A Primer on RFID

Radio-frequency identification (**RFID**) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders.

An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.

Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions. The second is an antenna for receiving and transmitting the signal. Chipless RFID allows for discrete identification of tags without an integrated circuit, thereby allowing tags to be printed directly onto assets at a lower cost than traditional tags.

Today, RFID is used in enterprise supply chain management to improve the efficiency of inventory tracking and management. However, growth and adoption in the enterprise supply chain market is limited because current commercial technology does not link the indoor tracking to the overall end-to-end supply chain visibility. Coupled with fair cost-sharing mechanisms, rational motives and justified returns from RFID technology investments are the key ingredients to achieve long-term and sustainable RFID technology adoption

Contents

1.History of RFID tags

An RFID tag used for electronic toll collection.

In 1946 Léon Theremin invented an espionage tool for the Soviet Union which retransmitted incident radio waves with audio information. Sound waves vibrated a diaphragm which slightly altered the shape of the resonator, which modulated the reflected radio frequency. Even though this device was a passive covert listening device, not an identification tag, it has been attributed as a predecessor to RFID technology. The technology used in RFID has been around since the early 1920s according to one source (although the same source states that RFID *systems* have been around just since the late 1960s).

Similar technology, such as the IFF transponder invented by the United Kingdom in 1939, was routinely used by the allies in World War II to identify aircraft as friend or foe. Transponders are still used by most powered aircraft to this day.

Another early work exploring RFID is the landmark 1948 paper by Harry Stockman, titled "Communication by Means of Reflected Power" (Proceedings of the IRE, pp 1196–1204, October 1948). Stockman predicted that "…considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored."

Mario Cardullo's U.S. Patent 3,713,148 in 1973 was the first true ancestor of modern RFID; a passive radio transponder with memory. The initial device was passive, powered by the interrogating signal, and was demonstrated in 1971 to the New York Port Authority and other potential users and consisted of a transponder with 16 bit memory for use as a toll device. The basic Cardullo patent covers the use of RF, sound and light as transmission media. The original business plan presented to investors in 1969 showed uses in transportation (automotive vehicle identification, automatic toll system, electronic license plate, electronic manifest, vehicle routing, vehicle performance monitoring), banking (electronic check book, electronic credit card), security (personnel identification, automatic gates, surveillance) and medical (identification, patient history).

2. A very early demonstration

A very early demonstration of **reflected power** (modulated backscatter) RFID tags, both passive and semi-passive, was performed by Steven Depp, Alfred Koelle and Robert Freyman at the Los Alamos National Laboratory in 1973. The portable system operated at 915 MHz and used 12-bit tags. This technique is used by the majority of today's UHFID and microwave RFID tags.

The first patent to be associated with the abbreviation RFID was granted to Charles Walton in 1983 U.S. Patent 4,384,288 .

3. RFID tags

RFID tags come in three general varieties:- *passive*, *active*, or *semi-passive* (also known as *battery-assisted*). Passive tags require no internal power source, thus being pure passive devices (they are only active when a reader is nearby to power them), whereas semi-passive and active tags require a power source, usually a small battery.

RFID backscatter.

To communicate, tags respond to queries generating signals that must not create interference with the readers, as arriving signals can be very weak and must be differentiated. Besides backscattering, load modulation techniques can be used to manipulate the reader's field.

Typically, backscatter is used in the far field, whereas load modulation applies in the nearfield, within a few wavelengths from the reader.

3.1 Passive

Passive RFID tags have no internal power supply. The minute electrical current induced in the antenna by the incoming radio frequency signal provides just enough power for the CMOS integrated circuit in the tag to power up and transmit a response. Most passive tags signal by backscattering the carrier wave from the reader. This means that the antenna has to be designed both to collect power from the incoming signal and also to transmit the outbound backscatter signal. The response of a passive RFID tag is not necessarily just an ID number; the tag chip can contain non-volatile data, possibly writable EEPROM for storing data.

Passive tags have practical read distances ranging from about 11 cm (4 in) with near-field (ISO 14443), up to approximately 10 meters (33 feet) with far-field (ISO 18000-6) and can reach up to 600 feet (183 meters)[6] when combined with a phased array. Basically, the reading and writing depend on the chosen radio frequency and the antenna design/size. Due to their simplicity in design they are also suitable for manufacture with a printing process for the antennas. The lack of an onboard power supply means that the device can be quite small: commercially available products exist that can be embedded in a sticker, or under the skin in the case of low frequency (LowFID) RFID tags.

In 2007, the Danish Company RFIDsec developed a passive RFID with privacy enhancing technologies built-in including built-in firewall access controls, communication encryption and a silent mode ensuring that the consumer at point of sales can get exclusive control of the key to control the RFID. The RFID will not respond unless the consumer authorizes it, the consumer can validate presence of a specific RFID without leaking identifiers and therefore the consumer can make use of the RFID without being trackable or otherwise leak information that represents a threat to consumer privacy.

In 2006, Hitachi, Ltd. developed a passive device called the µ-Chip measuring 0.15×0.15 mm (not including the antenna), and thinner than a sheet of paper (7.5 micrometers). Silicon-on-Insulator (SOI) technology is used to achieve this level of integration. The Hitachi µ-Chip can wirelessly transmit a 128-bit unique ID number which is hard-coded into the chip as part of the manufacturing process. The unique ID in the chip cannot be altered, providing a high level of authenticity to the chip and ultimately to the items the chip may be permanently attached or embedded into. The Hitachi µ-Chip has a typical maximum read range of 30 cm (1 ft). In February 2007 Hitachi unveiled an even smaller RFID device measuring 0.05×0.05 mm, and thin enough to be embedded in a sheet of paper. The new chips can store as much data as the older µ-chips, and the data contained on them can be extracted from as far away as a few hundred metres. The ongoing problems with all RFIDs is that they need an external antenna which is 80 times bigger than the chip in the best version thus far developed. Further, the present costs of manufacturing the inlays for tags has inhibited broader adoption. As silicon prices are reduced and new more economic methods for manufacturing inlays and tags are perfected in the industry, broader adoption and item level tagging along with economies of scale production scenarios; it is expected to make RFID both innocuous and commonplace much like barcodes are presently.

Alien Technology's Fluidic Self Assembly and HiSam machines, Smartcode's Flexible Area Synchronized Transfer (FAST) and Symbol Technologies' PICA process are alleged to potentially further reduce tag costs by massively parallel production· Alien Technology and SmartCode are currently using the processes to manufacture tags while Symbol Technologies' PICA process is still in the development phase. Symbol was acquired by Motorola in 2006. Motorola however has since made agreements with Avery Dennison for supply of tags, meaning their own tag production and PICA process may have been abandoned. Alternative methods of production such as FAST, FSA, HiSam and possibly PICA could potentially reduce tag costs dramatically, and due to volume capacities achievable, in turn be able to also drive the economies of scale models for various silicon fabricators as well. Some passive RFID vendors believe that industry benchmarks for tag costs can be achieved eventually as new low-cost volume production systems are implemented more broadly.

Non-silicon tags made from polymer semiconductors are currently being developed by several companies globally. Simple laboratory-printed polymer tags operating at 13.56 MHz were demonstrated in 2005 by both PolyIC (Germany) and Philips (The Netherlands). If successfully commercialized, polymer tags will be roll-printable, like a magazine, and much less expensive than silicon-based tags. The end game for most item-level tagging over the next few decades may be that RFID tags will be wholly printed – the same way that a barcode is today – and be virtually free, like a barcode. However, substantial technical and economic hurdles must be surmounted to accomplish such an end: hundreds of billions of dollars have been invested over the last three decades in silicon processing, resulting in a per-feature cost which is actually less than that of conventional printing.

3.2 Active

Unlike passive RFID tags, active RFID tags have their own internal power source, which is used to power the integrated circuits and to broadcast the response signal to the reader. Communications from active tags to readers is typically much more reliable (i.e. fewer errors) than those from passive tags due to the ability for active tags to conduct a "session" with a reader.

