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RFID (Radio Frequency Identification) growth in daily life

Parth R. Agarwal[1], Preksha R. Agarwal[2]
[1]Jyoti Microsystems Pvt. Ltd., Ahmedabad, Gujarat, India.
[2]Tata Consultancy Services (TCS), Ahmedabad, Gujarat, India.
Email:parthagarwal24@yahoo.co.in, agarwalpreksha@gmail.com

ABSTRACT: There are three general methods to identify and track assets: paper and pencil or similar manual record keeping techniques; bar code techniques using printed paper or plastic labels with laser readers. Barcode labels use light beams which cannot read through dirt, or around corners or through walls, or at distances significantly greater than six inches. Bar code was thus limited to clean environments with a direct line of sight from the reader, and the reader had to be close to the label. The development of radio frequency techniques promised to overcome these limitations and with the introduction of the Radio Frequency Identification products, this promise became reality. By this paper we hope to provide an insight into this new field of wireless technology.

Keywords-RFID; bar-code; wireless; tags; UPC; RFID tag; transponder

I. INTRODUCTION:

Radio Frequency Identification (RFID) is a Dedicated Short Range Communication technology used to describe various technologies that use radio waves to automatically identify people or objects.

A RFID (Radio-Frequency IDentification) tag is made up of a small silicon microchip connected to an antenna. The chip can be smaller than half a millimeter square – the size of a seed and thin enough to be embedded in paper. An RFID tag is capable of transmitting a unique serial number a distance of up several meters in response to a query from a reading device. RFID tags are already quite common in everyday life. Tens of millions of pets around the world have surgically embedded RFID tags that made it easier to identify them should they become lost.

RFID tags are NOT an "improved bar code" as the proponents of the technology would like you to believe. RFID technology differs from bar codes in three important ways:

1. With bar code technology, a can of Coke has the same UPC or bar code number as every other can. With RFID, each individual can of Coke would have a unique ID number which could be linked to the person buying it when they scan a credit card or a frequent shopper card (i.e., an "item registration system").

2. Unlike a bar code, these chips can be read from a distance, right through your clothes, wallet without your knowledge or consent -- by anybody with the right reader device. In a way, it gives strangers x-ray vision powers to spy on you.

3. Unlike the bar code, RFID could be bad for your health. In a world of RFID, we would be continually bombarded with electromagnetic energy. Researchers do not know the long-term health effects of chronic exposure to the energy emitted by these reader devices.

II. HISTORY:

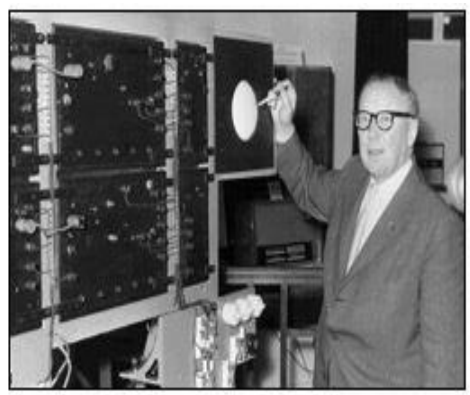

Fig. 1: Sir Alexander Wattson-Watt with the first reader apparatus

1800's: The primary understanding of electromagnetic energy came about.
1887: Hertz produced and studied electromagnetic waves.
1922: roughly considered birth of radar.
1935: The British and Sir Alexander Wattson-Watt developed the 1st Identify Friend or Foe (IFF) system.
1948: RFID invented
1950-1960: Development of theory of Rfid and laboratory experiments.
1973: Mario Cardullo receives first U.S patent for an active rfid tag with rewritable memory.
1970's: Explosion of Rfid development.

1980's: Commercial applications enter mainstream. First Rfid based toll-payment system emerges.
1990's: Emergence of standards and UHF systems developed and patented.
1999-2003: Auto Id canters gain support of companies and U.S. Defence.
2003: EPC commercialized.

III. TYPES OF RFID TAGS:

A. INDUCTIVELY COUPLED RFID TAGS:

This type of RFID tag has been used for years to track everything from cows and railroad cars to airline baggage and highway tolls. There are three parts to a typical inductively coupled RFID tag:

1) *Silicon microprocessor* - These chips vary in size depending on their purpose.

