sensitivity to liquids and metals, transponder tags of the UHF range were eliminated beforehand. Finally, the selected tag types (Fig. 1) were used in several practical trials in both the motor-manual and highly mechanised timber supply chain.

3. RFID in the Motor-Manual Timber Supply Chain – *RFID u ručno-strojnom lancu dobave drva*

For the use in the motor-manual timber supply chain it is a prerequisite that transponder tags can be fixed manually. After each work step the tag number can be recorded manually by means of a reader and a MDR (mobile data registration) device with subsequent transmission via GSM to a trial database.

The experiment took place in an old stand of Norway spruce and was carried out with transponder tag type (Fig. 1). Immediately after **cutting and processing long lengths**, 30 tags of each type were fixed on the front side of the thick log ends. Another 30 pieces of the nail transponder tags were driven through the bark laterally at a distance of approx. 2 cm to the cutting surface. The tags were fixed depending on the tag type always one tag per one log. The Signumat plates were fixed with a special hammer, the cards were fastened with a stapling machine, adhesive labels were also glued and stapled in order to prevent loss. The coins were screwed and the nail transponders were driven in. The experiment was carried out in December and January with strong frost. Fixing the nail transponders turned out to be the biggest problem. About 12% of the nail tags to be fixed on the front side, and 67% of the nail tags to be fixed laterally were destroyed. This was due to the fact that the penetration resistance for fixing across the fibre was often too high. Previous drilling or punching of holes for the nail tags could be of help. All the other tags were operational after fixing.

Once the tags were fixed, timber data were registered in the stand for each stem individually by means of the MDR device *TimbaTec Recon* with the software programme *MobileForst*. Subsequently, the number registered on the tag was read and linked with the timber data. The MDR device had a reading



(a) at the log-pusher – *na potiskivaču trupaca* (b) between debarking and chop cutting – *između koranja i cjepanja*

Fig. 2 Reading-antenna
Slika 2. *Antena za očitanje*

range of a few centimetres in the tested frequency ranges (LF and HF).

After **cable-skidding** the logs to the road, the transponder tags were read manually. As no timber data were entered there, and only the tag numbers were registered, the reading was clearly faster than the first reading in the stand. It turned out that two of the nails fixed laterally were destroyed during the extraction process. All other tags were still in place and operational. However, depending on the tag type and the situation of the stems on the pile, reading was partly difficult when the pile was not flush.

For log **transportation with a whole tree trailer**, the tags of a respective load were read manually after loading in the forest. It was easy to register the tags showing the direction of motion, because the stems were generally stacked flush and could be reached easily from the truck. On the contrary, it was often difficult to read tags looking backwards, because shorter stems or stems lying on top could hardly be reached with the MDR device. If two short stems are to be loaded one behind the other, attention must be paid to the fact that the marked stem end looks towards the outside and can be reached from the front or from the back. Except for one adhesive label, all transponder tags could be read after loading. No mechanical destruction was visible on the defective label. The reason for the defect was not clear. After transportation to the saw mill and subsequent stacking, the tags were read again by means of the MDR device. No other tags were destroyed during transportation and unloading.

At the **saw mill** the tag numbers were read after debarking and before chop cutting (Fig. 2). As the debarking knives reacted to pressure and were not controlled optically, 75% of the transponder tags fixed on the front were removed and/or destroyed during debarking. The laterally fixed nail tags did not survive the debarking process either. The rest of the functional tags were read by means of LF and HF antenna systems on the log-pusher. The log-pusher aligns the stems on the cross conveyor by exerting pressure on the thick-end of the stem in a way that the chop cutting saw cuts the stem by approx. 5 cm. The tags were read during the pushing process and, therefore the necessary reading distance was only a few cm. Recording of the intact tags with the reading antenna on the log-pusher was done without any problems except for the nail tags fixed on the front side (Fig. 1). They could not be read because of insufficient field-strength, which was due to the difference in size between the transponder antenna and the reading antenna.

