CSIE54600 Pervasive Computing

RFID

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Contents

- What is RFID
- RFID technology
- Standards
- Applications
- Problems and Issues

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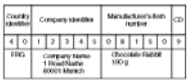
Brief History

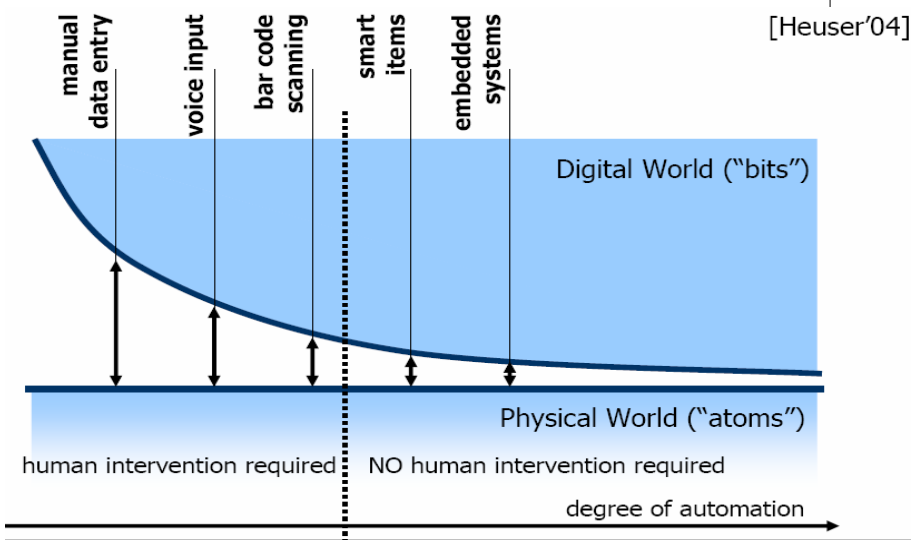
- Automatic Identification (Auto-ID) and Data Collection (AIDC) Technologies
- Ubiquitous:
  - Supermarket
  - Credit/Bank/ID Cards
  - Car Keys
- How Old Are These Technologies?
  - 1930's, 40's: Magnetic Stripes
  - 1950's, 70's: Bar Codes, UPC
  - 1949…: Radio Frequency ID



Auto-ID Technologies

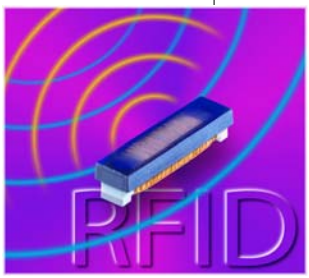



Physical and Digital Worlds

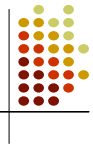


Definition

- RFID (Radio Frequency Identification) is a technology that enables the electronic and wireless labeling and identification of objects, humans and animals
- RFID technologies are grouped under the more generic Automatic Identification (Auto ID) technologies



What is RFID?



- Radio Frequency Identification
- Uses radio waves for identification
- New frontier in the field of information technology
- One form of Automatic Identification
- Provides unique identification or serial number of an object (pallets, cases, items, animals, humans)

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Origins

- RFID originally appeared during the Second World War
  - when radar was invented
- Initially radar was not able to distinguish British and German planes
- Introduction of an IFF (identification friend or foe) transponder
  - allowed differentiation of the returned signals.

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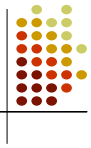
RFID History



- First Bar code patents – 1930s
- First use of RFID device – 2nd world war – Brittan used RFID-like technology for Identify- Friend or Foe
- Harry Stockman October 1948 Paper – Communication by means of reflected power (The proceedings of the Institute of Radio Engineers)
- First RFID Patent - 1973
- Auto-ID center founded at MIT – 1999
  - Standardization effort taken over by EPC Global (Electronic Product Code)
- Current thrust primarily driven by Wal-Mart and DoD
  - Automate Distribution:
    - Reduce cost (man power, shipping mistakes)
    - Increase sales (keep shelves full)
    - DoD Total Asset Visibility Initiative

Source of data: EDN – October 2004 - "Reading Between the Lines" Brian Dipert

Timeline

- **1940s – Radar refined and used, RFID invented in 1948**
- **1950s – Early exploration of RFID**
- **1960s – Development of the theory of RFID, field trials**
- **1970s – Explosion of RFID development and early adoption**
- **1980s – Commercial applications enter mainstream**
- **1990s – Emergence of standards, RFID widely deployed**
- **2000s – Over 350 direct reference patents, vast number of suppliers**