2) *Metal coil* - Made of copper or aluminum wire that is wound into a circular pattern on the transponder, this coil acts as the tag's antenna. The tag transmits signals to the reader, with read distance determined by the size of the coil antenna. These coil antennas can operate at 13.56 MHz.

3) *Encapsulating material* - glass or polymer material that wraps around the chip and coil Inductive RFID tags are powered by the magnetic field generated by the reader. The tag's antenna picks up the magnetic energy, and the tag communicates with the reader. The tag then modulates the magnetic field in order to retrieve and transmit data back to the reader. Data is transmitted back to the reader, which directs it to the host computer.

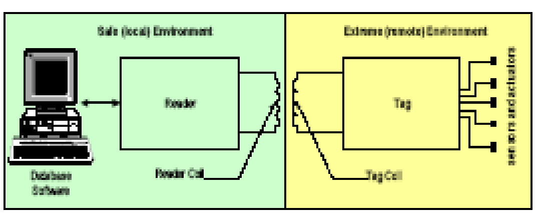

Fig. 2: A generic inductively coupled system

The system has two subsystems, local reader & remote sensing and actuating tag. The reader is connected to a PC, allowing real-time control of the tag sampling regime, display and storage of the data telemetered from the sensors connected to the tag as well as access to a distributed database.

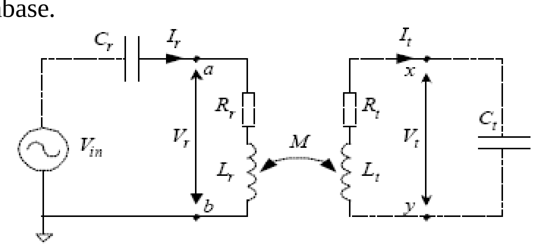

Fig. 3: A typical Inductively Coupled Circuit

As can be seen from Figure 2 the configuration is essentially a transformer circuit with a mutual inductance M linking the reader and tag circuits. From this circuit it is possible to derive two Thevenin circuits which clearly show how the system operates. The Thevenin reader circuit, Figure 3, comprises the reader source V_{in}, reader capacitance C_r and effective reader load impedance Z'_r, i.e. the impedance looking into the reader coil nodes a, b and including the mutual impedance of the tag.

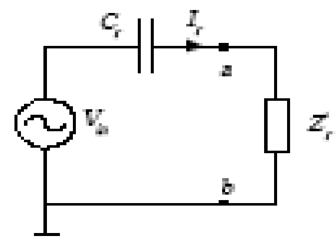

Fig. 4: Reader Thevenin Circuit

B. CAPACITIVELY COUPLED RFID TAGS:

Capacitively coupled RFID tags have been created in an attempt to lower the cost of radio-tag systems. These tags do away with the metal coil and use a small amount of silicon to perform that same function as an inductively coupled tag. A capacitively coupled tag also has three parts:

1) *Silicon microprocessor* - Motorola's BiStatix RFID tags use a silicon chip that is only 3 mm^2. These tags can store 96 bits of information, which would allow for trillions of unique numbers that can be assigned to products.

2) *Conductive carbon ink* - This special ink acts as the tag's antenna. It is applied to the paper substrate through conventional printing means.

3) *Paper* - The silicon chip is attached to printed carbon-ink electrodes on the back of a paper label, creating a low-cost, disposable tag that can be integrated on conventional product labels.

By using conductive ink instead of metal coils, the price of capacitively coupled tags are as low as 50 cents. These tags are also more flexible than the inductively coupled tag. Capacitively coupled tags, like the ones made by Motorola, can be bent, torn or crumpled, and can still relay data to the tag reader. In contrast to the magnetic energy that powers the inductively coupled tag, capacitively coupled tags are powered by electric fields generated by the reader.

The disadvantage to this kind of tag is that it has a very limited range. The range of Motorola's BiStatix tags is limited to just about 1 cm (.39 inch).

Based on the type of domain or application targeted, RFID systems are generally distinguished to three frequency ranges - Low, Intermediate and High. The following table summarizes these three frequency ranges, along with the typical system characteristics and examples of major areas of application:

TABLE 1 RFID USAGE BASED ON FREQUENCY

Typical Applications	Characteristics	Frequency Band
Low 100-500 KHz	Short to medium read range, inexpensive, low reading speed	Access control, Animal identification, Inventory control, Car Immobilizer
Intermediate 10-15 MHz	Short to medium read range, potentially inexpensive, medium reading speed	Access controls, Smart cards
High 850-950 MHz 2.4-5.8 GHz	Long read range, high reading speed, line of sight required, expensive	Railroad car monitoring, Toll collection systems

C. PASSIVE TAGS:

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 signal from the reader. This means that the antenna has to be designed to both 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 EEPROM for storing data.

