

APPLICATIONS OF RFID (RADIO FREQUENCY IDENTIFICATION) IN AGRICULTURE

Adrian Watts and Paul Miller from Silsoe Research Institute, and Dick Godwin from Cranfield University-National Soils Research Institute outline the features of a new automated method of data capture and transfer, and its application in agriculture.

Introduction

The use of barcodes and electronic tags is widespread in supermarkets and domestic retail outlets in the UK. Warehouse stock audits, airport baggage handling, and assembly operations have been made more efficient and less prone to error by giving single units an identity which can be read electronically and automatically.

The farm is an environment where the incorrect application of chemicals or other inputs could have significant environmental impacts, and yet such applications are commonly based on both farmers' judgement and agronomists' instruction. There is, therefore, the potential for substantial error in chemical use with existing systems (Miller, 1999).

The use of an identifier on the product which could automatically be read would enable the tractor/implement combination to make records about what is being put into the implement's hopper or tank. In the case of a chemical sprayer, the knowledge could be used to make sure that application rates are within recommended limits and combinations of chemicals are also approved. Knowledge of the chemical, combined with field, weather and operator data, would allow automatic monitoring of buffer zone width, thus ensuring LERAP compliance and generate automatic and detailed records of the day's spraying activities. The information held in the computer, in a standard format, would then be accessible to those further down the food supply chain.

Automated transfer and capture

Before data can be transferred electronically it must first be generated. One simple method of doing this is the keyboard. This is certainly a versatile method, however the keyboard operator will often make mistakes (a good typist makes one mistake in 300 (Osman, 2000)). Automation of the data input process would minimise the possibility of such errors (barcodes: 1 in 2,000,000 (Osman, 2000)) and speed up the input process. Information is input to a system either for storage, or to enable the computer to make decisions and initiate appropriate actions. Ultimately all information should be transferred to a master storage device (office computer) where it can be safely kept for reference purposes at a later date.

For systems to be automated each part of the system must, at the very least, have its own identity which can be electronically interpreted. This imposes limits as to which technology would be appropriate in any system. The

identifier must therefore be:

- *Small*: to make it easy to integrate with whatever it is identifying
- *Low cost*: to ensure that whatever it identifies has minimal price change
- *Low power*: has implications for size and cost as well as length of time information is stored
- *Reliable*: ease of data transfer with minimal risk of loss of information

Automatic data readers are the gateway for information to get into the system. They are therefore installed at a few key points. They can be bulkier, powered and proportionally more expensive. By appropriate connections they can be linked to one another and the central computer.

There are a number of technologies available that allow automatic identification and data transfer including barcodes, optical character recognition (OCR), spectral analysis and speech recognition. The RFID system is potentially the most suitable for farming applications and is therefore the subject of this article.

RFID (Radio Frequency Identification)

Although RFID has been in existence since the 1940s, only in the last 5 years have technological advancements allowed them to compete with barcodes on price, performance and size. Until recently there were limited standards for these devices. Today with many of the standards complete, or soon to be so, and with data storage capacities comparable with barcodes, RFID devices could be used for a totally automatic record creation system.

How they work

An RFID system is made up of a transmitter, receiver (transceiver) and a transponder. Firstly a low power radio frequency wave is propagated from the reader (Witt 1997), with sufficient energy in the wave to allow the generation of a voltage within the transponder aerial. This energy is then used to modulate the signal appropriately, which effectively puts the information on the tag into the signal. The receiver reads the modulated signal and decodes it accordingly. Some transponders have a capacitor within them that is charged during the transmission from reader. When the transmission of the signal has finished, the energy stored in the capacitor is dissipated within the transponder allowing a new wave to be formed. If longer range and greater storage capacity are required, this capacitor can be replaced with a battery thus



Figure 1. RFID tags – solid tags for containers/pallets; glass encapsulated tag for injection beneath skin; tag for moulding; tag integrated into key fob; tag integrated into I.D card (Source: Texas Instruments).

forming an active transponder. Transponders are available in a variety of sizes and types. These vary from glass or plastic encapsulated tags a few millimetres in diameter and length to a flat flexible type printed onto a PET substrate measuring typically 40 × 80 mm. Other types using different frequencies, manufacturing methods and whether they are active or passively powered all mean that a suitable RFID tag can be found for most applications. These features are discussed below.