Active tags, due to their onboard power supply, also may transmit at higher power levels than passive tags, allowing them to be more robust in "RF challenged" environments with humidity and spray or with RF-dampening targets (including humans and cattle, which contain mostly water), reflective targets from metal (shipping containers, vehicles), or at longer distances: Generating strong responses from weak reception is a sound approach to success. In turn, active tags are generally bigger (due to battery size) and more expensive to manufacture (due to price of the battery). However, their potential shelf life is comparable, as self-discharge of batteries competes with corrosion of aluminated printed circuits.

Many active tags today have operational ranges of hundreds of meters, and a battery life of up to 10 years. Active tags may include larger memories than passive tags, and may include the ability to store additional information received from the reader.

Special active RFID tags may include specialized sensors. For example, a temperature sensor can be used to record the temperature profile during the transportation and storage of perishable goods. Other sensor types used include humidity, shock/vibration, light, nuclear radiation, pressure and concentrations of gases such as ethylene.

The United States Department of Defense (DoD) has successfully used active tags to reduce search and loss in logistics and to improve supply chain visibility for more than 15 years (concept of in-transit-visibility ITV,).

3.3 Semi-passive

Semi-passive tags are similar to active tags in that they have their own power source, but the battery only powers the microchip and does not power the broadcasting of a signal. The response is usually powered by means of backscattering the RF energy from the reader, where energy is reflected back to the reader as with passive tags. An additional application for the battery is to power data storage.

If energy from the reader is collected and stored to emit a response in the future, the tag is operating active.

Whereas in passive tags the power level to power up the circuitry must be 100 times stronger than with active or semi-active tags, also the time consumption for collecting the energy is omitted and the response comes with shorter latency time. *The battery-assisted* reception circuitry of semi-passive tags leads to greater sensitivity than passive tags, typically 100 times more. The enhanced sensitivity can be leveraged as increased range (by one magnitude) and/or as enhanced read reliability (by reducing bit error rate at least one magnitude).

The enhanced sensitivity of semi-passive tags places higher demands on the reader concerning separation in denser population of tags. Because an already weak signal is backscattered to the reader from a larger number of tags and from longer distances, the separation requires more sophisticated anti-collision concepts, better signal processing and some more intelligent assessment of which tag might be where. For passive tags, the reader-to-tag link usually fails first. For semi-passive tags, the reverse (tag-to-reader) link usually collides first.

Semi-passive tags have three main advantages: greater sensitivity than passive tags; longer battery powered life cycle than active tags; they can perform active functions (such as temperature logging) under their own power, even when no reader is present for powering the circuitry.

3.4 Extended capability

Extended capability RFID defines a category of RFID that goes beyond the basic capabilities of standard RFID as merely a "license plate" or barcode replacement technology. Key attributes of extended capability RFID include the ability to read at longer distances and around challenging environments, to store large amounts of data on the tag, to integrate with sensors, and to communicate with external devices.

Examples of extended capability RFID tag technologies include EPC C1G2 with extended memory (e.g. 64Kb), battery-assisted passive, and active RFID. Battery-assisted passive, also known as semi-passive or semi-active, has the ability to extend the read range of standard passive technologies to well over 50 meters, to read around challenging materials such as metal, to withstand outdoor environments, to store an on-tag database, to be able to capture sensor data, and to act as a communications mechanism for external devices. Also, battery-assisted passive only transmits a signal when interrogated, thus extending battery life. Active RFID, which can have some of the features of battery-assisted passive, is commonly used for even longer distances and real-time locationing. It also actively transmits a signal, which often results in shorter battery life.

Common applications of extended capability RFID include Yard Management, Parts Maintenance and Repair Operations, Cold-Chain Management, Reusable Transport Items tracking, High Value/High Security Asset tracking, and other applications where extended capabilities are needed.

3.5 Antenna types

The antenna used for an RFID tag is affected by the intended application and the frequency of operation. Low-frequency is 30–300 kHz. LFID or LowFID passive tags are normally inductively coupled, and because the voltage induced is proportional to frequency, many coil turns are needed to produce enough voltage to operate an integrated circuit. Compact LowFID tags, like glass-encapsulated tags used in animal and human identification, use a multilayer coil (3 layers of 100–150 turns each) wrapped around a ferrite core.

High frequency is 3-30 MHz. At 13.56 MHz, a HFID or HighFID tag, using a planar spiral with 5–7 turns over a credit-card-sized form factor can be used to provide ranges of tens of centimeters. These coils are less costly to produce than LF coils, since they can be made using lithographic techniques rather than by wire winding, but two metal layers and an insulator layer are needed to allow for the crossover connection from the outermost layer to the inside of the spiral where the integrated circuit and resonance capacitor are located.

Ultrahigh-frequency or UHF is 300 MHz-3 GHz. UHFID and microwave passive tags are usually radiatively-coupled to the reader antenna and can employ conventional dipole-like antennas. Only one metal layer is required, reducing cost of manufacturing. Dipole antennas, however, are a poor match to the high and slightly capacitive input impedance of a typical integrated circuit. Folded dipoles, or short loops acting as inductive matching structures, are often employed to improve power delivery to the IC. Half-wave dipoles (16 cm at 900 MHz) are too big for many applications; for example, tags embedded in labels must be less than 10 cm (4 inches) in extent. To reduce the length of the antenna, antennas can be bent or meandered, and capacitive tip-loading or bowtie-like broadband structures are also used. Compact antennas usually have gain less than that of a dipole — that is, less than 2 dBi — and can be regarded as isotropic in the plane perpendicular to their axis.

Dipoles couple to radiation polarized along their axes, so the visibility of a tag with a simple dipole-like antenna is orientation-dependent. Tags with two orthogonal or nearly-orthogonal antennas, often known as dual-dipole tags, are much less dependent on orientation and polarization of the reader antenna, but are larger and more expensive than single-dipole tags.

Patch antennas are used to provide service in close proximity to metal surfaces, but a structure with good bandwidth is 3–6 mm thick, and the need to provide a ground layer and ground connection increases cost relative to simpler single-layer structures.

HFID and UHFID tag antennas are usually fabricated from copper or aluminum. Conductive inks have seen some use in tag antennas but have encountered problems with IC adhesion and environmental stability.

3.6 Tag attachment

There are three different kinds of RFID tags based on their attachment with identified objects, i.e. attachable, implantable and insertion tags. In addition to these conventional RFID tags, Eastman Kodak Company has filed two patent applications for monitoring ingestion of medicine based on a digestible RFID tag

3.7 Tagging positions

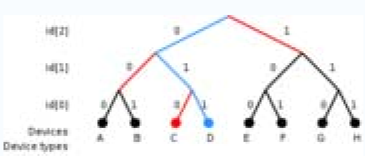
RFID tagging positions can influence the performance of air interface UHFID passive tags.

In many cases, optimum power from RFID reader is not required to operate passive tags. However, in cases where the effective radiated power (ERP) level and distance between reader and tags are fixed, such as in a manufacturing setting, it is important to know the location in a tagged object where a passive tag can operate optimally.

Resonance Spot (R-Spot), Live Spot (L-Spot) and Dead Spot (D-Spot) are defined to specify the location of RFID tags in a tagged object, where the tags can still receive power from a reader within specified ERP level and distance

3.8 Tag environments

The proposed ubiquity of RFID tags means that readers may need to select which tags to read among many potential candidates, or may wish to probe surrounding devices to perform inventory checks or, in case the tags are associated to sensors and capable of keeping their values, question them for environmental conditions. If a reader intends to work with a collection of tags, it needs to either discover all devices within an area to iterate over them afterwards, or use collision avoidance protocols.



Finding tags in a search environment.

To read tag data, readers use a tree-walking singulation algorithm, resolving possible collisions and processing responses one by one. *Blocker tags* may be used to prevent readers from accessing tags within an area without killing surrounding tags by means of suicide commands. These tags masquerade as valid tags but have some special properties: in particular, they may possess any identification code, and may deterministically respond to all reader queries, thus rendering them useless and securing the environment.