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. As of 2006, the smallest such devices measured 0.15 mm × 0.15 mm, and are thinner than a sheet of paper (7.5 micrometers). The addition of the antenna creates a tag that varies from the size of a postage stamp to the size of a post card. Passive tags have practical read distances ranging from about 10 cm up to a few meters depending on the chosen radio frequency and antenna design/size. Due to their simplicity in design they are also suitable for manufacture with a printing process for the antennas.

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).

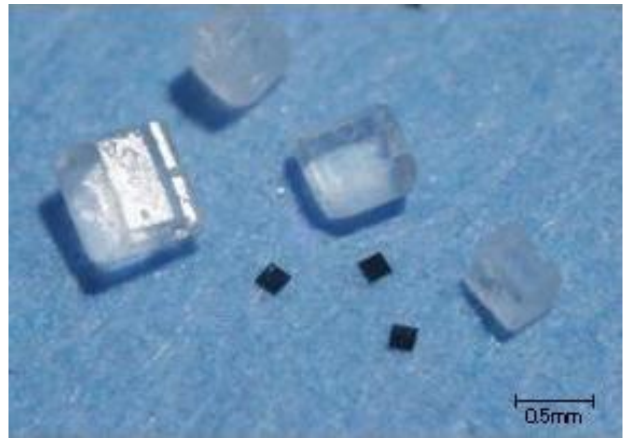

Fig. 5: Passive RFID tags

D. SEMI-ACTIVE (SEMI-PASSIVE) TAGS:

Semi-active tags have an on-board power source (for example, a battery) and electronics for performing specialized tasks. The on-board power supply provides energy to the tag for its operation. However, for transmitting its data, a semi-active tag uses the reader's emitted power. A semi-active tag is also called a battery-assisted tag. In tag-to-reader communication for this type of tag, a reader always communicates first, followed by the tag.

Why use a semi-passive tag over a passive tag? Because a semi-active tag does not use the reader's signal, unlike a passive tag, to excite itself, it can be read from a longer distance as compared to a passive tag. Because no time is needed for energizing a semi-active tag, such a tag could be in the read zone of a reader for substantially less time for its proper reading (unlike a passive tag). Therefore, even if the tagged object is moving at a high speed, its tag data can still be read if a semi-active tag is used. Finally, a semi-active tag might offer better readability for tagging of RF-opaque and RF-absorbent materials. The presence of these materials might prevent a passive tag from being properly excited, resulting in failure to transmit its data. However, this is not an issue with a semi-active tag. The reading distance of a semi-active tag can be 100 feet (30.5 meters approximately) under ideal conditions using a modulated backscatter scheme (in UHF and microwave).