SOURCE: Landt, Jeremy. Shrouds of time, AIM 2001

Other Identification Techniques

- Barcode labels
  - cheap
  - low storage capacity
  - cannot be rewritten or reprogrammed
  - only one label at a time can be read
  - requires line of sight to be read
  - generally identify a family of items
    - rather than an individual or unique item
  - Not very durable (as mostly printed paper)
  - low range for reading

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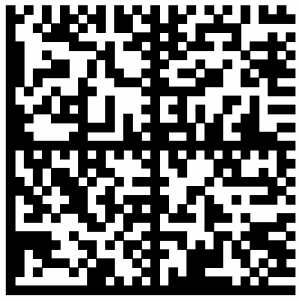
Other Identification Techniques

- 2D Barcodes
  - Printable postage ‘stamps’

  - ISO/IEC 16022 Data Matrix
    - see www.semacode.org



  - QR Code
    - widely used in Japan
      - urls on business cards, etc
  - many others...

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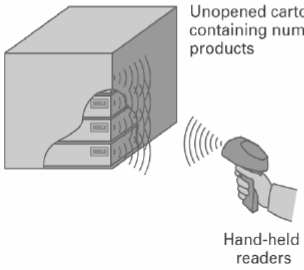
Bar Codes vs. RFID Tags

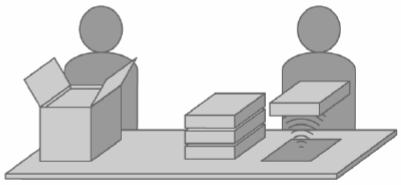
RFID

- No line of sight required
- Highly accurate
- Information captured in seconds
- RFID tags contain more information



Bar Codes

- Line of sight required
- Margin of error
- Time consuming
- Cost/labor intensive



1. Open carton and remove contents
2. Scan individual items

Bar Codes vs. RFID Tags

表一、條碼與RFID之功能比較

功能	條碼	RFID
讀取數量	條碼讀取時只能一次一個	可同時讀取多個RFID標籤資料
遠距讀取	讀條碼時需要光線	RFID標籤不需光線就可以讀取或更新
資料容量	儲存資料的容量小	儲存資料的容量大
讀寫能力	條碼資料不可更新	電子資料可以反覆被覆寫(R/W)
讀取方便性	條碼讀取時需要可看見與清楚	智慧型標籤可以很薄且如隱藏在包裝內仍然可讀取資料
資料正確性	條碼需要靠人工讀取，所以有人為疏失的可能性	RFID標籤可傳遞資料作為貨品追蹤與保全
堅固性	當條碼污穢或損壞將無法讀取，即無耐久性	RFID標籤在嚴酷、惡劣與骯髒的環境下仍然可讀取資料
高速讀取	移動中讀取有所限制	可以進行高速移動讀取

（資料來源：工研院經資中心整理）

Bar Codes vs. RFID Tags

表二、人工登入、條碼與RFID處理速度之比較

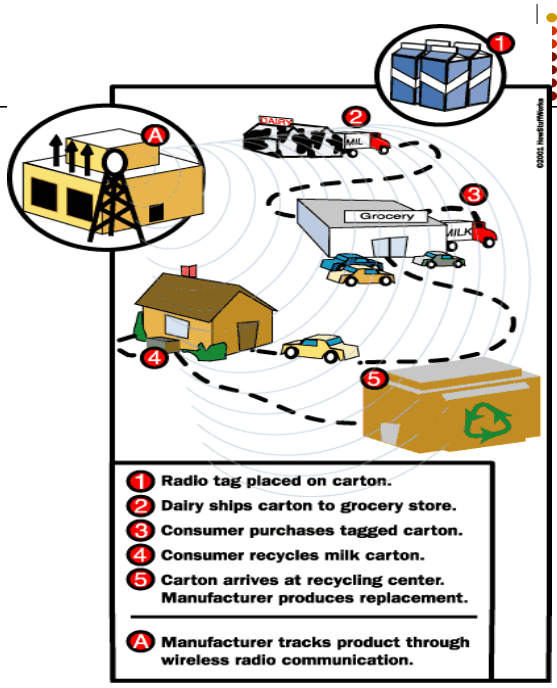
數據量 登入方式	1筆	10筆	100筆	1000筆
人工登入	10秒	100秒	1000秒	2小時47分
掃瞄條碼	2秒	20秒	200秒	33分
RFID辨識	0.1秒	1秒	10秒	1分40秒

