RFID - A PRACTICAL SOLUTION FOR PROBLEMS YOU DIDN'T EVEN KNOW YOU HAD!

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Introduction

Radio Frequency Identification (RFID) comprises a base radio transmitter/receiver, or reader, which can interrogate, display, and sometimes rewrite, an electronic code held in a remote device, transponder, and thus identify any item with which the transponder is associated. This paper introduces the ideas of RFID, using TIRIS technology as examples, with particular emphasis on how these principles can be utilised in practical applications.

A Brief History

Recently there has been such rapid development of RFID that products appearing today can be considered a totally new technology. The RFID concept began in the late 1940's to distinguish aircraft on radar. The idea of a radio transponder (*trans*mitter/res*ponder*) migrated into the commercial sector and found a few industrial applications using small battery powered modules, but the concept, remained fairly firmly anchored in aerospace until the Dutch Government voiced a new demand in the mid-1980's.

They wanted unique identification of around 75 million items almost impossible to label by other conventional techniques. Identification would greatly improve efficiency of handling, production and later processing, and secondly, there was a significant black economy with illicit transfers over the adjacent German border. The items had flexible surfaces unsuitable for gluing, few structural regions for tag attachment, were often exposed to weather, routinely caked in dirt, and not easily constrained to a fixed location. The items were pigs, and the result was the electronic tag.

This application required a totally new set of important parameters - particularly, small size, hermetic sealing and a freedom from batteries. By 1989 several companies responded with products, some of which are now in daily use by for pet ID, as the "microchip" required by the UK dangerous dogs laws, and identification of farm livestock. However, the very high volume market represented by millions of animals has yet to materialise due to slow establishment of international standards, and long safety approval cycles. Instead, manufacturers quickly recognised the enormous potential of RFID for industrial and commercial applications.

Early Commercial Directions

New generation transponders brought useful properties to the market:

- small size,
- passive battery-free designs,
- unique identity codes, and
- ability to be read over distances of approximately a metre.

They offer advantages over labels and bar-codes as the radio signal penetrates dirt, moisture, and most non-metallic objects. Many systems work at low frequencies where signals even travel round metallic obstructions. A security element is added because code is invisible without suitable readers, and with a passive tag the code is only broadcast by request in a period of less than one twentieth of a second.

The new concept attracted considerable imaginative interest, opened up new opportunities, and provided a solution to problems which had previously looked insoluble. Installed applications cover a very wide range of activities from access control to zoo management, from aerospace to underground mining. For those manufacturing companies in the RFID business, these opportunities also provided the spur to greater and ongoing technical development.

Technology Developments

The first tags were passive and **Read-Only** (R/O). This meant, that like anti-shoplifting tags, they were battery free, powered by the signal from the reading device. Tags are permanently uniquely coded during manufacture with a sixty four (64) bit binary number. The advanced design also includes hidden error checking codes to prevent data distortion by radio interference while FM transmission techniques offer noise immunity for many factory and office environments. This ensures accurate data can be retrieved in a single reading cycle unlike most other systems which require comparison of several consecutive values before displaying a result. R/O tags are effective, reliable, secure, and lowest cost.

R/O tags have one inconvenience - the numbers are set by the manufacturer and consequently are not always the most suitable for the application. This problem was solved by producing a **Read/Write** (R/W) tag capable of being programmed by the user. Further, tags can typically be rewritten more than 10,000 times. This opens up many applications, where, by being reusable, the cost per use of tags drops to fractions of a penny, way below the cost of many printed labels while still offering the precision of exact identification.

The very characteristic that makes reusable R/W tags suitable for so many applications, sadly also limits their use for others because the data is no longer secure - if the user can change it, then so can anyone else. R/W tags cannot be guaranteed to be unique. The **Multipage** (M/P) addressed this problem with a single device containing seventeen pages, each equivalent to one 64 bit transponder. Page 1 is factory programmed R/O, the next sixteen (P2-P17) are all R/W for user data. Capability to "lock" a page, converting it, once coded, to read only, is also provided, so some data, such as serial numbers, cannot be erased. Pages are individually addressable for both reading or writing, and readers can be set to default to a particular page containing specific data.