Transponder types

- **Tags.** Tags are designed so that they can be moulded into the object that they contain information about. They are hard and inflexible. The larger ones normally have mounting pads on to allow them to be screwed or bolted to objects. Applications for these include the identification of large warehouse containers and pallets. The smaller tags (sometimes glass encapsulated) can be moulded into animal ear tags, hidden under the skin of animals or taken in the form of a swallowed bolus. Examples of tags are shown in Figure 1. The antenna are generally of the wire around a ferrite core construction, or wire wound around the periphery of the tag, therefore determining a shape of either oblong tube or disk. The amount of information stored on tags can range from a 16-bit identifier to 8 kilobytes of data for a large powered disk type (Finken-zeller, 1999).
- **Smart labels.** Smart labels are designed to be integrated into or behind an existing barcode or information label. For the smart label to be as flat as possible the aerial is a loop type made from copper or aluminium etched onto a thin layer of plastic. The chip and the appropriate connections are then bonded to the plastic surface. Because they are thin (TI tag it label is 0.085 mm thick) these labels can conform to objects, and will not be broken by flexing. This allows the barcode or human readable information to be printed on after smart label

integration. Recent applications include the identification of airport baggage and higher value domestic goods identification, where the value of the label contributes only a small proportion of cost. The most recent standards (Anon, 2001) define a protocol for communicating with smart labels based on a frequency of 13.56 MHz. Manufacturers are now offering tags conforming to this standard with up to 10 kbits of storage capability. Smart labels are passive only. Examples of smart labels are shown in Figure 2.

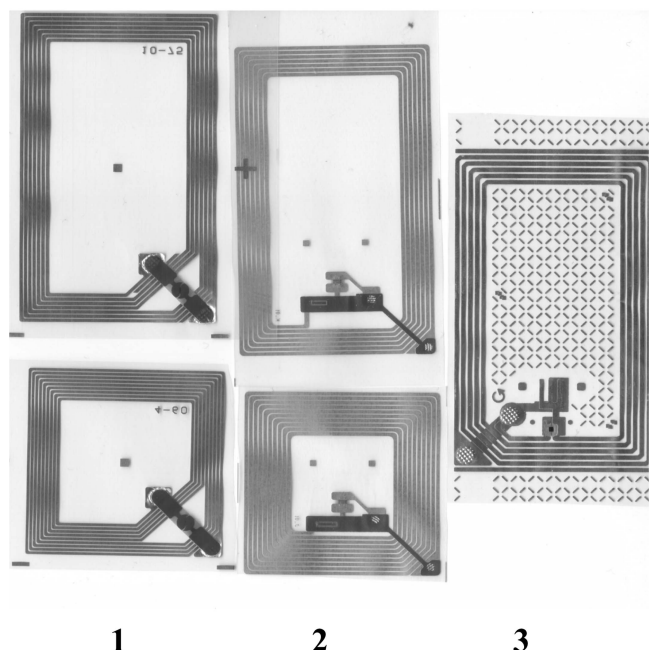


Figure 2. Examples of 13.56 MHz Smart labels: 1)Phillips I-Code labels; 2)Texas instruments Tag it; 3)Infineon ISO 15693 10Kbit My-d label.

Frequencies

RFID tags, and transmitters are available in a wide variety of frequencies. They are classified as short-range devices, and can work on unlicensed ISM (International Scientific and Medical) frequencies. Common standard frequencies include 135 kHz, 13.56 MHz, 868–870 MHz and 2.45 GHz. The frequency determines read range, the ability of the wave to penetrate objects and data transfer rate. Higher frequencies have less penetrating ability, but longer range, so, in line of sight applications have advantages. Lower frequency devices have less read range, and slower communication speed, but good penetrating ability enables them to be used when moulded or injected into an object or animal.

Alternatives to RFID

There are many alternatives to RFID systems. The most common one is the linear barcode, which is seen at most retailer outlets. These codes only carry a product identifier, and therefore need the support of a database. Product information can therefore be controlled centrally (Blackie & Dent, 1979). This is advantageous where products are not unique, and their location easily controlled. On the larger scale however, a database may be difficult to manage, and access to the information may be difficult. Other methods include magnetic barcodes, stripe cards, DNA/materials sampling, and audio recognition. Most of these are however not yet totally automated, are too costly, or have problems with dirty environments that will limit their application on a farm.

Applications in agriculture

There are a number of areas where the use of automatic identification and data capture systems would be beneficial on the farm. If trends continue such that the average grower has the responsibility for more land area, these advantages become more apparent. Larger farms mean a greater amount of information that the grower has to handle. Efficient manipulation of this data can only really be achieved by using the capability and speed of the computer. Using manual methods to enter the appropriate data has the problems outlined earlier, *i.e.* the potential for error and the low speed of data entry. It also adds burden on the grower who would inevitably be the bottleneck in the system.

Before information can be used it must be logged into the system. For this to occur, readers must be located in around areas where products are stored prior to use. Once logged, this information can be stored, and used where appropriate. Potential applications of this information are discussed below.

