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RFID Explained

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An Introduction to RFID and Tagging Technologies

By Raghu Das, IDTechEx

Radio Frequency Identification (RFID) is the use of radio frequencies to read information on a small device known as a tag. Nowadays, these tags may take many forms:

- Microchips only 40-60 microns thick and 0.4mm across with a tiny metal antenna such as the Hitachi 2.45 GHz Mew chip announced in 2001.
- Deposited alloys 0.5 to 5 microns thick on 20 micron polyester ribbon 1 mm across like banknote security ribbon.

Other RFID tags are applied to products and packaging in the form of a label, an example being the Texas Instruments Tag It label fitted to the packaging of 250,000 Xerox copiers shipped yearly in Europe and behind the cloth labels on Goldwin Sportswear made in China – using one million yearly. It is important to note that some RFID tags have a microchip in them and some do not.

Over 20% of RFID applications do not replace anything. An example is the “ScripTalk” pharmaceutical label for the blind that makes a gadget held near it speak out the type of drug and dosage required. Other examples are several hundred million car access clickers that have been sold and 50 million sold as an entertaining feature of the Hasbro Star Wars toy.

Choices

There are a number of different RFID technologies which all overlap to some extent, and have various pros and cons making them suitable for some applications and not others. Applications are so diverse that there is a place for most of these different technologies.

Definitions

Radio frequency Identification (RFID) is a term used for any device that can be sensed at a distance by radio frequencies with few problems of obstruction or misorientation. The origins of the term lie in the invention of tags that reflect or retransmit a radio-frequency signal. In its current usage, those working below 300Hz and those working above 300MHz, such as microwave (GHz) tags, are included. For example, one type of chipless tag works at only a few hertz and Inkode chipless taggants operate at around 20-25 GHz. Higher frequencies such as visible and infrared devices are excluded as these systems have very different properties and are frequently sensitive to obscuration, heat, light and orientation.

The term “tag” is used to describe any small device – shapes vary from pendants to beads, nails, labels or microwires and fibres that can be incorporated into paper and even special printed inks on, for example, paper.

Low Cost RFID

In the last few years, the term "low cost RFID" has begun to be used and this may seem an artificial distinction at first sight. However, low cost RFID tags, typically taken as those costing less than one dollar each for up to 1 metre range and under $5 above that, are different from conventional tags in several important respects. These differences mean that low cost RFID tags can be applied in very different, new applications and interest very different groups of suppliers and end users. This alternative to the barcode, magnetic stripe or printed label has advantages that include tolerance of misorientation and obscuration. Most importantly, they are usually cheap enough to be disposable and thin enough to go in new locations, even inside sheets of paper in some cases, so all flat versions are usually called smart labels.

Almost all conventional RFID devices contain a transistor circuit employing at least one microchip. By contrast, the potential in low cost RFID is equally split between chip-based technologies and "chipless" tags. Chipless tags can still be interrogated through a brick wall and hold data but they are cheaper and more primitive in electronic performance than the best low-cost chip devices.

Significance of EAS

Some RF tags contain no information. They are not RFID because they

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	Conventional RFID	Low Cost RFID
Mode of use	Re-used, usually.	Disposable, usually.
Typical shape	Pendants, nails, boxes of electronics, contactless smart cards, glass beads.	Labels, laminates.
Typical frequencies	Low (125 – 135 kHz) to keep system cost low where there are few tags per reader.	High (13.56MHz, 2.45GHz) to keep system cost low where there are many tags
Typical suppliers and value-added users	Electronics companies and some label makers.	Security printers, paper, packaging and label manufacturers, new start-ups. Sometimes electronics companies supply the naked tag called "inlet".
Typical end users and uses of the sys-	Manufacturers, heavy logistics (e.g., brewers), farming, car keys, financial cards,	Airlines (baggage), laundry, toys, libraries, passports.
Typical payback	Greater security, better flow.	Reduced losses, entertainment, automation, anti-counterfeiting.

are simply there or not there - call it 'one bit' of information. Because these are usually used as anti-theft devices in shops and libraries, this category is called Electronic Article Surveillance (EAS). About six billion are used every year. Some new forms of RFID perform EAS functions as well, obviating the need for a separate device, and adding more value to the tag. In addition all the main three EAS technologies have been developed into RFID versions, albeit with rather higher costs. An EAS tag costs about 2 to 6 cents. RFID tags usually cost more depending mainly on range and data capacity.