All these transponder types use the small size battery-free technology, and are generally compatible with each other so that in some applications they can be mixed and used together.

For wide market use, there are different packaging forms for convenient mounting or to provide different antenna designs for optimised reading performance. Transponders are available in miniature glass capsule, credit card, disk, and large cylindrical formats. Specially adapted designs can be provided quickly for some users. One such design, a mount-on-metal package for vehicles is now used in manufacturing and freight container tracking, while a compact form provides secure identification of computers.

Some Applications

So much for the technology, but how is it used? Let us now turn to some real applications.

Car Theft Prevention. In the UK, car crime has reached epidemic levels, peaking in 1992 with a car theft every 48 seconds! Alarms helped initially, but the "cry wolf" effect of the many false alarms quickly reduced their effectiveness. Ford took a radical view, realising they needed to immobilise the vehicle, but that setting procedures had to be simple if drivers were really going to use the system. RFID solved the problem, and TIRIS is now the basis for their "Safeguard" protection system.

Every key has a transponder moulded into the plastic head. In the vehicle, a low power reader is fitted around the ignition switch, and integrates with the engine management electronics.

When the driver tries to start the engine, the tag is verified before the vehicle starts. If the transponder is missing, or has the wrong identity, starting is inhibited. The advantages are that the system is secure, convenient, and does not require the driver to do anything extra.

As an indication of the security of the system, just one Safeguard equipped car was reported stolen in the first year of production - and that was parked with the keys in the ignition! Tests by several motoring consumer magazines, the most recent published in October 1996, consistently rate TIRIS equipped Ford cars as almost unstealable.

Ford have now fitted the system to their complete UK range for model year '95 onwards, have accelerated its introduction in Europe, and are incorporating it into US models from this year also. Their lead has been quickly followed by most other mainstream auto-makers, and crime statistics now show a 50% drop in new car theft, and thieves being forced to look at older unprotected vehicles.

For the US market, car crime is not recognised publicly as such a problem, so car makers provide added value with the key providing extra functions besides security. The "husband's" and "wife's" keys that automatically adjust seats, and mirrors already exist, but how about also pretuning favourite radio stations or selecting favourite tracks on the CD player, the "valet parking" key which restricts engine speed to below 2000 rpm and locks the boot and glovebox, or the "teenage driver" key which limits vehicle top speed to 50mph - and turns the stereo down to a reasonable volume!

Asset Protection. Low frequency signals have good penetration of non metallic materials meaning tags can be embedded into items which need surveillance. Their presence does not need to be indicated, nor does the reader, which can be concealed. Such tags can be used to trigger alarms on removal, confirm presence, or simply as an electronic registration number.

Readily available unnumbered presence indicating tags provide a cheap weapon against shop-lifting which RFID cannot yet meet on cost, although time is eroding price differences. But, for high value or priceless items, RFID can provide advantages.

One company uses tags to protect valuable antiques. Through a network of franchised craftsmen, tags are fitted during restoration, usually concealed under trim or veneers so as not to detract from the value. ID number, exact tag location and ownership validation details are kept on a database. If the item is stolen, a description can be circulated to Police and trade dealers. On recovery the tag is used to verify its identity. This concept is now being widened to encompass a variety of high value desirables including artworks, musical instruments, boats, jetskis and motorcycles.

A recent application is tagging of babies in hospital maternity departments allowing an immediate alarm and the unique number ensuring the baby is quickly recognised. A spin off from this application is the tagging of portable resuscitation equipment as the installed reading equipment allows instant location of the tagged item in an emergency.

Access Control. Access control is now a commodity market with very competitive pricing, but there are areas that gain from the added benefits of RFID. Transponders can be provided in a credit card or badge format, readable from a metre distance, even if in a bag, pocket or concealed by clothing. As a pure access method, the hands free convenience may not justify the added cost, but the equation changes if we consider the ability to switch off a dangerous machine automatically when the supervisor moves away, or shut down a sensitive computer terminal when the operator leaves the keyboard. A trading bank recently admitted losing about $50M in an illicit transfer on an open terminal while an operator went to the toilet.