（資料來源：工研院經資中心整理）

Applications

- Mobil Speedpass systems
- Automobile Immobilizer systems
- Fast-lane and E-Zpass road toll system
- Passports
- Animal Identification
- Humans
- Supply chain management

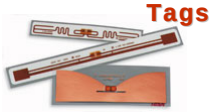
Example



Example

RFID Principal System Components

- Tag (Transponder)
  - Chip
  - Antenna



- Reader (Interrogator, Transceiver)
  - RF Module (Transmitter and Receiver)
  - Control Unit
  - Antenna
  - Several Interfaces (RS 232, RS 485, etc.)

- Host Computer
  - Middleware and Data processing subsystem

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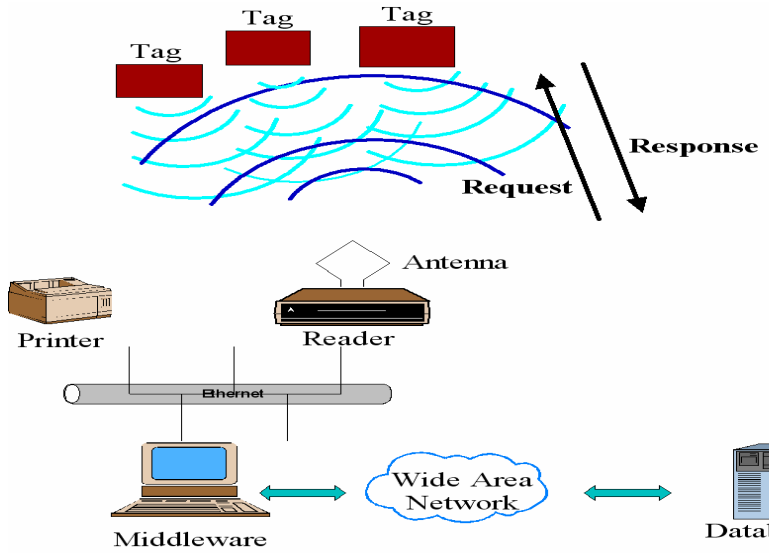
RFID System



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How does it works?

- Reader gets and executes commands from the back-end system
- Reader emits radio frequency (RF) waves via its antenna
- Waves travel through air and “energize” a passive transponder
- Tag responds and transmits data signal via its antenna
- Reader captures the tag data signal
- Reader processes data signal
- Reader delivers the processed information to the back-end system