Chip vs. Chipless Smart Labels

Many inventions in low-cost RFID split into tags that either do or do not contain a chip. There are radical differences in cost and performance between these two categories. In many cases RFID is referred to only as chip tags (especially by people creating chip tags!); with chipless types sometimes referred to as EMID and other things. However, because these two different technologies do overlap in some of the applications they can be used for, we incorporate all the alternative non-chip tag technologies when we discuss RFID – in some applications chipless is much more suited than chip tag offerings.

Chip tags cost more and do more with data. They can hold larger amounts of data, but due to the price of silicon and the processes involved in making the chips, these are currently relatively expensive: roughly speaking, chip tags are not usually available below $0.3 if ordered in quantities of less than 1 million. Chipless tags – of which there are eight different technologies working on different physical principles – are much cheaper because their price is only limited by the cost of the materials used, which are in most cases basic and readily available in large quantities. Chipless tags are usually $0.01 - $0.2 even for orders as few as 100,000 or less. Some chipless tags can be made for $0.001-$0.01 if billions are ordered and the range only need be a few millimeters. Chipless tags have the price advantage over chip tags, but currently cannot usually hold as much data without being unacceptably large. However, both are being improved.

Data Types

In RFID systems, there are two extremes of data storage. At one extreme, the interrogatory electronics simply sense something unique about the product, such as the random orientation of magnetic fibers in it – a pattern highly unlikely to ever be repeated. For this to be useful the computers in the system must have had prior notice of what the unique feature relates to, and this identity must be transmitted to all locations where the tag may need to be interrogated. This is known as Unique Signature, and even though it results in very cheap tags it is very limiting.

At the other extreme, the tag is capable of storing digital information to agreed rules, so that readers can retrieve information directly from the tag without needing to refer to a centralized database. Digitally Encoded tags are more expensive, but much more useful because they do not require great amounts of processing power, time, and unrealistic communications as unique signature tags do.

Range

The range of tags varies widely, and for all types, the greater the range required, the more expensive the tag. At a range of just a few millimeters the RFID tags can be embedded in banknotes and vouchers for high speed sortation and authentication, but for logistics often a range of up

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to 1 metre or more is required, with the ability to read many tags quickly. Other applications such as road tolling and the location of items in real time such as cars in a depot require read ranges up to kilometers.