Over the last three years, RFID has been used to tag runners in several city marathons in the USA, Japan, and Europe to provide automated race timing and instant print out of runners' names for the media. Although highly visible, and somewhat frivolous, this application highlights the suitability of using tags to monitor large numbers of people or equipment items which may need to pass a certain point, sometimes at speed.

With read ranges exceeding a metre, even at speed, tagging of vehicles for controlling entry to sites and parking areas is very practical. This is particularly valuable for fleet management where each vehicle could be used by any of a number of authorised drivers, but is also finding favour with local authorities world-wide for public parking, congestion limitation and public transport monitoring. A higher performance transponder has been specifically developed for these types of application, and is available in versions suitable for direct mounting on to the metal body or chassis of a vehicle. When coupled with a customised design of antenna embedded into the road surface (in exactly the same way as traffic light sensing loops are installed), an effective reading range of up to four metres can be achieved. This allows positive reading of vehicles of all types, regardless of ground clearance, and can allow readings as vehicle pass at normal city traffic speeds.

A water authority discovered contract tankers were bypassing normal gate controls at remote sewage treatment sites. This resulted in considerable losses from failure to collect revenue, and from contamination of the treatment plants by toxic industrial chemical wastes. Transponders allow trucks to enter the site, and be identified and checked by a robotic chemical analyser before the discharge valves will operate. Attempts to bypass the system are immediately signalled to HQ via a modem link.

Another vehicle application is implemented in various guises around the world - tagging of buses and emergency vehicles to interface with traffic lights. During rush hour, public transport gets priority at junctions with the lights changing to green more quickly, or delaying the red phase, as tagged buses approach. Fire engines, ambulances and police vehicles can be given higher priority still, with a guaranteed green light on approach. In future, R/W techniques will allow emergency destination codes to be loaded in the tag as it leaves the depot, thus allowing the traffic light control system to plan ahead and clear congestion before the vehicle arrives. Following a pilot study in Luton, systems have been provided in a number of British towns, while Sao Paulo in Brazil has just installed 11,000 transponders on buses and over a thousand reading points for a city-wide scheme.

An American truck operator suffered losses due to fraudulent use of credit cards issued to drivers to pay for fuel. With a 7,000 truck fleet this was a major cost. A transponder fitted in the fuel tank neck only allows the transaction to be authorised if the tag identity is verified by a reader in the pump nozzle. Later, the user added a modified "pseudo-transponder" coupled to the odometer, relaying mileage, thus allowing MPG calculation every time the truck was refuelled. This ended siphoning - their last main cause of fuel loss.

Intelligent Asset Management. Because each transponder can have a unique identity, a combination of access control with item tagging forms a basis for an intelligent security system.

In the office world, a laptop computer currently has a very short desk life span due to portability and desirability. However, the legitimate user almost certainly obtained the unit precisely to take it off the premises when needed. By matching the computer tag with the person carrying it through a monitored exit, it is easy to log authorised removal for records, but to raise an alarm upon unauthorised removal.

A similar technique can be used in the baby monitoring system mentioned above where mothers, babies and authorised medical staff are all tagged, and an alarm is only raised when an unauthorised person tries to remove the baby from its crib. This uses the reverse logic of checking that the baby is present where it is supposed to be, rather than trying to detect its passage through the very wide hospital doors. More complex logic would allow different personnel to take the baby to particular locations, but not to others. For example, the mother could move between nursery, and ward, while medical staff could also take it to treatment areas. Apart from improving detection rates, an alarm is raised almost instantaneously, thus giving hospital security the maximum time to prevent the abductor from leaving the premises.

The same reverse logic concept also sees real applications in museums and art galleries where the presence of valuable displays is constantly monitored. Apart from giving near instantaneous alarms, such a system provides automatic inventory auditing, and, with tags fitted in all artefacts, even those in a warehouse, stocktaking can be completed quickly using a handheld reader.

Logistics Management. As a final set of examples, let us consider applications in an area in which considerable "shrinkage" occurs commercially. That area is Logistics - manufacturing, materials handling and distribution. RFID brings a new dimension to this activity because identification is no longer constrained to a single factory warehouse or process line, and can thus allow you to "count them out, and count them back".