Besides this, tags may be *promiscuous*, attending all requests alike, or *secure*, which requires authentication and control of typical password management and secure key distribution issues. A tag may also be prepared to be activated or deactivated in response to specific reader commands.

Readers that are in charge of the tags of an area may operate in *autonomous mode* (as opposed to *interactive mode*). When in this mode, a reader periodically locates all tags in its operating range, and keeps a presence list with a persist time and some control information. When an entry expires, it is removed from the list.

Frequently, a distributed application requires both types of tags: passive tags are incapable of continuous monitoring and perform tasks on demand when accessed by readers. They are useful when activities are regular and well defined, and requirements for data storage and security are limited; when accesses are frequent, continuous or unpredictable, there are time constraints to meet or data processing (internal searches, for instance) to perform, active tags may be preferred.

3.9 The Art and Science of RFID Tagging

Water and **metal** objects are the most known factors that can decrease the performance of air interface Ultra High Frequency (UHF) communication between RFID passive tags and readers. Depending on RFID applications, several options to alleviate the material effect include the use of active tags, additional tag spacer or insert material, and specific tag or antenna design.

Two other factors that can also influence the performance of UHF RFID applications, yet less known, are **mobility** and **tagging position**. These two factors can be very significant in several applications, such as RFID vehicle and conveyor belt tracking systems.

Mobility is a critical factor for RFID tagged objects or readers that are moving or mobile. Depending on the configuration of a particular RFID system and environment, a significant change in mobility **path** (direction) and also **speed** (velocity) within a specified time can influence the successful identification rate of RFID tags.

Tagging position, on the other hand, is related to the position where RFID tags are embedded, attached or injected (in the case of animal or human tagging). In many cases, optimum power from RFID reader is not required to operate passive tags.

However, in cases where the Effective Radiated Power (ERP) level and distance between reader and tags are fixed, such as in manufacturing setting, it is important to know the location in a tagged object where a passive tag can operate optimally. Such location is defined as **R-Spot** or **Resonance Spot**.

R-Spot is a location in a tagged object where a passive tag can operate optimally within specified Effective Radiated Power (ERP) level and certain distance from a reader.

During RFID tagging, R-Spots are usually the reference tagging locations where the identification of tags will result in optimum performance.

In some cases, such as pallet and case tagging with different contents and materials, R-Spots are likely to be variably diverse. Such cases may introduce the difficulty in automation, because a fixed tagging location on all tagged objects may become a requirement to achieve an efficient automation. This situation introduces the importance of **L-Spot** or **Live Spot**, which is the location in a tagged object where a passive tag can still obtain power from a reader to operate within specified ERP level and certain distance from a reader.

L-Spot is the location in a tagged object where a passive tag can still obtain power from a reader to operate within specified ERP level and certain distance from a reader.

L-Spot includes R-Spots as well, but L-Spot does not always guarantee that the tagging position will result in optimum performance.

The opposite of L-Spot is **D-Spot** or **Dead Spot**, where tags can still receive power from a reader, but the obtained power is insufficient to operate tags within specified ERP level and certain distance from a reader, resulting in identification failures.

D-Spot is the location in a tagged object where passive tags can still obtain the power from a reader, but the obtained power is insufficient to operate tags within specified ERP level and certain distance from a reader.

There are still many areas in RFID tagging that are yet to be explored. This introduction to RFID tagging has shown that there is still room for improvement, while the art and science of RFID tagging advances along with the increasing adoption of RFID technology in diverse applications.

3.10 The RFID Physics

Physics: the cornerstone of RFID success

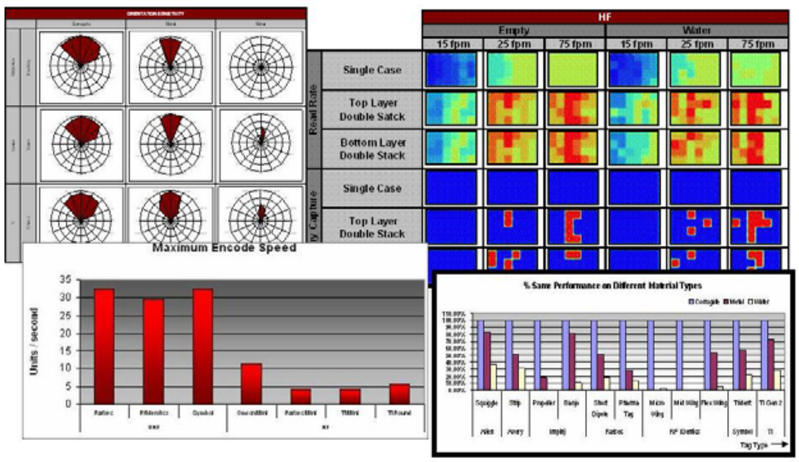
A RFID system is a like a building. Both require a strong foundation for long-term success. Physics is the bedrock of an RFID network. A properly integrated RFID system requires:

- Appropriate frequency
- Optimum readers
- Environmental protection
- “Best-Practice” tag type and location
- Optimum antenna pairing and tuning
- RF environmental alignment

- Standards considerations
- Global power considerations

Careful scientific testing and deployment up-front can save thousands of dollars over trial and error methods. Physics determines reader configuration parameters and dictates the complex environmental nuances. Since no single RFID reader does everything well, the right tools for the job must be selected and optimized.

FALKEN SECURE NETWORKS and its integration partners strive to make the **invisible visible** by producing thoughtful graphs and presentations which show exactly what is happening with an RFID system. Below are results from various projects which illustrate that a picture is worth a thousand words when trying to describe different levels of physics performance:



Myths have circulated for many years about RFID and art. If you want success with RFID focus more on Marconi than Picasso. The fact is, RFID is based on radio physics and you can use it to your advantage.

In this case, science has come to the rescue of a long standing myth about passive RFID and metals. While RFID does face many challenges operating effectively around metal, it works well when scientific principles are properly applied.

Take for example, the issue of attenuation. The most pernicious barrier to successful RFID reads around metals comes from the propensity of metallic surfaces to attenuate RFID antennas and make them less efficient conductors of RF energy. The metal detunes the antennas and makes them less likely to receive enough RF power to respond to the passive RFID readers.

While not completely immune to attenuation, active RFID systems largely overcome this issue through the use of an onboard power source to emanate tag signals. The problem is much more pronounced in passive RFID systems because they rely on energy from the fields generated by the reader. This is an issue for anyone who intends to cost effectively track IT assets, metal machine parts, steel pipes, material handling equipment or numerous other items.

So how can you overcome attenuation? Recently published research in ODIN labs' RFID Metal Mount Tag Benchmark evaluates the issue in detail and presents data on 17 of the most innovative and popular RFID tags designed for use on metal. They each use a combination of spacing, dialectic materials and creative antenna designs to achieve strong performance in some tough applications.

The spacing is based on science and demonstrates that tags perform better when encapsulated in non-conductive materials and are offset somewhat from the metal surface. The designs range from small 1 x 1 inch squares to tags with widths exceeding 6 inches. Not surprisingly, some manufacturers have succeeded more than others. In some instances, small tags actually out-perform larger tags showing that the physics of RF design can sometimes offset the advantages of larger tag antenna sizes.

The benchmark runs each of the tags through a battery of scientific tests including metal proximity testing, read distance, material dependence, orientation sensitivity and others. This leads to three positive results for end users. First, it demonstrates through hard science that passive RFID can work on metal items today. Second, it shows what factors are important when evaluating tags for different use cases in metal environments. Third, it provides insight into which vendors are truly developing outstanding tags for use on metal.

These are three good outcomes for everyone considering RFID for applications where metal surfaces are involved. It can also help end users already employing passive RFID but looking for better performance or more options. Best of all, the RFID Metal Mount Tag Benchmark comes with objective scientific data that goes beyond anecdote and art.

4.0 Current uses

RFID is becoming increasingly prevalent as the price of the technology decreases. In January 2003 Gillette announced in that it ordered 500 million tags from Alien Technology. Gillette VP Dick Cantwell says the company paid "well under ten cents" for each tag. The Japanese HIBIKI initiative aims to reduce the price to 5 Yen (4 eurocent).