4. RFID in the Highly Mechanised Timber Supply Chain – *RFID u visoko mehaniziranom lancu dobave drva*

In the highly mechanised sorting of short lengths with harvesters, the tags should be fixed automatically during processing. It would be neither very reasonable nor productive to interrupt this highly productive harvesting process for fixing tags manually. In the same way, the tags must be read automatically after hauling and transportation because manual recording would slow down the work considerably. Therefore, the subject of this study was automatic fixing of tags by the harvester, forwarder (automatic reading) and short timber truck.

The tag-fixing device developed for the **harvester** was designed in such a way that its incorporation into the saw box of the harvester-head Ponsse H73 was possible. For study purposes, the device was mounted in a separate saw box (Fig. 3). The additional saw box was necessary because it was not possible to permanently make tests on a complete head. The device is based on a pneumatic stapler. Staples of 25 mm leg length are used. A cartridge with 160 flexible ISO-cards (Fig. 1) is located behind the stapler head. The ISO-cards were used for the experiment because of the high reading range and because of the possibility to store them in a magazine and to automatically place them for fixing. The experiment took place in an old stand of Norway spruce.

In principle the device was working satisfactorily. During processing it was possible to mark several segments subsequently with a tagging card. Thereby the technical feasibility was proven in principle. During the tests, however, two weak points of the tag-fixing device were discovered. On several occasions the card supply did not work when cards from the cartridge got jammed in the guiding grooves. Furthermore, the device sometimes did not return completely into the saw box. This was due to the fact that the guiding bolt for stabilising the rotational motion in the guide rail produced a stronger friction resistance in the practical test than in the laboratory trial.

Fig. 3 Harvester head with RFID tagging-device
Slika 3. *Sječna glava s uređajem za postavljanje pločica za RFID*

Fig. 4 Reading-antenna behind the front grid of the forwarder
Slika 4. *Antena za očitanje iza prednje rešetke forvardera*

The pneumatic cylinder for the rotational motion was not strong enough for this purpose.

A HF antenna was developed and then used for the automatic reading of tags on the forwarder, on the short timber truck and later on in the saw mill. The antenna is composed of two one-turn copper coils with a diameter of 60 cm each. Each coil produces an individual reading field generating in total two partly overlapping reading fields.

On the **forwarder** the antenna was fixed behind the grid in front of the stakes (Fig. 4) and on the side at the stakes. The antenna was fixed as high up as possible behind the front grid, so that all sections could pass the reading field during the loading process. In analogy to the tag-fixing device developed for harvester heads the flexible ISO-cards were in use. When reading the tags it turned out that the front-grid metal reduced the reading range considerably. Whereas a reading range of about one meter could be reached without metal, this range was reduced to 50 cm due to the grid with the tag- and reading antennas in parallel, i.e. with fixing the tag cards to the sections on the front. However, this reading range still allowed good reading of the tags fixed on the front side. Laterally fixed tags produced an unfavourable mutual position of the antennas and, thus, the reading range partly sank to under 20 cm, which made automatic reading of all tags during loading almost impossible.

Lateral fixing of the antenna at the stakes had the advantage that no interference was produced by the metal of the stakes. Here again the tags were passed through the reading field of the antenna, which was possible without any problem during loading of the forwarder in the stand. With optimum orientation of the transponder tags (front side fixing) the reading range was more than 100 cm, with lateral fixing it was close to 50 cm. This range was sufficient for reading the tags during loading of the forwarder. In later practical application two reading antennas would be necessary, one on each side of the stakes. Whereas reading consumed no additional time as it could be integrated into the normal work process easily, there were problems with manipulating timber by crane. The reading antenna blocked the free space between two stakes and even overlapped it, which made smooth crane movements impossible.

In analogy to the lateral attachment on the forwarder, the antennas were also fixed to the stakes of a **short timber truck** (Fig. 5). The tags were read during loading in the forest. The findings were the same as in the forwarder experiment.