One of the most common techniques used today in automated processes is "memory mapping" where a replica of the production line and component positions is stored on computer. If items leave the line without passing a sensor, the memory map becomes out of step with remaining components. Transponders can be used as a specific identifier during manufacture, especially if customising is needed as in the motor industry. However, they can also signal removal of components from the production line without disrupting manufacture of other items, and can alarm on removal from the premises.

In the motor industry particularly, tags control all stages of vehicle build, provide location data during distribution to dealers, can be verified during warranty service, and can provide electronic VIN identity for owner security.

Most products today are moved on pallets or in tubs at some stage during their handling, and a R/W tag fitted to the container can be used to identify the product, quantity, and destination. On reuse, the tag is overwritten with the new data. This concept is already finding use on pallets in supermarkets, warehouses and manufacturing, in breweries for keg tracking, and in the chemical industry to track containers, especially those containing toxic residues. Several major companies are using vehicle mounted tags to track their fleet around the country between manufacturing and distribution sites.

Airlines and airports provide a unique demand, and have already commissioned a number of RFID projects. In this industry, there can be significant cost savings, and almost unquantifiable improvements in security. Some basic statistics can illustrate this.

- The world leading airlines carry over 100 million bags a year each.
- One of these airlines admits to spending over £20 million yearly on recovering lost bags.
- To keep a jumbo jet on the apron at Heathrow while baggage is reconciled against passengers who have actually boarded can cost £400 per minute.
- Optical character recognition systems to read bag labels cost up to £500K, and can be less than 67% efficient. That can represent 17 million bags per year requiring manual sorting at Heathrow alone.

To Whence from Here?

All the examples described above are happening today using current products. To the newcomer, these still sound new and exciting, but development continues.

The motor industry recognises that they are only ever a step or so ahead of the villain, and already new generations of tag with constantly varying "rolling codes" using R/W technology are being engineered into future immobiliser systems.

Less popular is the looming spectre of electronic toll collection on the motorways of the future. It might empty your bank account, but it can provide benefits, from recognising a breakdown as soon as a car stops, to pre-allocating parking spaces as you drive into a city.

Some authorities are also predicting the end of speeding fines, no, not by high levels of congestion, but by using a toll charging method which is lane, time and speed sensitive, similar to telephone call charges - if you want to exceed the speed limit in the outside lane, go ahead, but be prepared to pay dearly for the privilege - this is one area where competition is unlikely to drive prices down.

Equally, a transponder can relay other information. Mention has already been made of the pseudo tag, an early experimental device, but it could be replaced by a general digital tag, based on R/W technology so that data can be sent to, or received from, other instruments. Using technology developed from battery-free signal powered, a new generation of wireless links are becoming available making remote meter reading practical - no longer do you have to wait in for the gas man. In Europe, systems already allow all the meters in an apartment block to be combined and read remotely from outside, or relayed to a modem which communicates to the utility offices by telephone, modulating the power lines or high power radio link.

With the realisation that energy resources are finite, many companies are recognising a new market in energy efficiency. Some of the largest building management suppliers have developed methods to totally monitor energy usage and waste by comprehensively instrumenting customer premises, and then re-engineering the air conditioning and control systems. Because the instrumentation is only fitted temporarily, it is linked by radio to avoid cabling problems. However, the spin-off is that costs are dropping fast enough that even permanent wireless installations are becoming cost effective.

Conclusion

Following a long gestation period, RFID has developed into a mature product to provide new solutions to identification problems in many industries through its ability to provide unambiguous labelling and detection of objects that previously could not be tagged. For several years the industry was marked with unrealistic expectations, and many companies became casualties - both as suppliers, and as end users. Today, after considerable investment the industry has been taken up by the mainstream electronics suppliers, aided by very competent support companies, all of whom have gathered considerable experience of using RFID in real situations. In all the examples highlighted above, previously there were either no available solutions, or where there was a solution, RFID has proved to offer an elegant alternative. These illustrations should serve just to introduce the wide ranging opportunities RFID offer in problem solving - solutions which are, today, solid, proven and able to satisfy even the most conservative user.

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