Input recording (fertiliser and agrochemical)

The addition of an automated data capture device to an applicator (whether it be chemical or fertiliser), and an identifier on products would allow the sprayer/spreader and tractor combination to make records of how the tank or hopper contents will be used. Chemical containers with RFID tags attached could be programmed with product

specific information that could interface with the implement. An example of some basic product information is shown below. With this information, the tractor/implement combination could start to generate management records and check for compliance with regulations.

Spray type	fungicide
Container size (l)	5
Manufacture date	1/5/2002
Use by date	1/5/2003
Active Ingredient	trifloxystrobin
Maximum rate (l/ha)	2.0
Recommended Dilution rate	200:1
Harvest interval (days)	30
Spray Quality	medium
Recommended Pressure (bar)	2.5
LERAP Class	B
Crop Varieties	winter wheat, winter barley, spring barley
Controls	mildew, brown rust, net blotch

The data could be used as follows:

- *All data*: combined with weather, position, time and operator data, an automatic record of the days spraying events could be created.
- *Container size, rate and dilution*: automatically calculate amount of water required for correct dilution: prevent maximum dose rates being exceeded: match sprayer loading to the area to be treated.
- *Active ingredient*: check compatibility with other products.
- *LERAP class data combined with mapping*: automatically set the appropriate width buffer zones; generate record to prove compliance.
- *Crop varieties combined with positional data*: ensure spray is not applied to inappropriate target.
- *Date information*: automatically stops the grower using out of date substances.
- *Harvest interval*: avoid an excess residue problem by making sure harvest date is after the clearance date: the date of applications would be stored. This information could be used as a product check at the point of delivery.

Additional information such as requirements for PPE (Personal Protective Equipment) and COSHH (Control of Substances Hazardous to Health) regulations could also be added to the tag. This would allow the machine to prompt the operator regarding his requirements before allowing the filling of the implement.

The use of a radio link between tractor and office computer could allow a record to be created at the same time as the application is occurring, or automatically afterwards (Miller, 1999). As well as the record, the information can be used to interface with decision support systems, allow easier checking of records by regulatory bodies and aid stock control/purchasing arrangements for delivery to the farm.

A new and valuable tool for the agronomist is the PDA (Portable Digital Assistant). This gives the ability to crop

walk and enter data into a computer system. This information could in future be downloaded to the sprayer and used as a cross-referencing tool, making sure there was no accidental error between actual application and agronomist recommendation.

The European Crop Protection Association is currently in the process of standardising the use of barcodes and the supporting databases on agrochemical packaging, to enable trading partners to realise the benefits of electronic commerce (Debecker, 2001). Claimed benefits include reduced inventory, less product obsolescence and improved administration efficiency. This does not extend to the grower. However, it would be possible to use the barcode as an identifier on the farm at a later date, by adding to the proposed 'Cristal' database, or implementing a separate one with a greater amount of product specific technical information.

Equipment setup

Many tractors now use computers to control functions such as gearshift patterns, hydraulics, PTO speeds and engine operation. Normally before start up, the tractor user will have to program in his requirements, depending on the implement that is attached. The use of an RFID tag or barcode on an implement, coupled with an appropriate reader on the tractor, the tractor could automatically know the implement characteristics. The information on the storage device could carry manufacturer recommendations relating to setup. For example, if a fertiliser spreader was attached to the tractor, the tractor would automatically know that position control of the rear linkage should be set and that a 540 rpm PTO is needed to operate the machine correctly. This would enable the farmer to determine implement utilisation and reduce complicated setup time.

Farm management

Remote links to fertiliser and chemical stores, combined with antenna fixed to doors or shelving, would make it possible to log what the store held at any particular time. This could minimise over ordering, keep hazardous inventory to a minimum, could indicate automatically when a product is going out of date, or automatically inform the farmer that a product should be destroyed as advised by legislative bodies.

One of the most important aspects of running a business is the preparation of accounts, calculations of the cost of production, performance and profit/loss. By recording what the inputs and outputs are more accurately, it should be possible to determine the cost of operations, machine utilisation and system efficiency.

Outlook

There are problems with RFID tags and their associated reading systems. Although the cost of the RFID tag is small in comparison with that of say a 5 litre container of chemical, bag of fertiliser or tonne of grain, it is still an added cost. The technology is not compatible with water-soluble packages. Tags are more appropriate as the move to returnable containers becomes established.

Another problem is that the read is not instant. The more data that has to be transferred means that the tag has to stay within the vicinity of the reader for longer. Speed of transfer and range are dependent on operational frequency, and thus there will always be a compromise of the two. Operational range is still an issue where regulations limit radio power, and there is the potential for non-operation where there is a lot of interference.