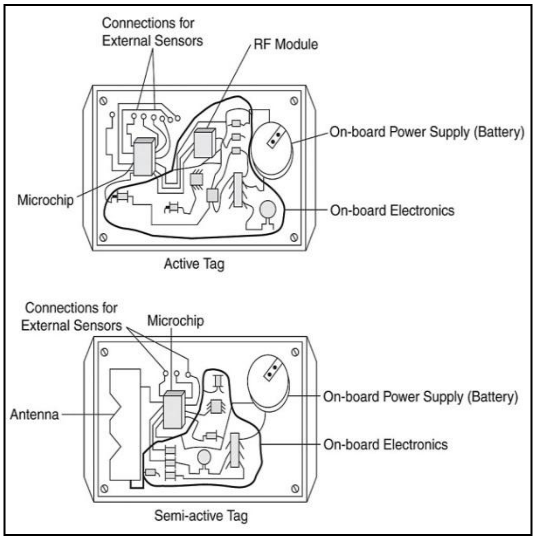

Fig. 6: Semi-Passive RFID tags

E. ACTIVE RFID TAGS

Unlike passive RFID tags, active RFID tags have their own internal power source which is used to power any ICs that generate the outgoing signal. Active tags are typically much more reliable (e.g. fewer errors) than 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 transmit at higher power levels than passive tags, allowing them to be more effective in "RF challenged" environments like water (including humans/cattle, which are mostly water), metal (shipping containers, vehicles), or at longer distances. Many active tags have practical ranges of hundreds of meters, and a battery life of up to 10 years. Some active RFID tags include sensors such as temperature logging which have been used in concrete maturity monitoring or to monitor the temperature of perishable goods. Other sensors that have been married with active RFID include humidity, shock/vibration, light, radiation, temperature and atmospherics like ethylene. Active tags typically have much longer range (approximately 300 feet) and larger memories than passive tags, as well as the ability to store additional information sent by the transceiver. The United States Department of Defense has successfully used active tags to reduce logistics costs and improve supply chain visibility for more than 15 years. At present, the smallest active tags are about the size of a coin and sell for a few dollars.

IV. COMPONENTS:

An RFID system is an integrated collection of components that implement an RFID solution. An RFID system consists of the following components (in singular form) from an end-to-end perspective:

1) Tag: This is a mandatory component of any RFID system.
2) Reader: This is a mandatory component, too.
3) Reader antenna: This is another mandatory component.
4) Some current readers available today have built-in antennas Controller. This is a mandatory component. However, most of the new-generation readers have this component built in to them.
5) Sensor, actuator, and annunciator: These optional components are needed for external input and output of the system.
6) Host and software system. Theoretically, an RFID system can function independently without this component. Practically, an RFID system is close to worthless without this component.
7) Communication infrastructure: This mandatory component is a collection of both wired and wireless network and serial connection infrastructure needed to connect the previously listed components together to effectively communicate with each other. An RFID system is an integrated collection of components that implement an RFID solution.

A. RFID ANTENNA:

An antenna or aerial is an arrangement of aerial electrical conductors designed to transmit or receive radio waves which is a class of electromagnetic waves. In other words, antennas basically convert radio frequency electrical currents into electromagnetic waves and vice versa. Antennas are used in systems such as radio and television broadcasting, point-to-point radio communication, radar, and space exploration. Antennas usually work in air or outer space, but can also be operated under water or even through soil and rock at certain frequencies for short distances.

Physically, an antenna is an arrangement of conductors that generate a radiating electromagnetic field in response to an applied alternating voltage and the associated alternating electric current, or can be placed in an electromagnetic field so that the field will induce an alternating current in the antenna and a voltage between its terminals. Some antenna devices (parabola, horn antenna) just adapt the free space to another type of antenna.

The antenna in an RFID tag is a conductive element that permits the tag to exchange data with the reader. Passive RFID tags make use of a coiled antenna that can create a magnetic field using the energy provided by the reader's carrier signal.

A number of factors can affect the distance at which a tag can be read (the read range). The frequency used for identification, the antenna gain, the orientation and polarization of the reader antenna and the transponder antenna, as well as the placement of the tag on the object to be identified will all have an impact on the RFID system's read range.

B. THE TRANSPONDER:

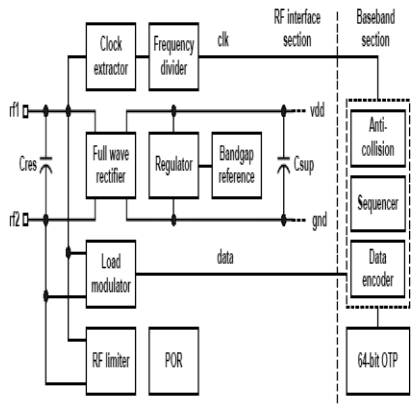

Fig. 7: Block diagram of Transponder

The transponder is divided into two sections: (I) RF interface section and (II) Baseband section.

The RF interface consists of analog circuits that performs power conversion through a full-wave rectifier and extracts the system clock from the incoming RF signal. The data from the Baseband section corresponding to a unique ID from the one-time PROM is encoded and sent back to the reader via a load modulation scheme. In this system, the transponder is designed to support multiple accesses with an Anti-collision feature. The RF resonant coupling elements use 13.56MHz signal as a carrier frequency. The details of each sub block in the transponder are described below.

1) RF INTERFACE SECTION consists of:
- RF limiter
- Half wave rectifier
- Power supply regulator
- Band gap reference
- Load modulator

2) BASEBAND SECTION consists of:
- Sequence and data encoder
- Anti-collision
- One-time PROM

C. READER:

The RFID reader provides the connectivity between individual tags and the tracking/management system. Available in a variety of form factors, it is typically small enough to be mounted on a counter, tripod, or wall. Depending on the application and operating conditions, there may be a multiplicity of readers to fully service a specific area. In a warehouse, for example, a network of readers can ensure that 100% of all pallets are queried and logged as they pass from point A to point B.

