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Overview: passive RFID technology in agriculture

In various modern industrial applications, RFID technology (Radio Frequency Identification) helps to provide accurate information related to a certain object to an exactly defined point. In agriculture too, RFID technology is widely spread and has proved to be successful. It will be shown, that new fields of application of RFID in agriculture can be realised by continuous development, such as system miniaturization, low cost manufacturing and continuous addition of features.

Keywords
RFID, transponder, innovation, technology transfer

Abstract
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A RFID system comprises a transponder attached on, or in, an object or living creature. It also includes a reader for communicating the data stored in the transponder. The amount of data that can be stored in the transponder ranges from a few bytes (e.g. for identification numbers) to several kilobytes (e.g. documentation of process flows). The reader instrument steers the actual reading process and represents via middleware the interface to further IT systems and databanks. RFID systems thus enable the automatic identification of objects and living creatures as well as continual updating of recorded and stored data.

The system energy supply is of central importance

In the following is briefly explained how RFID transponder technology has proved itself in agriculture. An important reason for this success story is that passive transponders require no own energy source but instead receive the necessary energy for power via electromagnetic coupling over the reader. Through this these transponders have an almost unlimited operating time, are cost efficient to manufacture and work very reliably.

In practical application inductive coupling via an oscillating magnetic field (proximity coupling at 125 kHz or 13.56 MHz) and electromagnetic radiation coupling (far field coupling at, for example, 868 MHz or 2.4 GHz) have become established with passive transponder technology [1]. The given frequencies are according to international standards that establish, among other things, frequencies and maximum field strengths in order to avoid or minimise systems affecting each other's performance. Basically, what happens in bi-directional communication between reader and transponder is that the reader sends an order or data to the transponder via the electromagnetic alternating field and so communicates with it. The transponder modulates the signal by altering its impedance so that in this case an altered return signal is produced which in itself can be detected by the reader via the coupling [1; 2].

So that a bi-directional data transmission takes place and, with that, a successful communication between transponder and reader, sufficient power must be coupled over the antennae of the transponder and made available to the transponder chip. For this, the distance between transponder and reader must not be too great. This requirement can pose a problem in practice because often the distance cannot be reduced when required, or it proves not possible to couple enough energy because of interference sources (metals, conducting liquids), or because of antennae adjustments not being optimal.

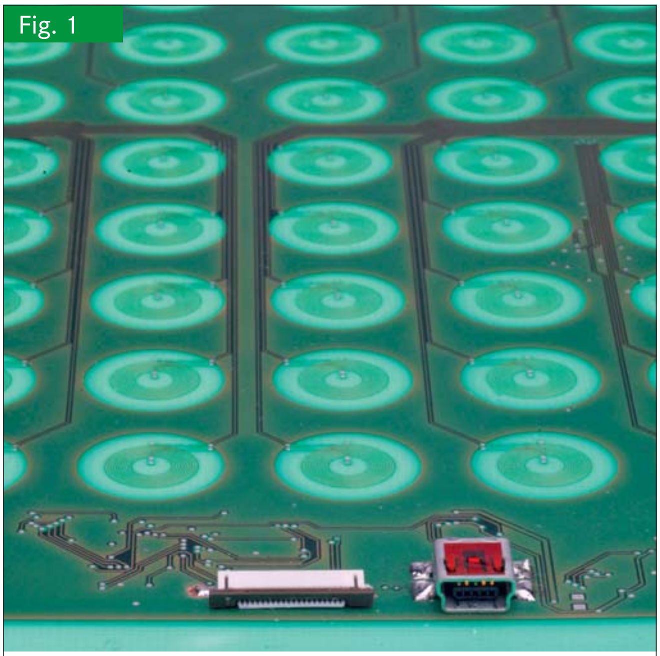
This means the available standard transponders and readers are therefore no longer sufficient for many situations in practice. This applies especially in agricultural engineering where special demands include resistance against dirt and moisture as well as mechanical stress. Required here are individual adaptions of antennae coil, substrate and encapsulation (to protect the electronics).