The use of RFID tags will not stop deliberate fraudulent activity, but it could make it more difficult. RFID would raise the standard of records, with buyers of product either paying a price premium for improved traceability with complete and electronic records, or demanding that the new standard is met before purchase.

Although the concept of RFID is not new, recent developments in the manufacturing of tags have allowed the cost to be reduced to the extent that they are now suitable for a wide variety of applications. Now that their potential has been realised, there is considerable research into increasing storage space, range, functionality and reducing cost. These can only bring more comprehensive benefits to the farmer, and consumer. One example is that of a tag which can monitor simple environment properties, such as product storage temperature. These are already being used for high value food products.

Overall, it is certain that the responsibility of the grower is increasing as regulations become stricter, and the areas farmed by one person become larger. Although the RFID tag will not remove that responsibility, it will improve the growers ability to process a larger and more detailed amount of information. This will enable farm efficiency to be maintained or improved whilst still being legally compliant.

Conclusions

It has been demonstrated outside the farming industry that the electronic transfer of information using barcodes, RFID and other devices can speed up operations and improve data accuracy. Some of these practices could be directly transferred onto the arable farm, to increase the production efficiency, traceability, regulatory conformance and reduce grower workload. To make sure no additional procedures are imposed, non-contact (*i.e.* free air interface) reading of devices must be implemented to completely automate procedures. Only RFID and barcodes meet this criteria, at an appropriate cost and size. The robustness of a barcode and reader is open to question in the naturally dirty farm environment, and this aspect of performance is currently being studied (Watts, 2002). It is likely that the RFID tag will provide a relatively cheap and robust method of automatic data transfer on arable farms, with particular applications in the transferring of detailed information to the control systems of application machinery.

References

- Anon, (2001) British Standard BS ISO/IEC 15693. *Identification Cards – Contactless Integrated circuit(s) cards – Vicinity cards, Part 3: Anticollision and transmission protocol*, British Standards, UK.

DATA PROCESSING

- Blackie, M. J.; Dent, J. B. (1979) *Information Systems for Agriculture*. Applied Science Publishers, UK.
- Debecker, G. (2001) Cristal: A standard to support E-Commerce within the European agrochemical industry. *Pesticide Outlook* 6, 118–120.
- Finkenzeller, K. (1999) *The RFID Handbook (Radio Frequency Identification Fundamentals and Applications)*, John Wiley & Sons, Chippingham, UK.
- Furness, A. (2000) Machine-readable data carriers – a brief introduction to automatic identification and data capture. *Assembly Automation* 20, 28–34.
- Miller, P. C. H. (1999) Automatic recording by application machinery of rates and spatial distribution of field inputs. Proceedings 439. International Fertiliser Society, York.
- Osman, K. (2000) *Assembly Automation* 20, 52–57.
- Watts, A.J. (2002) *The monitoring and control of chemical inputs in arable farming systems*. Eng.D. 2nd year progress report. Silsoe: Cranfield University at Silsoe.
- Witt, C. E. (1997) RFID: The future of data acquisition. *Material Handling Engineering* 52(5), 37–40. Cleveland, USA.

Adrian Watts is currently studying for an Engineering Doctorate in association with Cranfield University at Silsoe and Silsoe Research Institute. His project is concerned with the monitoring and control of chemical inputs to arable farming systems and is sponsored by the Engineering and Physical Sciences Research Council (EPSRC) and the Douglas Bomford Trust.

Paul Miller is the Project Director at Silsoe Research Institute and leads the research division in which work relating to pesticide application is conducted. He has been involved with many aspects of crop spraying research over the last 15 years and has published many papers and reports on this subject.

Dick Godwin is Head of Engineering, National Soils Research Institute and Director of Post-graduate Research at Cranfield University at Silsoe. He leads the work in precision farming, agricultural engineering and soil dynamics.

SILSOE RESEARCH INSTITUTE (SRI)

SRI is the only research centre in the UK dedicated to the application of engineering and physical sciences to a wide range of biological systems and processes, including applications in the food processing industry. SRI's remit was to develop the mechanisation of UK agriculture, but over the last 20 years there has been a strong move towards topics with a process engineering, modelling and optimisation, or environmental objective.

Science groups

- Environment
- Biomaterials Group
- Livestock Engineering
- Mathematics & Decision Systems
- Soil Science
- Image Analysis
- Chemical Applications
- Heat & Mass Flow
- International Development
- Robotics & Automation

Of particular interest to readers of *Pesticide Outlook* will be the Chemical Applications Group which has extensive experience of research on pesticide application systems, and how the behaviour of sprays from nozzle to target influence losses to drift.

For further information

Silsoe Research Institute, Wrest Park, Silsoe, Bedford MK45 4HS, UK (<http://www.sri.bbsrc.ac.uk>)