4.1 Race Timing

Many forms of Transponder timing have been in use for timing races of different types since 2004. "Software Outsourcing System" of India has designed and implemented this method for registering race start and end timings for individuals in a marathon-type race where it is impossible to get accurate stopwatch readings for every entrant. Individuals wear a chest number containing passive tags which are read by antennae placed alongside the track. Rush error and accidents at start time are avoided since anyone can start and finish anytime without being in a batch mode. This method is being adapted by many recruitment agencies which have a PET (Physical Endurance Test) as their qualifying procedure especially in cases where the candidate volumes may run into millions (Indian Railway Recruitment Cells, Police and Power sector).

4.2 Passports

RFID tags are being used in passports issued by many countries, including Malaysia (early 2000), New Zealand (November 4, 2005), Belgium, The Netherlands (2005), Norway (November 2005)[14], Ireland (2006), Japan (March 1, 2006), Pakistan, Germany, Portugal, Poland (2006), The United Kingdom, Australia and the United States (2007).

Standards for RFID passports are determined by the International Civil Aviation Organization (ICAO), and are contained in ICAO Document 9303, Part 1, Volumes 1 and 2 (6th edition, 2006). ICAO refers to the ISO 14443 RFID chips in e-passports as "contactless integrated circuits". ICAO standards provide for e-passports to be identifiable by a standard e-passport logo on the front cover.

The first RFID passports ("E-passport") were issued by Malaysia in 1998. In addition to information also contained on the visual data page of the passport, Malaysian e-passports record the travel history (time, date, and place) of entries and exits from the country.

In 2006, RFID tags were included in new US passports. The US produced 10 million passports in 2005, and it has been estimated that 13 million will be produced in 2006. The chips will store the same information that is printed within the passport and will also include a digital picture of the owner. The US State Department initially stated the chips could only be read from a distance of 10 cm (4 in), but after widespread criticism and a clear demonstration that special equipment can read the test passports from 10 meters (33 ft) away, the passports were designed to incorporate a thin metal lining to make it more difficult for unauthorized readers to "skim" information when the passport is closed. The department will also implement Basic Access Control (BAC), which functions as a Personal Identification Number (PIN) in the form of characters printed on the passport data page. Before a passport's tag can be read, this PIN must be entered into an RFID reader. The BAC also enables the encryption of any communication between the chip and interrogator

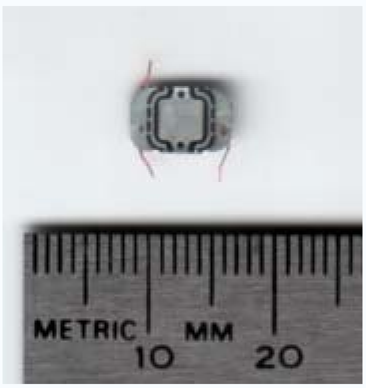
The new Passport Card also incorporates RFID technology. The Center for Democracy and Technology has issued warnings that significant security weaknesses that the Passport Card could be used to track U.S. travelers are apparent in the specifications of the card design as outlined by the U.S. Department of State.

Security expert Bruce Schneier has suggested that a mugger operating near an airport could target victims who have arrived from wealthy countries, or a terrorist could design an improvised explosive device which functioned when approached by persons from a particular country.

Some other European Union countries are also planning to add fingerprints and other biometric data, while some have already done so.

4.3 Transportation payments

An Electronic Road Pricing gantry in Singapore. Gantries such as these collect tolls in high-traffic areas from active RFID units in vehicles.



PayPass RFID chip removed from a MasterCard.

- Throughout Europe, and in particular in Paris (system started in 1995 by the RATP), Lyon, Bordeaux and Marseille in France, Porto and Lisbon in Portugal, Milan, Turin, and Florence in Italy, and Brussels in Belgium), RFID passes conforming to the Calypso (RFID) international standard are used for public transport systems. They are also used now in Canada (Montreal), Mexico, Israel, Bogotá and Pereira in Colombia, Stavanger in Norway, etc.

- In Toronto, Ontario, Canada and surrounding areas, Electronic Road Pricing systems are used to collect toll payments on Highway 407.

- In Seoul, South Korea and surrounding cities, T-money cards can be used to pay for public transit. Some other South Korean cities have adopted the system, which can also be used in some stores as cash. T-money replaced Upass, first introduced for transport payments in 1996 using MIFARE technology.

- In Turkey, RFID has been used in the motorways and bridges as a payment system over ten years; it is also used in electronic bus tickets in Istanbul.

- In Hong Kong, mass transit is paid for almost exclusively through the use of an RFID technology, called the Octopus Card. Originally it was launched in September 1997 exclusively for transit fare collection, but has grown to be similar to a cash card, and can still be used in vending machines, fast-food restaurants and supermarkets. The card can be recharged with cash at add-value machines or in shops, and can be read several centimetres from the reader. The same applies for Delhi Metro, the rapid transit system in New Delhi, capital city of India.

- The Moscow Metro, the world's second busiest, was the first system in Europe to introduce RFID smartcards in 1998.
- The Washington, D.C. Metrorail became the first U.S. urban mass-transit system to use RFID technology when it introduced the SmarTrip card in 1999.
- JR East in Japan introduced SUICa (Super Urban Intelligent Card) for transport payment service in its railway transportation service in November 2001, using Sony's FeliCa (Felicity Card) technology. The same Sony technology was used in Hong Kong's Octopus card, and Singapore's EZ-Link card.
- In Singapore, public transportation buses and trains employ passive RFID cards known as EZ-Link cards. Traffic into crowded downtown areas is regulated by variable tolls imposed using an active tagging system combined with the use of stored-value cards (known as CashCards).
- RFID is used in Malaysia Expressways payment system. The name for the system is Touch 'n Go. As the system's name indicates, the card is designed to only function as an RFID card when the user touches it.
- Since 2002, in Taipei, Taiwan the transportation system uses RFID operated cards as fare collection. The Easy Card is charged at local convenience stores and metro stations, and can be used in Metro, buses and parking lots. The uses are planned to extend all throughout the island of Taiwan in the future.
- In the USA, The Chicago Transit Authority has offered the Chicago Card and the Chicago Card Plus for rail payments across the entire system since 2002 and for bus payments since 2005. The New York City Subway is conducting a trial during 2006, utilizing PayPass by MasterCard as fare payment. The Massachusetts Bay Transportation Authority introduced the use of a CharlieCard RFID as a fare payment system which is cheaper than its paper or cash equivalent. Six transit agencies in the King County region of Washington State are collaborating to introduce the Smart Card, or Orca Card.
- In the UK, operating systems for prepaying for unlimited public transport have been devised, making use of RFID technology. The design is embedded in a creditcard-like pass, that when scanned reveals details of whether the pass is valid, and for how long the pass will remain valid. The first company to implement this is the NCT company of Nottingham City, where the general public affectionately refer to them as "beep cards". It has since been successfully implemented in London, where "Oyster cards" allow for pay-as-you-go travel as well as passes valid for various lengths of time and in various areas.

- In Oslo, Norway, the upcoming public transport payment is to be entirely RFID-based. The system was slated for introduction around spring 2007.

- In Norway, all public toll roads are equipped with an RFID payment system known as AutoPass.