Trends in technical advances within transponder technology

a) Precise location readings: Through special positioning of several readers the RFID system allows a precise placement of transponder positions. This allows accurate searching for the actual position of transponders, or of implements equipped with transponders. For example, 225 transponders or even more can be read in less than two seconds (**figure 1**) [3]. Collision recognition and, with that, sequential reading of several chips in a reader area is also pos-

sible in some RFID ranges (among others, at 13.56 MHz).
b) High reliability/very robust transponders: Compared with barcode systems reading a transponder is less strongly affected by dirt or wear because no optical communication is necessary. With an appropriate encapsulation, passive RFID systems are thus very robust in the face of environmental influences. They are also absolutely maintenance free.
c) Coupling of transponders with display elements: Also realisable is the coupling of a passive transponder with bistable optical displays according to the principle of Electronic Paper Display Technology (EPD) [4]. While the RFID components carry out the conventional identification of the object, transponder contents are simultaneously directly readable for the user via the display (**figure 2**). No own energy supply is required here for maintenance of information on the display. Only a change in the contents of the display results in an energy requirement. This, however, can be wholly supplied by the coupled energy of the reader.
d) Optimisation by given model size: With many applications the location of transponder and, with that, the antennae area is predetermined. But the antennae area has a direct effect on the reader range and thus reliable data exchange, and often makes an individual electrical adjustment of the transponder antennae necessary. Modern simulation programs now allow three-dimensional layout and optimisation of antennae.
e) Transponder use in association with sensors: The extension of transponders with sensory abilities will significantly increase the future area of use, especially with passive transponders. Challenges here, however, will be the development and selection of sensory abilities with lowest energy requirement because the energy supply of the passive systems takes place completely over the electromagnetic coupling.

Fig. 1



Exact localization with multiple readers

Fig. 2

RFID transponder with display

f) Transponders on flexible materials: The application area of RFID technology will be significantly expanded through new load-bearing materials and construction technology:

- The application of extremely slimmed-down transponder circuits enables the construction of flexible transponders.
- The use of elastic substrate materials allow the application on animals or people, for instance in a chest strap. The realisation of metallic conductors with flexible or elastic materials means that electrical and mechanical framework conditions are altered. For instance a special demand is presented by the meander-form layout of metallic conductors in the case of elastic materials [5].
- New applications for integrated transponders in textiles. This application goes so far that the antennae structures can be manufactured through interwoven or sewn-in conductor threads [6].

g) Cost efficient assembly procedures: Especially with high unit numbers, transponder manufacturing costs play an important role. For application as mass products, transponders should not cost more than a few cents apiece. The realisation of the transponder antennae in reel-to-reel processes [7] enables, with the help of printing techniques and the use of cost-efficient silver conductivity paste, a very economic manufacturing process. Compared to the barcode system, the current transponder with costs of 20 cents remains simply much too expensive. Higher prices may be justifiable, however, if additional benefits can be offered, or multiple applications.

Application of RFID in sectors related to agriculture

Passive RFID technology has been applied for many years now for animal identification [8; 9]. The technology in this case has proved itself under unfavourable environmental conditions and has been further developed. Highlighting other application possibilities in agriculture are two further uses presented below, whereby the application of RFID technology is for other reasons.

The first application is in horticulture where passive RFID transponders are used in a tree nursery to identify a special type of elm (Resista ®) [10]. The transponder is implanted under the bark and remains there even after delivery to the customer. With this method the tree nursery can give a guarantee of authenticity, and of the tree's source.

The second application comes from the construction machinery sector. Such equipment work under hard conditions with tough requirements made on the robustness of the technology. In this case the RFID technology supports management of different attachment tools for hydraulic diggers [11]. The fully automatic coupling systems are equipped with a RFID reader from manufacturer Pepperl + Fuchs and the attachment tools themselves fitted with passive RFID transponders (**figure 3** and **4**). This allows transmission of relevant data e.g. oil level, pressure and type of oil, when the digger and the respective tool are coupled. The working hours of the attachment tool is also recorded and transmitted for further processing. This information can support equipment use analysis within the company or can be applied in calculations for leased equipment.