Overall, the reader provides three main functions: bidirectional communication with the tags to isolate individual ones; initial processing of received information; and connection to the server that links the information into the enterprise.

The RFID reader must deal with multiple tags within the field of interest—a very important consideration in applications with many tags within a confined spatial area (for example, multiple tagged products residing on numerous factory pallets).The primary challenge in a multiple reader/tag scenario is that collisions will occur when many readers send out queries and multiple tags respond at the same time. The most common way to avoid this problem is to use some form of time-division multiplexing algorithm. Readers can be set to interrogate at different times, while tags can be configured to respond after a random time interval. It is clear that having the ability to implement this function in embedded software provides additional flexibility.

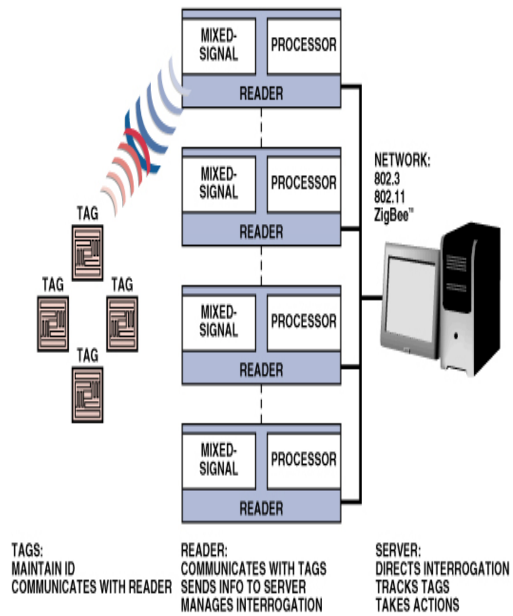

Fig. 8: Complete RFID system

The object to be tracked is affixed with a RFID tag or transponder. The reader, kept at some position like entrance or door frame through which objects to be tracked pass, emits radio signals. When the object containing RFID tag comes within the range of radio signals emitted by the reader, the tag is activated and it starts sending the information stored in it in the form of radio signals. The reader captures the radio signals, decodes it to a byte stream, and sends the information for further processing to the host system connected to it.

RFID employs a numbering scheme called EPC (for "electronic product code") which can provide a unique ID for any physical object in the world. The EPC is intended to replace the UPC bar code used on products today. Unlike the bar code, however, the EPC goes beyond identifying product categories--it actually assigns a unique number to every single item that rolls off a manufacturing line. Once assigned, this number is transmitted by a radio frequency ID tag (RFID) in or on the product.

A UPC (**U**niversal **P**roduct **C**ode) is the sequence of numbers in a U.S.-standard barcode today. An EPC (**E**lectronic **P**roduct **C**ode) is a standard for data formats in RFID tags that is meant to replace that for barcodes. For example, an EPC-96 code has four components:

1. A version number, indicating the tag type (e.g., 96-bit EPC Class 1);
2. A domain manager, i.e., a number specifying the entity that administers the tag code, e.g., "ABC Sneaker Co".;
3. An object class, i.e., a number specifying the type of product the RFID tag is attached to, e.g., "Model L high-top sneaker"
4. A unique identifier, a number that, in combination with the other EPC components, uniquely specifies the tag (and object).

The following diagram summarizes the EPC structure. Numbers here are bit lengths for the various EPC components.

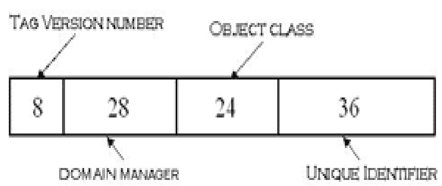

Fig. 9: 96 BIT EPC STRUCTURE

In addition, a tag contains two non-readable data elements: A 16-bit checksum (cyclic redundancy code) used to identify transmission errors, and a PIN, used for such operations as "killing," i.e., permanent disablement of the tag for privacy enforcement.