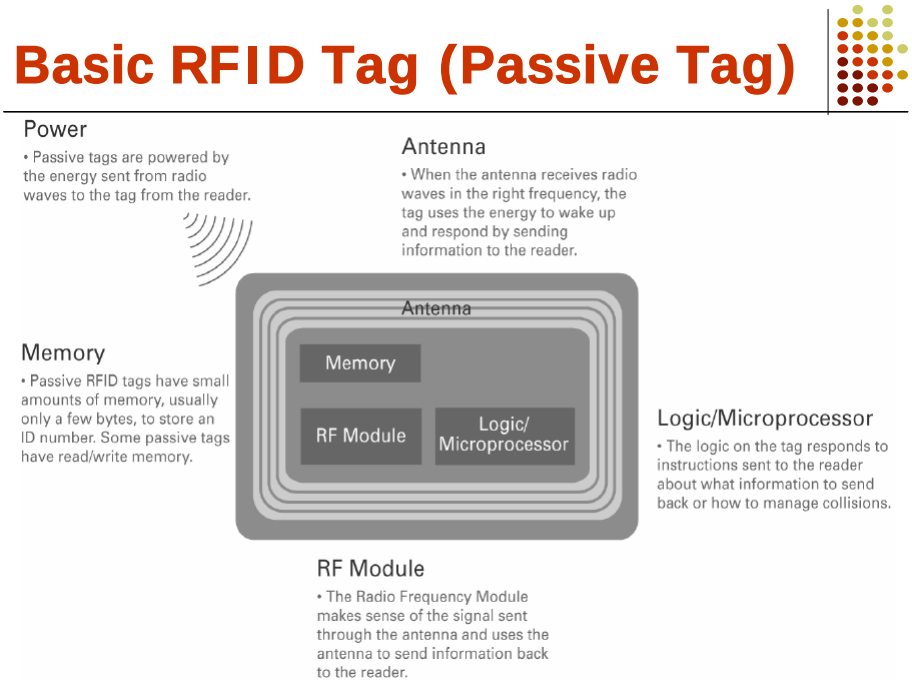
Types of Tags

- **Passive**
  - Operational power scavenged from reader radiated power

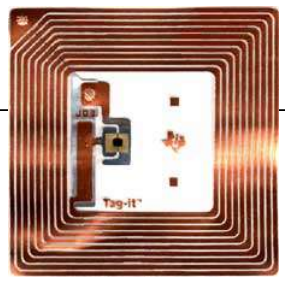
- **Semi-passive**
  - Operational power provided by battery

- **Active**
  - Operational power provided by battery
  - Transmitter built into tag

Basic RFID Tag (Passive Tag)



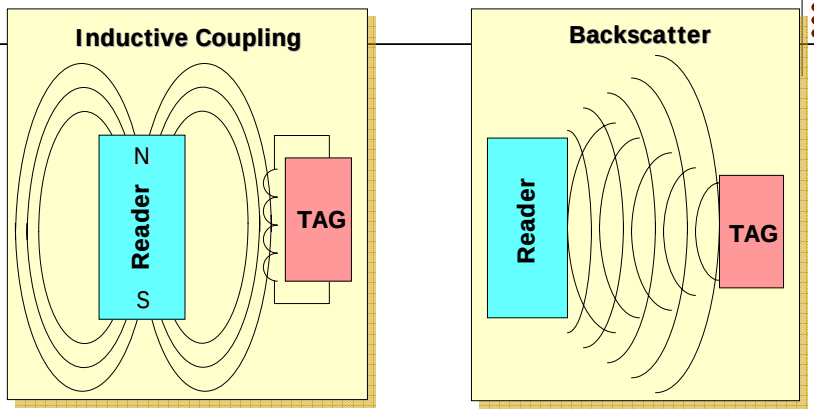
RFID Tag



- Composed of
  - antenna
  - wireless transducer
  - an encapsulating material
- Tags can be active, passive or semi-passive
  - active tags have on-chip power, 10-100m range
  - passive tags draw power from the electro-magnetic field of the RFID reader, transmit by backscattering
    - cheaper but with lower range (<10 metres)
    - more sensitive to regulatory and environmental constraints
  - short-range 'near-field' systems use magnetic field induction for communication (0-200mm)

Printers

Basic Tag Operational Principles



- Near field (LF, HF): inductive coupling of tag to magnetic field circulating around antenna (like a transformer)
  - Varying magnetic flux induces current in tag. Modulate tag load to communicate with reader
  - field energy decreases proportionally to $1/R^3$ (to first order)
- Far field (UHF, microwave): backscatter.
  - Modulate back scatter by changing antenna impedance
  - Field energy decreases proportionally to 1/R
- Boundry between near and far field: R = wavelength/2 pi so, once have reached far field, lower frequencies will have lost significantly more energy than high frequencies
- Absorption by non-conductive materials significant problem for microwave frequencies

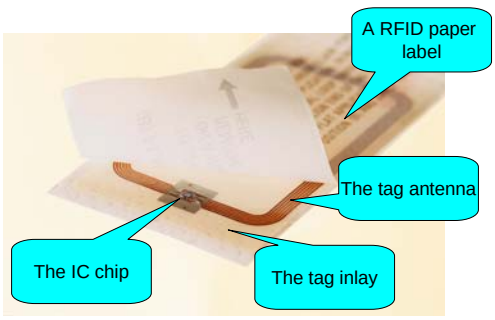
RFID Tags

2 most common types:

Active	Passive
Powered by battery	Powered by reader
Range up to hundred meters	Range up to a few meters
Large memory size	Small memory size
Relatively expensive	Relatively cheap
Relatively large in size	Relatively small