- RFID tags are used for electronic toll collection at toll booths with Georgia's Cruise Card, California's FasTrak, Colorado's E-470, Illinois' I-Pass, Oklahoma's Pikepass, the expanding eastern states' E-ZPass system (including Massachusetts's Fast Lane,Delaware, New Hampshire Turnpike, Maryland, New Jersey Turnpike, Pennsylvania Turnpike, West Virginia Turnpike, New York's Thruway system, Virginia, and the Maine Turnpike),Central Florida also utilizes this technology, via its E-PASS System. E-PASS and Sunpass are mutually compatible. Florida's SunPass, Various systems in Texas including D/FW's NTTA TollTag, the Austin metro TxTag and Houston HCTRA EZ Tag (which as of early 2007 are all valid on any Texas toll road), Kansas's K-Tag, The "Cross-Israel Highway" (Highway 6), Philippines South Luzon Expressway E-Pass, Brisbane's Queensland Motorway E-Toll System in Australia, Autopista del Sol (Sun's Highway), Autopista Central (Central Highway), Autopista Los Libertadores, Costanera Norte, Vespucio Norte Express and Vespucio Sur urban Highways and every forthcoming urban highway (in a "Free Flow" modality) concessioned to private investors in Chile, all toll tunnels in Hong Kong (Autotoll) and all highways in Portugal (Via Verde, the first system in the world to span the entire network of tolls), France (Liber-T system), Italy (Telepass), Spain (VIA-T), Brazil (Sem Parar - Via Fácil). The tags, which are usually the active type, are read remotely as vehicles pass through the booths, and tag information is used to debit the toll amount from a prepaid account. The system helps to speed traffic through toll plazas as it records the date, time, and billing data for the RFID vehicle tag. The plaza- and queue-free 407 Express Toll Route, in the Greater Toronto Area, allows the use of a transponder (an active tag) for all billing. This eliminates the need to identify a vehicle by licence plate.[*citation needed*]

- The Transperth public transport network in Perth, Western Australia uses RFID technology in the new SmartRider ticketing system.

- In Atlanta, MARTA (Metropolitan Atlanta Rapid Transit Authority) has transitioned its bus and rail lines from coin tokens to the new Breeze Card system which uses RFID tags embedded in disposable paper tickets. More permanent plastic cards are available for frequent users.

- In Rio de Janeiro, "RioCard" passes can be used in buses, ferries, trains and subway. There are two types, one you cannot recharge, the other one can be recharged if it's been bought by the company you work for, if they provided it (only in Brazil).

- A number of ski resorts, particularly in the French Alps and in the Spanish and French Pyrenees, have adopted RFID tags to provide skiers hands-free access to ski lifts. Skiers don't have to take their passes out of their pockets.

- In Santiago (Chile) the subway system Metro and the recently implemented public transportation system Transantiago use an RFID card called "Bip" or "Multivia".

- In Medellín (Colombia) the recently-implemented card system for the Metro system uses an RFID card called Cívica.

- In Dubai, (United Arab Emirates) drivers through Sheikh Zayed Road and Garhoud Bridge pay tolls using RFID tags called Salik (Road Toll).

- In Milano (Italy), the ATM "Azienda Trasporti Milanese" has implemented RFID tags for frequent users.

- In Mumbai, the busiest suburban rail transport in the world, which transports 3.5 million commuters per day, has implemented the use of RFID ticket cards.[*citation needed*]

- In New Delhi, the underground subway or metro system implements RFID ticket coins.

- In Barcelona, RFID technology is used to identify users in a bike sharing system called Bicing to prevent bicycle theft and track bicycle usage.

- In the Netherlands the new OV-chipkaart system will eventually replace current bus, tram, metro and train payment systems, allowing for more accurate fares, access control to stations, and more accurate determination of government fees to the various public transportation companies

4.4 Product tracking

- The Canadian Cattle Identification Agency began using RFID tags as a replacement for barcode tags. The tags are required to identify a bovine's herd of origin and this is used for tracing when a packing plant condemns a carcass. Currently CCIA tags are used in Wisconsin and by US farmers on a voluntary basis. The USDA is currently developing its own program.

- High-frequency RFID or HFID/HighFID tags are used in library book or bookstore tracking, jewelry tracking, pallet tracking, building access control, airline baggage tracking, and apparel and pharmaceutical items tracking. High-frequency tags are widely used in identification badges, replacing earlier magnetic stripe cards. These badges need only be held within a certain distance of the reader to authenticate the holder. The American Express Blue credit card now includes a HighFID tag. In Feb 2008, Emirates airline started a trial of RFID baggage tracing at London and Dubai airports.
- BGN has launched two fully automated Smartstores that combine item-level RFID tagging and SOA to deliver an integrated supply chain, from warehouse to consumer.
- UHF, Ultra-HighFID or UHFID tags are commonly used commercially in case, pallet, and shipping container tracking, and truck and trailer tracking in shipping yards.
- In May 2007, Bear River Supply began utilizing ultrahigh-frequency identification (UHFID) tags to help monitor their agricultural equipment.

- In Colombia, "Federación Nacional de Cafeteros" uses an RFID solution to trace the coffee.
- Logistics & Transportation is a major area of implementation for RFID technology. For example, Yard Management, Shipping & Freight and Distribution Centers are some areas where RFID tracking technology is used. Transportation companies around the world value RFID technology due to its impact on the business value and efficiency.

4.5 Lap scoring

Passive and active RFID systems are used in off-road events such as Enduro and Hare and Hounds racing. Riders have a transponder on their person, normally on their arm. When they complete a lap they swipe or touch the receiver which is connected to a computer and log their lap time. The Casimo Group Ltd sells such a system.

4.6 Animal identification

Implantable RFID tags or transponders can be used for animal identification. The transponders are more well-known as passive RFID technology, or simply "Chips" on animals.

4.7 Inventory systems

An advanced automatic identification technology such as the Auto-ID system based on the Radio Frequency Identification (RFID) technology has significant value for inventory systems. Notably, the technology provides an accurate knowledge of the current inventory. In an academic study[performed at Wal-Mart, RFID reduced Out-of-Stocks by 30 percent for products selling between 0.1 and 15 units a day. Other benefits of using RFID include the reduction of labor costs, the simplification of business processes, and the reduction of inventory inaccuracies.

In 2004, Boeing integrated the use of RFID technology to help reduce maintenance and inventory costs on the Boeing 787 Dreamliner. With the high costs of aircraft parts, RFID technology allowed Boeing to keep track of inventory despite the unique sizes, shapes and environmental concerns. During the first six months after integration, the company was able to save $29,000 in just labor.

4.7.1 RFID mandates

Wal-Mart and the United States Department of Defense have published requirements that their vendors place RFID tags on all shipments to improve supply chain management. Due to the size of these two organizations, their RFID mandates impact thousands of companies worldwide. The deadlines have been extended several times because many vendors face significant difficulties implementing RFID systems. In practice, the successful read rates currently run only 80%, due to radio wave attenuation caused by the products and packaging. In time it is expected that even small companies will be able to place RFID tags on their outbound shipments.

Since January 2005, Wal-Mart has required its top 100 suppliers to apply RFID labels to all shipments. To meet this requirement, vendors use RFID printer/encoders to label cases and pallets that require EPC tags for Wal-Mart. These smart labels are produced by embedding RFID inlays inside the label material, and then printing bar code and other visible information on the surface of the label.

Another Wal-Mart division, Sam's Club, has also moved in this direction. It sent letters dated Jan. 7, 2008 to its suppliers, stating that by Jan. 31, 2008, every full single-item pallet shipped to its distribution center in DeSoto, Texas, or directly to one of its stores served by that DC, must bear an EPC Gen 2 RFID tag. Suppliers failing to comply will be charged a service fee.

4.7.2 Promotion Tracking

Manufacturers of products sold through retailers promote their products by offering discounts for a limited period on products sold to retailers with the expectation that the retailers will pass on the savings to their customers. However, retailers typically engage in *forward buying*, purchasing more product during the discount period than they intend to sell during the promotion period. Some retailers engage in a form of arbitrage, reselling discounted product to other retailers, a practice known as *diverting*. To combat this practice, manufacturers are exploring the use of RFID tags on promoted merchandise so that they can track exactly which product has sold through the supply chain at fully discounted prices.[23]

4.7.3 Human Implants

Hand with the planned location of the RFID chip.

Just after the operation to insert the RFID tag was completed.

Implantable RFID chips designed for animal tagging are now being used in humans. An early experiment with RFID implants was conducted by British professor of cybernetics Kevin Warwick, who implanted a chip in his arm in 1998. Night clubs in, Spain and in Rotterdam, The

Netherlands, use an implantable chip to identify their VIP customers, who in turn use it to pay for drinks.