RFID is a two-part system including interrogators and tags. The interrogators are the "readers" and the tags are the pieces that store the information. Compared with a barcode system, the barcode scanner is like the reader and the barcode label itself is like the RFID tag. A RFID tag can store up to 2000 bits of information. They come in a variety of shapes and sizes. For example, animal tracking tags inserted beneath the skin are small as pencil. Tags used to track trees or wooden items are screw shaped. Credit card shaped tags are used for security applications. In order for this system to work, each product will have to be given a unique product number.

MIT's Auto-ID Center, created a couple of years ago, and is working on an Electronic Product Code (EPC) identifier that could replace the UPC. Every smart label could contain 96 bits of information, including the product manufacturer, product name and a 40-bit serial number.

Using this system, a smart label would communicate with a network, called the Object Naming Service. This database would retrieve information about a product and then direct information to the manufacturer's computers. The information stored on the smart labels would be written in a Product Markup Language (PML), which is based on the Extensible Markup Language (XML). PML would allow all computers to communicate with any computer system in a similar way that Web servers read HTML.

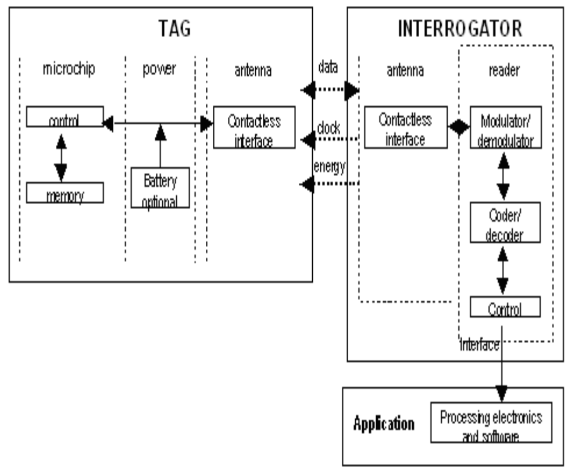

Fig. 10. DATA Flow in RFID system

V. CONTROVERSY:

Unlike a bar code, these chips can be read from a distance, right through your clothes, wallet, backpack or purse -- without your knowledge or consent -- by anybody with the right reader device. In a way, it gives strangers x-ray vision powers to spy on you, to identify both you and the things you're wearing and carrying.

RFID "spy chips" have been hidden in the packaging of products you might buy and they are already being used to spy on people. Each tiny chip is hooked up to an antenna that picks up electromagnetic energy beamed at it from a reader device. When it picks up the energy, the chip sends back its unique identification number to the reader device, allowing the item to be remotely identified. Spy chips can beam back information anywhere from a couple of inches to up to 20 or 30 feet away. Gillette has been caught hiding tiny RFID surveillance chips in the packaging of its shaving products. This technology is rapidly evolving and becoming more sophisticated. Now RFID spy chips can even be printed, meaning the dot on a printed letter "i" could be used to track you. Researchers do not know the long-term health effects of chronic exposure to the energy emitted by these readers.

Fig. 11. Gillette pack with hidden RFID tag

VI. COST CONSIDERATIONS:

At present, basic RFID tags in small quantities can cost as much as $1.50. RFID tags are very expensive on a per-unit basis, costing anywhere from $1 for passive button tags to $200 for battery-powered, read-write tags. The high cost for these tags is due to the silicon, the coil antenna and the process that is needed to wind the coil around the surface of the tag. By using conductive ink instead of metal coils, the price of capacitively coupled tags are as low as 50 cents.

The future looks rosier for RFID as costs to make the chips decline and governments take a keener interest.

The Passive tags can cost as little as 30 cents or even less if bought in bulk

Active tags can cost anywhere from $.75 to $3.00. Some Active tags even come with temperature or pressure sensors built in, which cost more than $100.

The cost of making an RFID tag is about 14 euro cents today and needs to go lower.

Expected price in the future is $0.10.

Readers, likewise, are expensive at present, costing as much as several thousand dollars each.

Most RFID scanners cost from several hundred to several thousand dollars.

The conventional wisdom in the Automatic ID industry is that you can’t use a $4 to $6 RFID tag on aan item that costs less than $50. But that is not necessarily correct, in fact as noted, the read/write technologies and the passive qualities of many transponders mean that ID tags can now be used and reused indefinitely, amortizing the cost of each transponder to a level competitive with many other ID technologies.