Limitations and future challenges

But it has to be recognised that RFID technology has its physical limits, especially with regard to reader operational range and sensory possibilities. The pushing outwards of these limits and the further improvement of activity areas for RDIF systems under difficult conditions is the aim of current developments:

- Utilising higher frequency ranges for RFID systems (100 GHz and higher)
- Improving simulation and optimisation processes in the development phase towards increasing reader reliability/ reader speeds
- Further increase of functionality with passive transponders through integration of additional components (sensors, displays, etc.)
- Further miniaturisation and form adjustments of RFID systems and the realisation of more complex packaging concepts (shape-adapted, material-adapted, extremely thin, very small, etc.)
- Application of transponders in high and low temperature surroundings (< −40 °C and > 150 °C)
- Further reductions of manufacture costs for transponders

Examples of future applications for passive RFID technology

A research project underway within the Agricultural Engineering Section of the Department of Crop Sciences at the Georg August University in Göttingen emphasises the possibilities of greatly improved RFID systems. Investigated in this project is to what extent the traceability of marked individual grain batches can be supported with the help pf RFID technology. The concept in this case features introduction of RFID transponders in the grain as early as harvest time when it is still in the combine. Such transponders must be adapted to fit the particle characteristics of the grain through special encapsulation to avoid the transponders becoming segregated from the material. This concept means clearly traceable grain right up to shortly before its processing [12; 13].

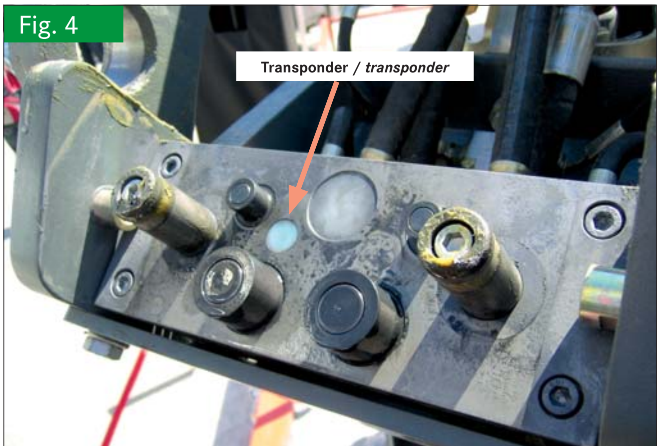
This application has become possible through the miniaturisation of RFID components in recent years without which the project described above would have been unthinkable. Here, though, the limited range of the technology has to be taken into consideration. The information in the transponders cannot simply be recovered at any point along the transport chain. Instead, this can only occur at certain narrowed points, e.g., pipes with additional separating action.

A further challenge is the integration of RFID transponders directly into objects. The advantage of this approach is that accidental separation of transponder and object is prevented with the required information remaining almost inseparably affixed. Exemplifying this approach is the embedding by the company FESTO of RFID transponders in spare parts as protection against copies [14]. In this case a functional RFID transponder

Fig. 3

Hydraulic shovel with attachments

Fig. 4



Attachment with embedded transponder

has been embedded in a plastic replacement part despite temperatures in the manufacture that, for short periods, reached over 240°C.

Conclusions

Passive RFID technology has developed significantly in recent years. Through miniaturisation and increased reliability, even under difficult conditions, new application fields have been opened up. The current manufacturing process enables nowadays cost-effective transponder production with realisable prices in the lower double figure cent range. The practical applications presented in this paper show the breadth of application possibilities for RFID technology. However, it is always necessary to adapt technology to requirements and, where necessary, readjust individual process steps for the practical application of a new process. The examples given for future applications offer an impression of the areas where a proportion of the challenges lie, e.g., operating range and temperature resistance.

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