In 2004, the Mexican Attorney General's office implanted 18 of its staff members with the Verichip to control access to a secure data room. (This number has been variously mis-reported as 160 or 180 staff members.)

Security experts have warned against using RFID for authenticating people due to the risk of identity theft. For instance a man-in-the-middle attack would make it possible for an attacker to steal the identity of a person in real-time. Due to the resource constraints of RFIDs it is virtually impossible to protect against such attack models as this would require complex distance-binding protocols.

4.7.4 Libraries

RFID tags used in libraries: square book tag, round CD/DVD tag and rectangular VHS tag.

Among the many uses of RFID technologies is its deployment in libraries. This technology has slowly begun to replace the traditional barcodes on library items (books, CDs, DVDs, etc.). The RFID tag can contain identifying information, such as a book's title or material type, without having to be pointed to a separate database (but this is rare in North America). The information is read by an RFID reader, which replaces the standard barcode reader commonly found at a library's circulation desk. The RFID tag found on library materials typically measures 50 mm X 50 mm in North America and 50 mm x 75 mm in Europe. It may replace or be added to the barcode, offering a different means of inventory management by the staff and self service by the borrowers. It can also act as a security device, taking the place of the more traditional electromagnetic security strip And not only the books, but also the membership cards could be fitted with an RFID tag.

While there is some debate as to when and where RFID in libraries first began, it was first proposed in the late 1990s as a technology that would enhance workflow in the library setting. Singapore was certainly one of the first to introduce RFID in libraries and Rockefeller University in New York may have been the first academic library in the United States to utilize this technology, whereas Farmington Community Library in Michigan may have been the first public institution, both of which began using RFID in 1999. In Europe, the first public library to use RFID was the one in Hoogezand-Sappemeer, the Netherlands, in 2001, where borrowers were given an option. To their surprise, 70% used the RFID option and quickly adapted, including elderly people.

Worldwide, in absolute numbers, RFID is used most the United States (with its 300 million inhabitants), followed by the United Kingdom and Japan. It is estimated that over 30 million library items worldwide now contain RFID tags, including some in the Vatican Library in Rome.

RFID has many library applications that can be highly beneficial, particularly for circulation staff. Since RFID tags can be read through an item, there is no need to open a book cover or DVD case to scan an item. This could reduce repetitive-motion injuries. Where the books have a barcode on the outside, there is still the advantage that borrowers can scan an entire pile of books in one go, instead of one at a time. Since RFID tags can also be read while an item is in motion, using RFID readers to check-in returned items while on a conveyor belt reduces staff time. But, as with barcode, this can all be done by the borrowers themselves, meaning they might never again need the assistance of staff. Next to these readers with a fixed location there are also portable ones (for librarians, but in the future possibly also for borrowers, possibly even their own general-purpose readers). With these, inventories could be done on a whole shelf of materials within seconds, without a book ever having to be taken off the shelf. In Umeå, Sweden, RFID is being used to assist visually impaired people in borrowing audiobooks. In Malaysia, Smart Shelves are used to pinpoint the exact location of books in Multimedia University Library, Cyberjaya. In the Netherlands, handheld readers are being introduced for this purpose.

The Dutch Union of Public Libraries ('Vereniging van Openbare Bibliotheken') is working on the concept of an interactive 'context library', where borrowers get a reader/headphones-set, which leads them to the desired section of the library (using triangulation methods, rather like GPS or TomTom) and which they can use to read information from books on the shelves with the desired level of detail (e.g. a section read out loud), coming from the book's tag itself or a database elsewhere, and get tips on alternatives, based on the borrowers' preferences, thus creating a more personalised version of the library. This may also lead them to sections of the library they might not otherwise visit. Borrowers could also use the system to exchange experiences (such as grading books). This is already done by children in the virtual realm at mijnstempel.nl, but the same could be done in physical form. Borrowers might grade the book at the return desk.

However, as of 2008 this technology remains too costly for many smaller libraries, and the conversion period has been estimated at 11 months for an average-size library. A 2004 Dutch estimate was that a library which lends 100,000 books per year should plan on a cost of €50,000 (borrow- and return-stations: 12,500 each, detection porches 10,000 each; tags 0.36 each). RFID taking a large burden off staff could also mean that fewer staff will be needed, resulting in some of them getting fired, but that has so far not happened in North America where recent surveys have not returned a single library that cut staff because of adding RFID. In fact, library budgets are being reduced for personnel and increased for infrastructure, making it necessary for libraries to add automation to compensate for the reduced staff size. Also, the tasks that RFID takes over are largely not the primary tasks of librarians. A finding in the Netherlands is that borrowers are pleased with the fact that staff are now more available for answering questions.

A concern surrounding RFID in libraries that has received considerable publicity is the issue of privacy. Because RFID tags can in theory be scanned and read from up to 350 feet (100 m), and because RFID utilizes an assortment of frequencies (both depending on the type of tag, though), there is some concern over whether sensitive information could be collected from an unwilling source. However, library RFID tags do not contain any patron information, and the tags used in the majority of libraries use a frequency only readable from approximately ten feet. Also, libraries have always had to keep records of who has borrowed what, so in that sense there is nothing new. One simple option is to only let the book transmit a code, that will only mean anything in conjunction with the library's database. Another step further is to give the book a new code every time it is returned. And if in the future readers become ubiquitous (and possibly networked), then stolen books could be traced even outside the library. Removing of the tags could be made difficult if they are so small that they fit invisibly inside a (random) page, possibly put there by the publisher.

4.7.5 Schools and universities

School authorities in the Japanese city of Osaka are now chipping children's clothing, back packs, and student IDs in a primary schoolA school in Doncaster, England is piloting a monitoring system designed to keep tabs on pupils by tracking radio chips in their uniforms.. St Charles Sixth Form College in West London, England, started September, 2008, is using an RFID card system to check in and out of the main gate, to both track attendance and prevent unauthorized entrance.

4.7.6 Museums

RFID technologies are now also implemented in end-user applications in museums. An example is the custom-designed application "eXsport" at the Exploratorium, a science museum in San Francisco, California. A visitor entering the museum receives an RF Tag that can be carried on a card or necklace. The eXspot system enables the visitor to receive information about the exhibit and take photos to be collected at the giftshop. Later they can visit their personal Web page on which specific information such as visit dates, the visited exhibits and the taken photographs can be viewed

4.7.7 Social retailing

When customers enter a dressing room, the mirror reflects their image and also images of the apparel item being worn by celebrities on an interactive display. A webcam also projects an image of the consumer wearing the item on the website for everyone to see. This creates an interaction between the consumers inside the store and their social network outside the store. The technology in this system is an RFID interrogator antenna in the dressing room and Electronic Product Code RFID tags on the apparel item