For recording the transponder tag numbers in the context of factory measurement, the reading antenna

Fig. 5 Reading antenna at the stakes of the short-wood truck
Slika 5. *Antena za očitanje na ručicama kamiona*

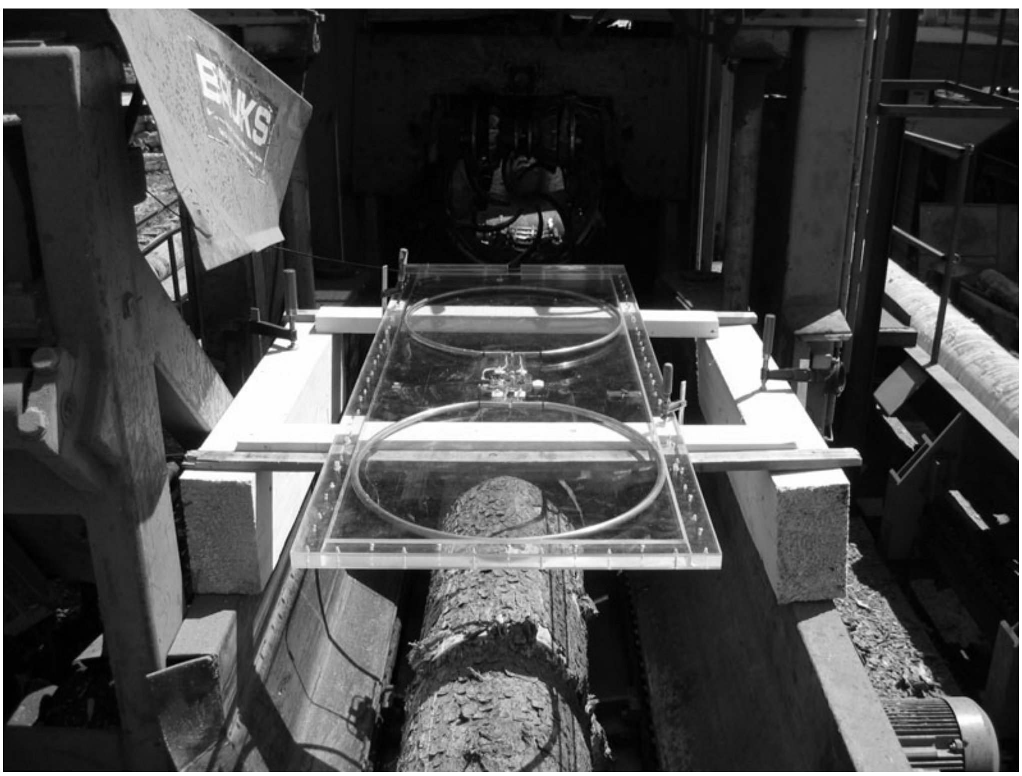


Fig. 6 Reading antenna in front of the debarker
Slika 6. *Antena za očitavanje ispred linije za otkoravanje*

was mounted in the **saw mill**. As the reading of the tags fixed on the sides had to be done before debarking, the antenna was mounted directly in front of the debarker at a height of 100 cm above the longitudinal conveyor (Fig. 6). The tag cards in use could be read without problems regardless of their orientation. With the corresponding reading adjustment, even laterally fixed tags lying directly on the metal surface of the cross conveyor and, thus, passing the antenna at maximum distance (100 cm) could be read. Cards that were later experimentally fixed on the front side could also be read reliably with the antenna equipment installed.

The tag-fixing device and the antenna system are only utility models which have not been designed for practical application and, hence, do not meet the requirements of long-term practical use. They are rather meant for gathering first experience and serve as a basis for further industrial development work.

5. Requirements for RFID in the Timber Supply Chain – *Zahtjevi RFID-a u lancu dobave drva*

For both the motor-manual and highly mechanised timber supply chains, the following requirements can be deducted regarding work frequency, with respect to the reading range, design and location of tags to be met by the RFID systems (Kaul 2007).

In the **motor-manual timber supply chain** it is of advantage to fix the transponder tag on the front side of the stem, because there is less mechanical load during cable logging than on the sides. After skidding, manual reading with a MDR device can be done by a forest worker on site. Here it is of advantage to have the tags fixed to the front side because they can be found more easily in stacked timber.