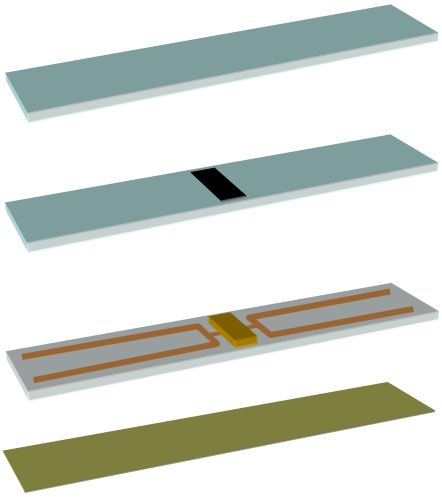
RFID Tags (cont)

- Made up of three parts
  - Chip with memory that holds the intended information
  - Antenna, which is used to transmit information or in passive tags, to harvest power
  - Packaging, which encases the chip and the antenna
- Memory configuration
  - Read-only (RO)
  - Write-once-read-many (WORM)
  - Read-write (R/W)



RFID Tags (cont)

Construction



Top Overlay (printed layer)

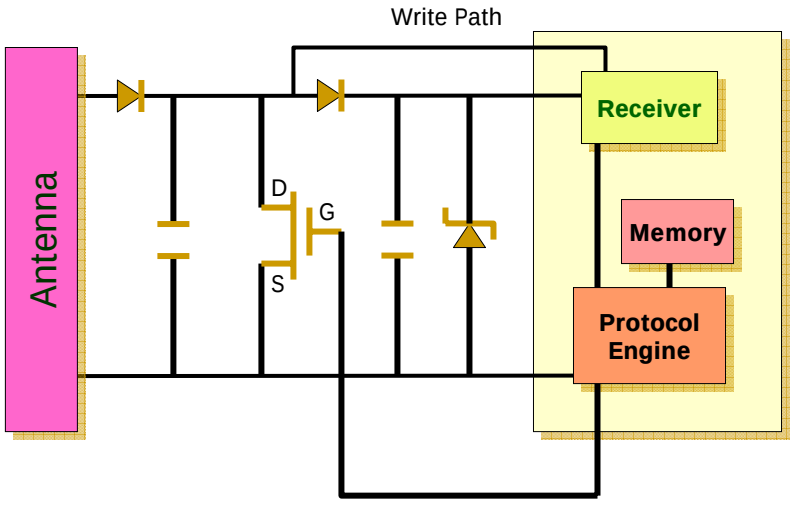
Spacer (Protective Layer)

Inlet (RFID Tag)

Bottom Layer (Adhesive)

Generic Tag Architecture

(Highly Simplified)



RFID Reader

- Also known an interrogator
- Reader powers passive tags with RF energy
- Can be handheld or stationary

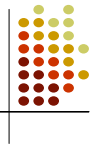
Reader

Antenna

RFID Reader

- RFID reader
  - consists of
    - Antenna
    - Transceiver
    - Microprocessor/decoder
    - Network interface
  - sends periodic signals to inquire about any tag in vicinity
  - on receiving any signal from a tag
    - passes on information to the data processor

Reader Implementation Challenges



- Reader must deliver enough power from RF field to power the tag
- Reader must discriminate backscatter modulation in presence of carrier at same frequency
- 70db magnitude difference between transmitted and received signals
- Interference between readers
- Hugh volume of tag data – readers need to filter data before releasing to enterprise network

Trivia on Passive UHF RFID

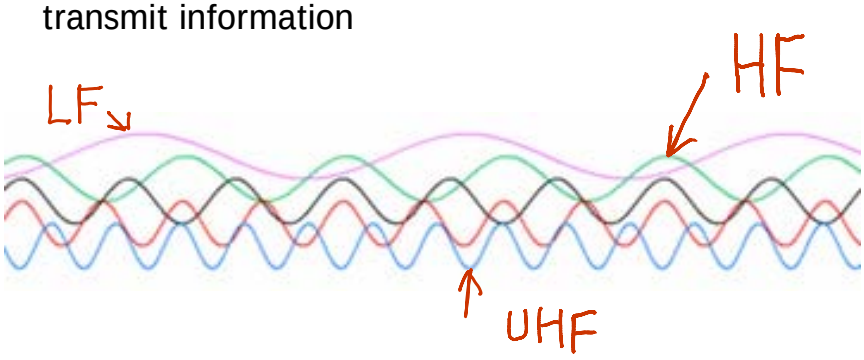
- How far can a reader read a tag?
  - Less than 20 feet using legal equipment
- What causes interference at these frequencies?
  - Metal reflects the energy and can shield
  - Water absorbs the energy. Microwaves operate at 2.4 GHz because water absorbs energy at these frequencies. Passive UHF operates around 900 MHz, which is close enough.