4.7.8 Miscellaneous

- In February 2008, ThingMagic announced a partnership with Dewalt and Ford to equip 2009 Ford F-150, F-Series Super Duty pickups and E-Series vans with an embedded RFID asset tracking system enabled by ThingMagic's Mercury5e readers.
- In November 2007, French company Violet started selling its RFID-enabled Nabaztag with children's books (from publisher Gallimard Jeunesse) that included RFID tags inside the front cover. When the book is passed in front of the Nabaztag, it downloads the audio book on the Internet and reads the book out loud.
- Some hospitals use Active RFID tags to perform Asset Tracking in Real Time.
- In 2006, the Smart Conveyor Tunnel, designed by Blue Vector, was introduced. This allowed the pharmaceutical industry to track both UHF and HF tags. Rite Aid utilized the technology with some of McKesson Corporation's products.
- The NEXUS and SENTRI frequent traveler programs use RFID to speed up landborder processing between the U.S. and Canada and Mexico.
- NADRA has developed an RFID-based driver license that bears the license holder's personal information and stores data regarding traffic violations, tickets issued, and outstanding penalties. The license cards are designed so that driving rights can be revoked electronically in case of serious violations.
- Sensors such as seismic sensors may be read using RFID transceivers, greatly simplifying remote data collection.
- In August 2004, the Ohio Department of Rehabilitation and Correction (ODRC) approved a $415,000 contract to evaluate the personnel-tracking technology of Alanco Technologies. Inmates will wear wristwatch-sized transmitters that can detect attempted removal and alert prison computers. This project is not the first rollout of tracking chips in US prisons. Facilities in Michigan, California and Illinois already employ the technology.
- Transponder timing at mass sports events.
- Used as storage for a video game system produced by Mattel, "HyperScan".
- RFIQin, designed by Vita Craft, is an automatic cooking device that has three different sized pans, a portable induction heater, and recipe cards. Each pan is embedded with an RFID tag that monitors the food 16 times per second while an MI tag in the handle of the pans transmits signals to the induction heater to adjust the temperature.
- Slippery Rock University is using RFID tags in their students' ID cards beginning in the fall 2007 semester.
- 25 real-world application case studies can be found in a 61 page free Ebook RFID Technology Applications
- RFID tags are now being embedded into playing cards that are used for televisied poker tournamnets, so commentators know exactly what cards have been dealt to whom, as soon as the deal is complete.
- The Iraqi army uses an RFID security card that contains a biometric picture of the soldier. The picture in the chip must match the picture on the card to prevent forgery.
- Theme parks (such as Alton Towers in the United Kingdom) have been known to use RFID to help them identify users of a ride in order to make a DVD of their time at the park. This is then available for the users to buy at the end of the day. This is voluntary by the users by wearing a wristband given to them at the park.
- Access control - many places which employ traditional swipe cards for access control are slowly shifting to RFID no-contact cards.

- Meetings and conventions have also implemented RFID technology into attendee badges allowing the ability to track people at conferences. This provides data that can display what rooms people have enter and exited during the day. This data is available to show organizers to help them improve the content and design of the conference. RFID is also being used to improve the lead retrieval process for exhibitors at exhibitions.
- RFID transponder chips have been implanted in golf balls to allow them to be tracked. The uses of such tracking range from being able to search for a lost ball using a homing device, to a computerized driving range format that tracks shots made by a player and gives feedback on distance and accuracy.
- In 2007 artist couple artcoon starts their world project Kansa. Sirpa Masalins human like wooden sculptures carry an RFID inside. Hans-Ulrich Goller-Masalin created a New Media Art work which traces the individual sculptures of Kansa in the internet. Owners are asked to register the city where their sculpture is located. By comparing the RFIDs unique number referenced at artcoon the owner can identify his sculpture as the original one.
- Some casinos are embedding RFID tags into their chips. This allows the casinos to track the locations of chips on the casino floor, identify counterfeit chips, and prevent theft. In addition, casinos can use RFID systems to study the betting behavior of players.

5.0 Potential uses

5.1 Replacing barcodes

RFID tags are often a replacement for UPC or EAN barcodes, having a number of important advantages over the older barcode technology. They may not ever completely replace barcodes, due in part to their higher cost and the advantage of multiple data sources on the same object. The new EPC, along with several other schemes, is widely available at reasonable cost.

The storage of data associated with tracking items will require many terabytes. Filtering and categorizing RFID data is needed to create useful information. It is likely that goods will be tracked by the pallet using RFID tags, and at package level with Universal Product Code (UPC) or EAN from unique barcodes.

The unique identity is a mandatory requirement for RFID tags, despite special choice of the numbering scheme. RFID tag data capacity is large enough that each individual tag will have a unique code, while current bar codes are limited to a single type code for a particular product. The uniqueness of RFID tags means that a product may be tracked as it moves from location to location, finally ending up in the consumer's hands. This may help to combat theft and other forms of product loss. The tracing of products is an important feature that gets well supported with RFID tags containing a unique identity of the tag and also the serial number of the object. This may help companies to cope with quality deficiencies and resulting recall campaigns, but also contributes to concern about tracking and profiling of consumers after the sale.

It has also been proposed to use RFID for POS store checkout to replace the cashier with an automatic system which needs no barcode scanning. This is not likely without a significant reduction in the cost of tags and changes in the POS process. There is some research taking place, however, this is some years from reaching fruition.

An FDA-nominated task force concluded, after studying the various technologies currently commercially available, which of those technologies could meet the pedigree requirements. Amongst all technologies studied including bar coding, RFID seemed to be the most promising and the committee felt that the pedigree requirement could be met by easily leveraging something that is readily available.

5.2 Telemetry

Active RFID tags also have the potential to function as low-cost remote sensors that broadcast telemetry back to a base station. Applications of tagometry data could include sensing of road conditions by implanted beacons, weather reports, and noise level monitoring.

It is possible that active or semi-passive RFID tags used with or in place of barcodes could broadcast a signal to an in-store receiver to determine whether the RFID tag (product) is in the store.

5.3 Identification of patients and hospital staff

In July 2004, the US Food and Drug Administration issued a ruling that essentially begins a final review process that will determine whether hospitals can use RFID systems to identify patients and/or permit relevant hospital staff to access medical records. Since then, a number of U.S. hospitals have begun implanting patients with RFID tags and using RFID systems, usually for workflow and inventory management. There is some evidence, as well, that nurses and other hospital staff may be subjected to increased surveillance of their activities or to labor intensification as a result of the implementation of RFID systems in hospitals. The use of RFID to prevent mixups between sperm and ova in IVF clinics is also being considered .

In October 2004, the FDA approved USA's first RFID chips that can be implanted in humans. The 134 kHz RFID chips, from VeriChip Corp. can incorporate personal medical information and could save lives and limit injuries from errors in medical treatments, according to the company. The FDA approval was disclosed during a conference call with investors. Shortly after the approval, authors and anti-RFID activists Katherine Albrecht and Liz McIntyre discovered a warning letter from the FDA that spelled out serious health risks associated with the VeriChip. According to the FDA, these include "adverse tissue reaction", "migration of the implanted transponder", "failure of implanted transponder", "electrical hazards" and "magnetic resonance imaging [MRI] incompatibility."

6.0 Possible uses for medical field

Human tagging and tracking could be useful in hospitals, especially emergency rooms. A nurse or doctor could easily access patient history or information concerning files, allergies, or any other complications from the incoming patient.

6.1 Yoking

It has been proposed to use a strong cryptography-based scheme to generate forensic evidence that two RFID tags were in proximity at the time of scanning.

7.0 Regulation and standardization

There is no global public body that governs the frequencies used for RFID. In principle, every country can set its own rules for this. The main bodies governing frequency allocation for RFID are:

- USA: FCC (Federal Communications Commission)
- Canada: CRTC (Canadian Radio-television and Telecommunications Commission)
- Europe: ERO, CEPT, ETSI, and national administrations (note that the national administrations must ratify the usage of a specific frequency before it can be used in that country)
- Malaysia: Malaysian Communications and Multimedia Commission (MCMC)
- Japan: MIC (Ministry of Internal Affairs and Communications)
- China: Ministry of Information Industry
- Taiwan: NCC (National Communications Commission)
- South Africa: ICASA
- South Korea: Ministry of Commerce, Industry and Energy
- Australia: Australian Communications and Media Authority.
- New Zealand: Ministry of Economic Development
- Singapore: Infocomm Development Authority of Singapore
- Brazil: Anatel (Agência Nacional de Telecomunicações)

Low-frequency (LF: 125–134.2 kHz and 140–148.5 kHz) (LowFID) tags and high-frequency (HF: 13.56 MHz) (HighFID) tags can be used globally without a license. Ultra-high-frequency (UHF: 868–928 MHz) (Ultra-HighFID or UHFID) tags cannot be used globally as there is no single global standard. In North America, UHF can be used unlicensed for 902–928& MHz (±13 MHz from the 915 MHz center frequency), but restrictions exist for transmission power. In Europe, RFID and other low-power radio applications are regulated by ETSI recommendations EN 300 220 and EN 302 208, and ERO recommendation 70 03, allowing RFID operation with somewhat complex band restrictions from 865–868 MHz. Readers are required to monitor a channel before transmitting ("Listen Before Talk"); this requirement has led to some restrictions on performance, the resolution of which is a subject of current research. The North American UHF standard is not accepted in France as it interferes with its military bands. For China and Japan, there is no regulation for the use of UHF. Each application for UHF in these countries needs a site license, which needs to be applied for at the local authorities, and can be revoked. For Australia and New Zealand, 918–926 MHz are unlicensed, but restrictions exist for transmission power.