In the motor-manual timber supply chain there is no need for a high reading range because the tags are read manually. This allows the use of both LF and HF transponder tags. A high reading range and bulk reading at the stack and on the long-timber truck would facilitate and speed up the work process. However, when reading the tag numbers on the cutting area and in the saw mill, individual stems must be recorded specifically. Therefore, bulk reading is probably counterproductive in those cases.

The tag design used should be robust and weather resistant. Apart from that there are no further special design requirements. However, the fixing method and the necessary tools depend on the tag design. Regarding dimension and weight, every tag-fixing tool should be as compact and light as possible. In order to be handy it should be possible to wear it on the working belt. Thus, it can be reasonably expected for a forester to carry an extra stapling machine or light hammer.

In the **highly mechanised timber supply chain** the tags should be attached without any considerable delay and without interruption of the working cycle, because even minor losses in productivity would show clearly in the cost statement due to the high share of fixed costs. Therefore, the tags should be fixed by the harvester during tree processing. This implies that a tag-fixing device must be incorporated directly into the harvester head. Then the tag numbers can be linked to the relevant data of the section in the harvester's records.

For lateral attachment the tags can be fixed during cross-cutting, which does not need extra time. Furthermore, it is possible to mark the log section already processed. Front side attachment of the tags would highly facilitate the subsequent logistic processes because of the more favourable orientation of the tag antenna. However, it can only be done after cross-cutting, which necessarily needs more time. In addition, log marking is done before processing. The problem is that it is often not clear before processing and measuring if there is another log section to be cut. Marking on the front side of the section already processed is technically not possible, because the log section falls down after cross-cutting. Reading of the transponder tags should take place only after successful tag attachment in order to ensure the operability of the tags after their attachment. In the process of short-timber extraction on the cutting area the logs sections are loaded by crane onto the forwarder and not hauled by cable over the forest ground. Thus, the lateral mechanical pressure is limited to the contacts between the log sections and the contact with the grapple during the loading processes. Therefore, a lateral attachment is feasible in principle. However, fixing the tags on the front side would be more suitable because, on one hand the tags would be better protected and, on the other hand, they would be better oriented towards the reading antennas, which would clearly increase the reading range. This is also the case for loading on a short-timber truck.

For automatic reading during forwarder or truck loading, reading ranges of more than 0.5 m are obligatory and more than 1 m would be desirable. In any case, bulk reading is necessary as several log sections are transported simultaneously by the loading crane. Therefore, LF tags are not suitable in the highly mechanised timber supply chain. The HF tags used met the requirements.

Magazine feeding is a precondition for automatic tag fixing and requires a magazine suitable tag design. Every re-loading of magazines means an interruption of the working process, which should happen as seldom as possible. Therefore, a high feeding capacity of the magazine is desirable although the small space available in the harvester head is a limiting factor.

At the **saw mill** reading of both the tags fixed laterally and on the front side is technically feasible. The tags fixed laterally must be read in any case before the debarking process. In case of unsatisfactory debarking, however, stems are again put in front of the debarker, which changes the order of the stems that are not marked any more after debarking. Thus, the tag information can no longer be linked clearly with those of the later factory measurements. Consequently, it would be preferable to read the tags after debarking but before chop cutting. To realize this, the tags must go through the debarking process without being damaged. This is only possible with central fixing on the front side and debarking devices that are controlled optically.

In view of different stem diameters, laterally fixed tags require reading ranges of up to one meter. If the position of the antenna is always adjusted to the respective stem diameter (e.g. antenna curtain) lower reading ranges are also possible. In principle, LF and HF tags can be used here.

These results confirm that RFID technology is suitable for use in the timber supply chain. The tag-fixing device and the antennas that were developed are preliminary models. Further research is necessary for the development of tag design as well as for fixing and reading methods.