Maximum Distances to Read UHF Passive Tag

Antenna Gain (天線增益) (dBi)	Distance (meters)	Distance (feet)
6 (legal)	5.8	19*
9	8.3	27
12	11.7	38
15	16.5	54

Carrier Frequencies

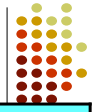
- What is frequency?
  - Refers to the property of radio waves used to transmit data
  - Roughly speaking, it is the intensity of waves used to transmit information



Carrier Frequency

- RFID systems may use a particular frequency band depending on:
  - Application
  - Legislature
  - Cost considerations

Tag Details



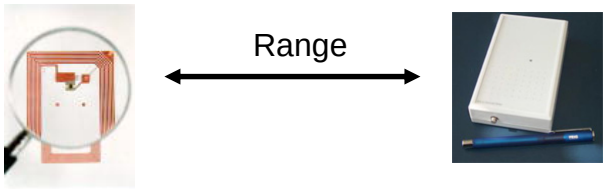
	LF	HF	UHF	Microwave
Freq. Range	125 - 134KHz	13.56 MHz	866 - 915MHz	2.45 - 5.8 GHz
Read Range	10 cm	1M	2-7 M	1M
Market share	74%	17%	6%	3%
Coupling	Magnetic	Magnetic	Electro magnetic	Electro magnetic
Existing standards	11784/85, 14223	18000-3.1, 15693,14443 A, B, and C	EPC C0, C1, C1G2, 18000-6	18000-4
Application	Smart Card, Ticketing, animal tagging, Access, Laundry	Small item management, supply chain, Anti-theft, library, transportation	Transportation vehicle ID, Access/Security, large item management, supply chain	Transportation vehicle ID (road toll), Access/Security, large item management, supply chain

Frequency and Bandwidth

- Frequency is of primary importance when determining data transfer rates (bandwidth)
- The higher the frequency, the higher the data transfer rate

Range

- Range – the working distance between a tag and a reader



Range and Power Levels

- The range that can be achieved in an RFID system is determined by
  - The power available at the reader
  - The power available within the tag
  - The environmental conditions and structures
    - More important at higher frequencies than at lower frequencies

Frequency Ranges

- Low Frequency (LF)
  - 120 - 135 kHz
  - short range inductive applications
    - animal ID
    - door entry cards
- High Frequency (HF)
  - 13.56 MHz
  - worldwide common frequency
  - smart cards and labels
  - also used for nearfield systems
- Ultra High Frequency (UHF)
  - 433 MHz
    - Active low power tags
  - 860 - 960 MHz
    - consumer durables
    - warehouse distribution
- Microwave 2450 MHz
  - Active tag technology gives range and fast data rates

Frequency Details: LF

- Low Frequency: 125 kHz
- Range: < 50 cm (cheap tags typically: few cm)
- Tag construction
  - hard copper coil
  - eeprom chip
- Costs: < 15 cent
- Data transfer: Slow readout, non-concurrent
- Application: product automation, entrance check, environment with metal
- Often used as passive tag
- Require less power
- Go around shapes and penetrate water and metal to some extend

Frequency Details: HF

- High Frequency: 13.56 MHz
- Range passive: < 1.2 m
  Range active: upto 30m
- Tag construction
  - coil can be a printed ink on a paper like substrate
  - has an eeprom added to it
- Costs: < 40 cent (passive)
- Data transfer: Medium readout, concurrent < 50 items (Fast enough to check a small cart with some groceries)
- Application: item tracking, entrance check, ...
- Absorbed by metals

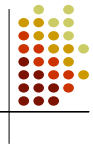
Frequency Details: UHF

- Ultra High Frequency: 868MHz (Europe), 950MHz (Japan), 915MHz (USA)
- Range: < 4-6 m
- Tag construction
  - coil can be a printed easily
- Costs: > $1
- Data transfer: High readout speed, concurrent >100 items
- Application: supply chain management
- Reflected by metals (signal collision!)