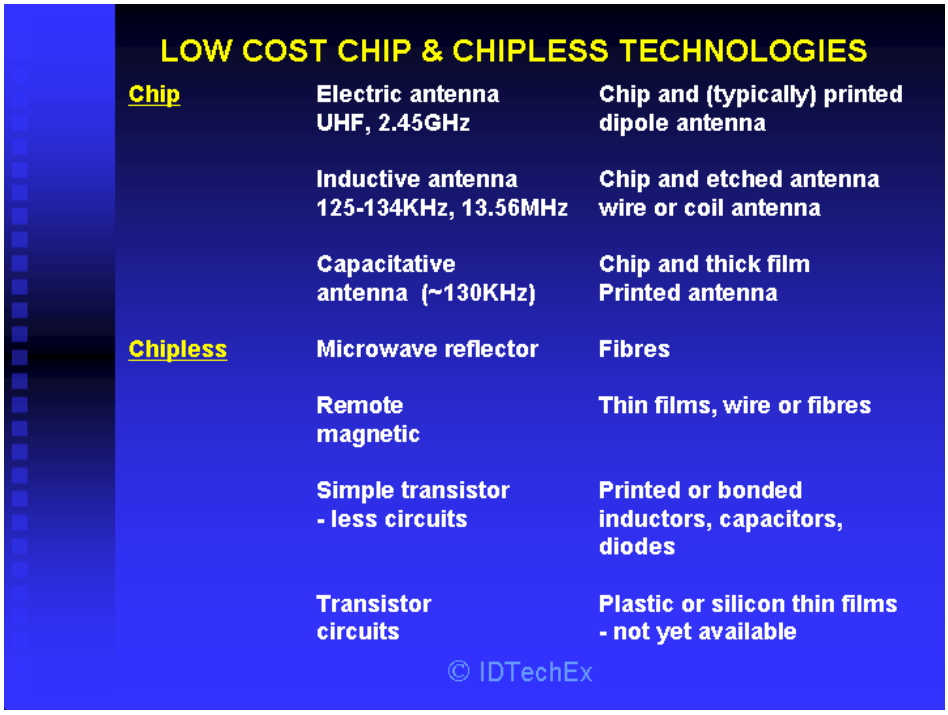
Cost

Cost is probably the most crucial issue at the moment. When we are talking about billions of these devices yearly in one application, the use of smart labels is only affordable if the labels are very cheap because they form a large part of the total system cost. To reach the ultra low cost required, smart labels need to be stripped of unnecessary functions which add cost, and a healthy race is developing for new, faster and cheaper processes for smart labels and new designs. In contrast to the internet and computers evolving upwards in size and complexity, smart labels are going in the opposite direction for highest volume use.

As noted, RFID is much more than a barcode replacement. The same tag may obviate the need for a separate anti-theft EAS device, it may be used to prove ownership of goods, provide covert authentication, speed up shopping, remove the need for tills and floor space, and ultimately speed up the time items take to go through the whole supply chain, due to the better flow of information between each link. Product recalls can be more effective and auditable. These benefits can result in huge cost savings and brand protection. However, although identifying that most players in the supply chain plus the users at the end will benefit may be easy, persuading one or all of them to pay the upfront cost of RFID can be problematic.

At item level, replacing a barcode is no easy feat, since barcodes cost next to nothing, therefore supermarkets and FMCG manufacturers say barcodes would need to be replaced by a device costing $0.01 at most. However, for a smart label, with the necessary data, reaching this cost will take at least three years. By contrast, vehicle and freight barcodes have already frequently been replaced with RFID devices costing over $1 each because so many benefits accrue. Reading at high speed, tolerance of misorientation and far fewer false reads or failed reads are among them. Tagging cartons with readily available off-the-shelf tags today costing less than one dollar each can result in paybacks within one year or less, because the tag is used for many years over the life of the carton.

Tag price is only critical when very large numbers are used, particularly large numbers per reader. The most extreme case is the dream of The Internet of Things where tens of trillions of one cent tags will be used yearly notably on fast-moving consumer goods. Massachusetts Institute of Technology is working on this with the backing of thirty of the world's largest companies and others. By contrast, a payback of less than a year may be achieved with a $100 tag if its sophistication is needed.



Applications

The applications of smart labels are incredibly diverse, and the matrix shown lists just a few of them. As noted above, all the technologies have a role to play and some are more suited to some applications than others, depending on parameters including cost, range, data capabilities, ruggedness etc.

The Future

Entry to market is being slowed in most cases by the cost of the tag and by the lack of standards. We will therefore see in the short term increasing numbers of smart labels being sold into “closed” applications, where often only a relatively small number of labels are required without the need for standards. For example, one supplier could supply all the tags and readers to track the movement of assets in a particular building – in this case, the payback is simply de-