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Sažetak

Primjena RFID-a (radijske frekvencijske identifikacije) u lancu dobave drva

U radu se prikazuju mogućnosti primjene radijske frekvencijske identifikacije (RFID) u lancu dobave drva. U procesu dobave drva od šume do drvne industrije u Njemačkoj sudjeluje velik broj malih i srednje velikih šumarskih tvrtki, što ima za posljedicu visok stupanj dezintegracije toka materijala i informacija. Ipak, nadzor i/ili kontrola dobave nemoguća je bez poznavanja koliko se drva nalazi gdje u određeno vrijeme. Dugo vrijeme isporuke i povezani gubici u kakvoći pritom postaju neizbježni. Pokušaji da se nedostatak informacija nadoknadi višestrukim izmjerama i inventurom obloga drva na određenim točkama u lancu dobave su skupi i često stvaraju pogreške pri procjeni, unošenju i prenošenju podataka. Unapređenje cjelokupnoga procesa moguće je uspostavom sustava za upravljanje lancem dobave drva. U tom se smislu u posljednje vrijeme povećana pažnja pridaje mogućnosti *primjene radijske frekvencijske identifikacije u kontekstu jasnoga prepoznavanja proizvoda u lancu dobave. Time bi se ostvario značajan doprinos nadzoru i kontroli toka proizvodnje i informacija te pružila jasna slika o vrsti i količini proizvoda na određenom mjestu u određeno vrijeme.*

Radijska frekvencijska identifikacija zasniva se na razmjeni podataka elektromagnetskim valovima između nosača podataka (primopredajnik, pločica) i čitača podataka. Primopredajnik se u osnovi sastoji od mikročipa za pohranu podataka i zavojnice koja služi kao antena. Ako se primopredajnik nalazi u elektromagnetskom polju čitača, tada je moguća razmjena podataka između primopredajnika i čitača.

U radu je ispitana mogućnost primjene RFID-a u ručno-strojnom te visoko mehaniziranom lancu dobave drva. U oba slučaja istraživanjima su obuhvaćene sve karakteristike važne za praktičnu primjenu RFID-a. Testirane su različite vrste primopredajnih pločica prema tipu, obliku, načinu pričvršćivanja na trupce, području rada (LF – niske frekvencije, HF – visoke frekvencije). Promatrani su domet očitanja, osjetljivost na tekućine i metale, kapacitet očitanja obujma (istodobno očitanje više pločica), mjesto postavljanja pločica na trupcima i gubitak pločica pri sječi, izradi, privlačenju i transportu. Za primjenu u ručno-strojnom lancu dobave drva preduvjet je ručno postavljanje primopredajnih pločica. U sastojini su zabilježeni podaci svakoga trupca posebno i povezani s brojem pločice. Nakon svake faze rada pojedina je pločica ručno evidentirana pomoću čitača i mobilnoga uređaja za registraciju podataka te naknadno putem GSM-a odaslana u probne baze podataka. Nekoliko vrsta primopredajnih pločica bilo je moguće očitati na svim dijelovima puta od sastojine do drvne industrije.

Pri visoko mehaniziranom postupku pridobivanja drva pomoću harvestera pločice se moraju automatski postaviti prilikom sječe i izrade. Ručno postavljanje pločica neproduktivno je i nerazumno ometanje i prekidanje u visokoproduktivnom procesu pridobivanja drva. Na isti način pločice je potrebno očitavati automatski nakon izvoženja i transporta trupaca. Stoga je u istraživanjima promatrano automatsko postavljanje pločica pri radu harvestera te automatsko očitanje pločica pri utovaru drva na forvarder, na šumski kamion te pri istovaru u pilani. Na harvestersku je glavu ugrađen poseban uređaj za postavljanje primopredajnih pločica čime je omogućeno njihovo automatsko postavljanje. Pločice se također automatski očitavaju pri utovaru trupaca za izvoženje iz sastojine ili prijevoz do pilane.

Rezultati su istraživanja pokazali da je primjena RFID-a u lancu dobave drva tehnički moguća. Uređaj za postavljanje pločica i antene razvijene za istraživanja su početni modeli. Za praktičnu primjenu RFID-a potrebna su daljnja istraživanja i unapređenja posebno s obzirom na oblik i vrstu primopredajnih pločica te način njihova postavljanja i očitavanja.

Ključne riječi: *lanac dobave drva, RFID, uređaj za postavljanje pločica, identifikacija trupaca, tehnički zahtjevi*

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