VII. APPLICATIONS:

RFID, which creates a dynamic link between people, objects and processes, has established itself as a primary player in the future of data collection, identification and analysis systems. Specific applications to name a few are:

- Automotive - Auto-makers have added security and convenience into an automobile by using RFID technology for anti-theft immobilizers and passive-entry systems.
- Animal Tracking - Ranchers and livestock producers use RFID technology to meet export regulations and optimize livestock value.
- Supply Chain - Wal-Mart, Target, Best Buy, and other retailers have discovered that RFID technology can help in different aspects
- Asset tracking - tracking of assets in offices, labs, warehouses, pallets and containers in the supply chain, books in libraries
- Medical applications - linking a patient with key drugs, personnel giving the drugs, biometric measurements
- Human implants for people tracking
- Manufacturing - tracking of parts during manufacture, tracking of assembled items
- Retail - tracking store trolleys in supermarkets, active shelves
- Warehouses - Real-time inventory by automated registration of items in a warehouse or store-room
- Timing - sports event

Examples:

- Called as magic-mirror system, it has an RFID interrogator along with a digital display for offering detailed information on the piece of clothing that you plan to try on.
- Expect your cell phone to become a digital wallet in the near future with the help of NFS (Near Field Communications).
- Digital Angel had created syringe-implantable glucose-sensing RFID microchip for diabetic patients.

Since the year 2005, the U.S. Army has been utilizing RFID.

Fig. 12. An RFID tag used for electronics toll collection

Fig. 13. Magic-mirror example

A. PRESENT AND FUTURE:

Some of the latest RFIDs are:

- Smart Label Low cost single chip solution.
- HF tag for pharmaceutical Industry In pharmaceutical industry this tag is used on corrugated and folded boxboard packages, medical leaflets, prescription labels etc.
- UHF Enterprise RFID reader: The Alien ALR-8800 Enterprise RFID Reader enables users to deploy manageable, robust, best-in-class RFID across the supply chain.
- High Temperature withstand tag: It withstands contact with most of the solvents and acids generally used in industrial processes.
- Magnetic stripe badge transponder The Tag-it™ ISO badges carry a 2000-bit memory for stronger security and on-the-card data programming.

SMART LABELS:

A less expensive form of RFID that might be on your favorite commodities on store shelves works as follows:

In order for this system to work, each product will have to be given a unique product number. Every smart label could contain 96 bits of information, including the product manufacturer, product name and a 40bit serial no.

A global RFID rollout is beginning. Never again would you have to sort recyclables from other garbage. Once Rfid is on everything you might buy a robot that could fetch and arrange objects based on their tag id.

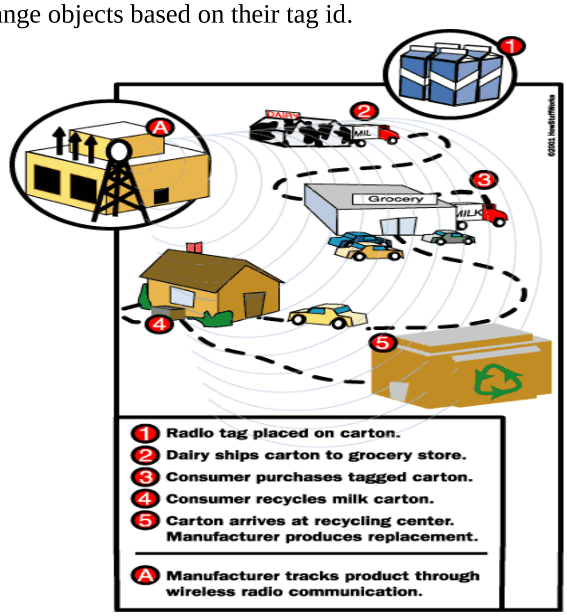

Fig. 14. RFID role in manufacturing to distribution

I. CONCLUSION:

RFIDs represent a great potential boon to many segments of industry, from manufacturing to shipping to retail.

Any inventory could be instantly located in any warehouse, high risk security institutions are able to keep a constant eye on dangerous offenders, lost pets can be returned to their owners...the list goes on.

RFID can dramatically cut cycle times in any number of services, industrial and manufacturing settings, all of which create new savings of time and money.

When a secure form of RFID is created for the consumer population and privacy issues are resolved, RFID tags will change the world.

RFID technology is continuously advancing, and the very near future will see science fiction become reality as Radio Frequency Identification makes its way into everyday functions.

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