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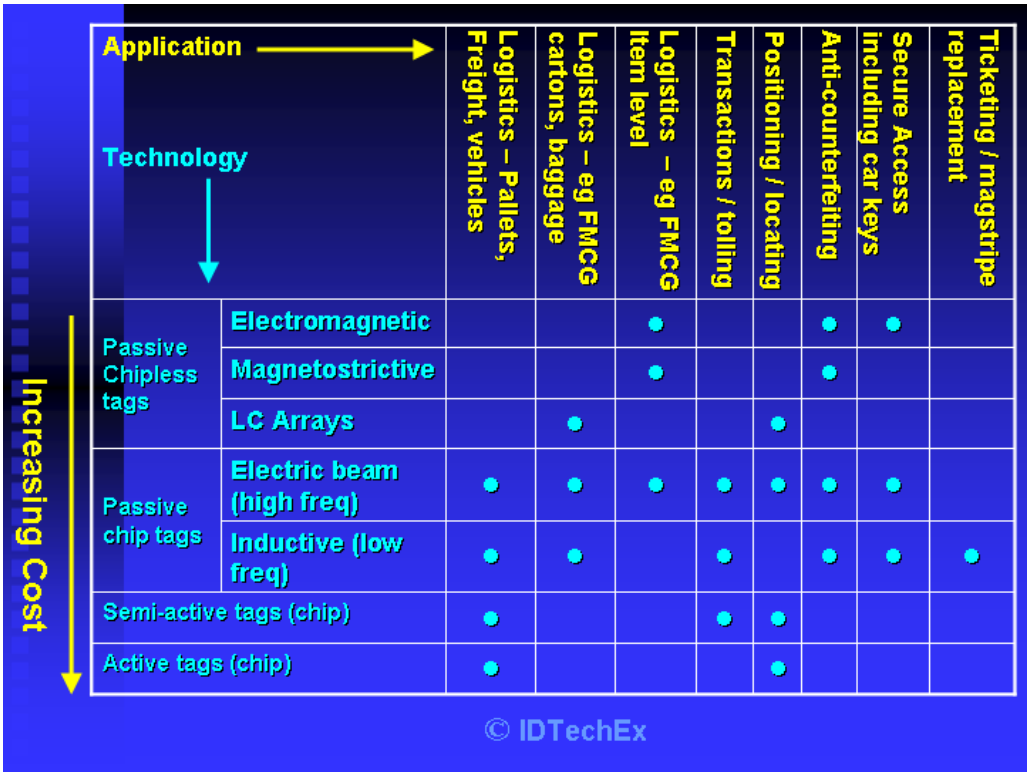

termined from a cost analysis. However, open systems – which hold the potential for billions and even trillions of smart labels yearly, require low cost labels and standards, such that tags can be multiple-sourced, and installed readers can read a tag from any supplier. There is already much work going on creating standards for chip smart labels, and with the prices of smart labels reducing we will soon see the adoption of smart labels in open systems, resulting in an expected $4 Billion RFID market by 2005.

The Internet of Things

The FMCG industry has an even grander vision than the “barcode of the future". It is called The Internet of Things, a term coined by Massachusetts Institute of Technology which has done most of the work on it so far. MIT Auto ID Center is funded by Gillette, Procter & Gamble and other FMCG companies plus Alien Technology and other electronics companies and the RFID industry.

The Internet of Things is sometimes called The Product Internet or T2T (Thing to Thing). The MIT vision is to have trillions of things communicating with each other without human intervention. It would be low cost because most of the time it would involve smart labels costing under 5 cents and preferably 1 cent and the existing Internet would be used as appropriate.

The prize is to go far beyond an equivalent of the barcode that can be read more reliably and identify individual items. MIT talk of cradle to grave tracking plus electronically telling the freezer to restock, the microwave oven to cook correctly and finally the recycler to separate the materials correctly, all without human intervention. MIT talk of the medicine chest in the home that will not dispense contraindicated medicines (not their best idea in our opinion) and all manner of anti-theft, anti-tampering and product diversion procedures that take place automatically.

Both chip and chipless smart labels technologies are contenders for The Internet of Things which will be getting under way anyway with various higher-cost tags. For example, low cost, short range smart labels can permit boxes of pharmaceuticals to be monitored and that wireless network could talk to a more expensive, longer range network that monitors whether a truckload so much as enters a lay-by. These systems exist today. The ultra-low-cost smart label uniquely identifying every blow pack, pot or vial can come later and we shall have networks within networks within networks and so on.

The use of smart labels today is incredibly varied, and the potential is stunning. IDTechEx provide services to help you digest all this information, and in particular, our reports (listed on the next page), cover in great depth the technologies involved, markets, applications and so on. Further, our regular conferences are the largest in the world on the topic and provide an ideal place to network with others, and hear the latest advancements in the industry.