These frequencies are known as the ISM bands (Industrial Scientific and Medical bands). The return signal of the tag may still cause interference for other radio users.

Some standards that have been made regarding RFID technology include:

- ISO 14223/1 – Radio frequency identification of Animals, advanced transponders – Air interface
- ISO 14443: This standard is a popular HF (13.56 MHz) standard for HighFIDs which is being used as the basis of RFID-enabled passports under ICAO 9303.
- ISO 15693: This is also a popular HF (13.56 MHz) standard for HighFIDs widely used for non-contact smart payment and credit cards.
- ISO/IEC 18000: Information technology — Radio frequency identification for item management:
    - Part 1: Reference architecture and definition of parameters to be standardized
    - Part 2: Parameters for air interface communications below 135 kHz
    - Part 3: Parameters for air interface communications at 13.56& MHz
    - Part 4: Parameters for air interface communications at 2.45 GHz
    - Part 6: Parameters for air interface communications at 860-960 MHz
    - Part 7: Parameters for active air interface communications at 433 MHz
- ISO 18185: This is the industry standard for electronic seals or "e-seals" for tracking cargo containers using the 433 MHz and 2.4 GHz frequencies.
- EPCglobal – this is the standardization framework that is most likely to undergo International Standardisation according to ISO rules as with all sound standards in the world, unless residing with limited scope, as customs regulations, air-traffic regulations and others. Currently the big distributors and governmental customers are pushing EPC heavily as a standard well-accepted in their community, but not yet regarded as for salvation to the rest of the world.
- ASTM D7434, Standard Test Method for Determining the Performance of Passive Radio Frequency Identification (RFID) Transponders on Palletized or Unitized Loads

- ASTM D7435, Standard Test Method for Determining the Performance of Passive Radio Frequency Identification (RFID) Transponders on Loaded Containers

7.1 EPC Gen2

EPC Gen2 is short for *EPCglobal UHF Class 1 Generation 2*.

EPCglobal (a joint venture between GS1 and GS1 US) is working on international standards for the use of mostly passive RFID and the EPC in the identification of many items in the supply chain for companies worldwide.

One of the missions of EPCglobal was to simplify the Babel of protocols prevalent in the RFID world in the 1990s. Two tag air interfaces (the protocol for exchanging information between a tag and a reader) were defined (but not ratified) by EPCglobal prior to 2003. These protocols, commonly known as Class 0 and Class 1, saw significant commercial implementation in 2002–2005.

In 2004 the Hardware Action Group created a new protocol, the Class 1 Generation 2 interface, which addressed a number of problems that had been experienced with Class 0 and Class 1 tags.

The EPC Gen2 standard was approved in December 2004, and is likely to form the backbone of passive RFID tag standards moving forward. This was approved after a contention from Intermec that the standard may infringe a number of their RFID-related patents. It was decided that the standard itself did not infringe their patents, but it may be necessary to pay royalties to Intermec if the tag were to be read in a particular manner. The EPC Gen2 standard was adopted with minor modifications as ISO 18000-6C in 2006.

The lowest cost of Gen2 EPC inlay is offered by SmartCode at a price of $0.05 apiece in volumes of 100 million or more. Nevertheless, further conversion (including additional label stock or encapsulation processing/insertion and freight costs to a given facility or DC) and of the inlays into usable RFID labels and the design of current Gen 2 protocol standard will increase the total end-cost, especially with the added security feature extensions for RFID Supply Chain item-level tagging.

8.0 Problems and concerns

8.1 Global standardization

The frequencies used for RFID in the USA are currently incompatible with those of Europe or Japan. Furthermore, no emerging standard has yet become as universal as the barcode.

8.2 Security concerns

A primary RFID security concern is the illicit tracking of RFID tags. Tags which are world-readable pose a risk to both personal location privacy and corporate/military security. Such concerns have been raised with respect to the United States Department of Defense's recent adoption of RFID tags for supply chain management. More generally, privacy organizations have expressed concerns in the context of ongoing efforts to embed electronic product code (EPC) RFID tags in consumer products.

EPCglobal Network, by design, is also susceptible to DoS attacks. Using similar mechanism with DNS in resolving EPC data requests, the ONS Root servers become vulnerable to DoS attacks. Any organisation planning to embark on EPCglobal Network may cringe upon discovering that the EPCglobal Network infrastructure inherits security weaknesses similar to DNS'.

A second class of defense uses cryptography to prevent tag cloning. Some tags use a form of "rolling code" scheme, wherein the tag identifier information changes after each scan, thus reducing the usefulness of observed responses. More sophisticated devices engage in Challenge-response authentications where the tag interacts with the reader. In these protocols, secret tag information is never sent over the insecure communication channel between tag and reader. Rather, the reader issues a challenge to the tag, which responds with a result computed using a cryptographic circuit keyed with some secret value. Such protocols may be based on symmetric or public key cryptography. Cryptographically-enabled tags typically have dramatically higher cost and power requirements than simpler equivalents, and as a result, deployment of these tags is much more limited. This cost/power limitation has led some manufacturers to implement cryptographic tags using substantially weakened, or proprietary encryption schemes, which do not necessarily resist sophisticated attack. For example, the Exxon-Mobil Speedpass uses a cryptographically-enabled tag manufactured by Texas Instruments, called the Digital Signature Transponder (DST), which incorporates a weak, proprietary encryption scheme to perform a challenge-response protocol for lower cost.

Still other cryptographic protocols attempt to achieve privacy against unauthorized readers, though these protocols are largely in the research stage. One major challenge in securing RFID tags is a shortage of computational resources within the tag. Standard cryptographic techniques require more resources than are available in most low cost RFID devices. RSA Security has patented a prototype device that locally jams RFID signals by interrupting a standard collision avoidance protocol, allowing the user to prevent identification if desired. Various policy measures have also been proposed, such as marking RFID-tagged objects with an industry standard label.

8.3 Exploits

Ars Technica Reported in March 2006 an RFID buffer overflow bug that could infect airport terminal RFID Databases for baggage, and also Passport databases to obtain confidential information on the passport holder.

8.4 Passports

In an effort to make passports more secure, several countries have implemented RFID in passports. However, the encryption on UK chips was broken in under 48 hours. Since that incident, further efforts have allowed researchers to clone passport data while the passport is being mailed to its owner. Where a criminal previously needed to secretly open and then reseal the envelope, now it can be done without detection, adding some degree of insecurity to the passport system.

8.5 Shielding

A number of products are available on the market that will allow a concerned carrier of RFID-enabled cards or passports to shield their data. In fact the United States government requires their new employee ID cards to be delivered with an approved shielding sleeve or holder. There are contradicting opinions as to whether aluminum can prevent reading of RFID chips. Some people claim that aluminum shielding, essentially creating a Faraday cage, does work. Others claim that simply wrapping an RFID card in aluminum foil, only makes transmission more difficult, yet is not completely effective at preventing it.

Shielding is again a function of the frequency being used. Low-frequency LowFID tags, like those used in implantable devices for humans and pets, are relatively resistant to shielding, though thick metal foil will prevent most reads. High frequency HighFID tags (13.56 MHz — smart cards and access badges) are sensitive to shielding and are difficult to read when within a few centimetres of a metal surface. UHF Ultra-HighFID tags (pallets and cartons) are difficult to read when placed within a few millimetres of a metal surface, although their read range is actually increased when they are spaced 2–4 cm from a metal due to positive reinforcement of the reflected wave and the incident wave at the tag. UHFID tags can be successfully shielded from most reads by being placed within an anti-static plastic bag.