For more information, see **www.idtechex.com** or email **info@idtechex.com** .

Let us know if there are any areas our consultancy can help you with.

IDTechEx is the world’s leading expert on the development and application of low cost RFID technologies.

IDTechEx Publications

Full details of these publications (including a contents list) can be found at www.idtechex.com

The IDTechEx Web Journals — Published Monthly

Smart Labels Analyst and Smart Packaging Journal—NEW

These web journals are the first to concentrate primarily on low-cost RFID and other responsive devices, colloquially known as smart labels and smart packaging. We try to give a balanced view of the subject. To this end we do not accept paid advertising or sponsorship. Our text is not therefore advertising by another name. Further, we seek to provide original useful material, not available elsewhere. For example, we attend many of the conferences you may miss and we analyse their content. We visit faraway places where interesting work is being done and give you the news first. We interpret future trends and regularly have guest columnists giving insights from their expertise.

Almost all articles are written by our own technical graduates as they travel the world, visiting the start-ups, the conferences and so on. However, to broaden the viewpoint we also commission experts from around the world to give their own input on important topics. Above all, we wish to tune these journals to what you need. The Journals are an ideal way to remain updated with the latest industry developments.

The Complete Introductory Report in low-cost RFID and beyond

The Smart Label Revolution

Mid 2002 New

By Dr Peter Harrop and Raghu Das, IDTechEx

Totally new mid 2002 • International case histories and company profiles • Technologies evaluated • 252 pages • Over 90 detailed tables and figures • Forecasts by technology etc to 2010 • Sales leads

The one stop guide to chip and chipless technologies, markets, standards, statistics, trends, lessons of success and failures, future opportunities, and the RFID movers, makers and shakers. Your business needs this knowledge to get ahead, whether you wish to make, install, or use these revolutionary devices. This 252 page report is illustrated with over 90 detailed tables and diagrams.

Over 60 international case histories and company profiles from: Australia, China, Japan, Eastern Europe, Singapore, South Africa, USA and Western Europe

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In Depth on Chipless: The World's only in depth report on this topic

The Future of Chipless Smart Labels: Markets, Players and Forecasts

Mid 2002 New

By Dr Peter Harrop and Raghu Das, IDTechEx

Totally new mid 2002 • Forecasts by technology etc to 2010 • Latest new products and inventions • 271 pages • Over 105 detailed tables and figures • Extensive sales leads

This report expands on The Smart Label Revolution, by looking in far more detail at chipless tags, including a much wider range of technologies. These have enormous market potential. They are usually ultra low-cost from 0.1 to 10 cents each, even in modest quantities. This second report also analyses how the silicon chip and even batteries in conventional RFID will become printed, to lower cost and improve ruggedness so eventually most forms of low cost RFID become "chipless".

In Depth on Chip

Chip Smart Labels: The Intelligent RFID

By Raghu Das and Dr Peter Harrop, IDTechEx

This report completes the series by looking in far more detail at chip tags. Disposable chip smart labels have a huge potential. At present there is a wide variety of technologies, including a diversity of frequencies and ranges, and this is complicated further by the evolution of standards. This report provides a comprehensive explanation of the technologies and standards involved, as well as analysing the potential of this industry, including new and conventional markets. Whether you wish to make, install or use chip smart labels , or consider the business case of these revolutionary devices, this report enables you to gain the knowledge to get ahead. The standards chapter is written by Professor Anthony Furness.

Publications	Net Price (GB£)	Net Price (US$)	Quantity	Total Price (£/$)
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Smart Packaging Journal: 12 month subscription (monthly)	£399* (£468.83 inc. VAT)	$640* $752 inc. VAT)		
The Smart Label Revolution (Introductory Report)	£600	$950		
The Future of Chipless Smart Labels : Markets, Players and Forecasts (In depth on chipless)	£600	$950		
Chip Smart Labels (In depth on chip)	£600	$950		
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