Frequency Details: MW

- Micro Wave: 2,45 GHz
- Range passive: > 6m
- Range active: upto 200km
- Tag Construction
  - battery incorporated
- Costs: more expensive
- Data transfer: fast
- Application: container management, “tolsystemen”
- In some countries: use limited by legislation

Effect Material on Readout

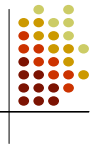


Background Material	Effect on RFID signal
Cardboard	Absorbtion (moisture) Detuning (dielectric)
Conductive fluid	Absorbtion
Plastics	Detuning
Metal	Complex effects: lens, filter Reflection (UHF) Absorbtion (MF)
People	Absorbtion Detuning (dielectric) Reflection)

Collision

- Reader collision: multiple readers are trying to read the same tag at the same time -> disturbance
- Tag collision: multiple tags are present in the field of the reader and are all trying to send their id to the reader at the same time -> disturbance
- Solution: use special anti-collision protocols

RFID Standards



- RFID standards are concerned
  - Air Interface Protocol
    - the way tags and readers communicate
  - Data Content
    - the organising of data
- Two main bodies involved are
  - ISO
  - Auto-ID Centre
    - now handled by EPC Global
- see also http://www.nfc-forum.org for nearfield systems

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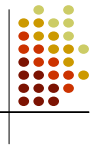
Electronic Product Code (EPC) Global



- Electronic Product Code (EPC)
  - unique number reference for a physical object
    - e.g. product, case or pallet
- Electronic tags
  - uniquely identifies an object, to which attached
    - EPC number can be read without contact by a RFID reader
- Object Naming Service (ONS)
  - uses EPC number to informs the host
    - where to find information about the object
- RFID Air Interfaces
  - specify radio communication protocol between tags and readers

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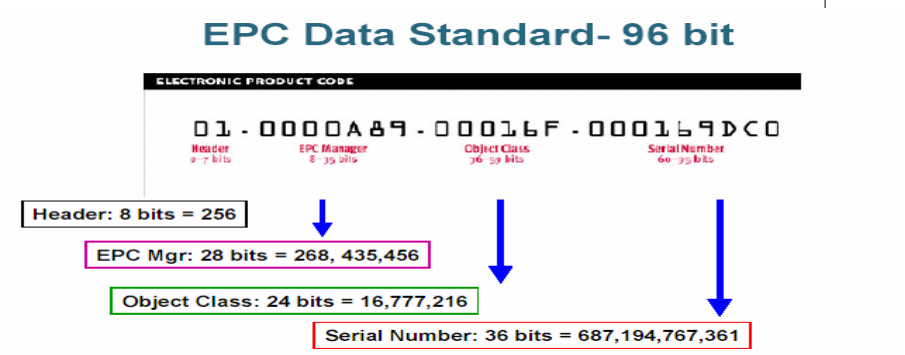
Electronic Product Code



- Every product has unique identifier
- 96 bits can uniquely label all products for the next 1,000 years
- 2^96 = 79,228,162,514,264,337,593,543,950,336

Electronic Product Code

- Header - Tag version number
- EPC Manager - Manufacturer ID
- Object class - Manufacturer's product ID
- Serial Number - Unit ID

- With 96 bit code, 268 million companies can each categorize 16 million different products where each product category contains up to 687 billion individual units
- 64bits and 256bits versions

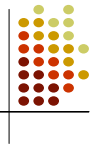
EPCglobal, Inc.

- Not-for-profit organization developing commercial, world-wide RFID standards
- Joint venture between EAN International and the Uniform Code Council (UCC).
  - UCC standardized Universal Product Code (UPC) barcodes in US
  - EAN standardized barcodes in Europe
  - UCC and EAN combined to form GS1
- http://www.epcglobalinc.org/
- UHF Class-1 Generation-2 (Class-1 Gen-2 or commonly known as Gen-2)
  - ISO 18000-6C standard

EPC vs. UPC (Barcodes)

- Both are forms of Automatic identification technologies
- Universal Product Code (UPC) require line of sight and manual scanning whereas EPC do not
- UPC require optical reader to read whereas EPC reader reads via radio waves
- EPC tags possess a memory and can be written while UPC do not
- EPC tags cost 5 cents, UPC tags cost 1/10 cent

EPCglobal Inc. UHF Specification History

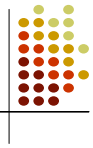


- EPCglobal UHF Class-0
- EPCglobal UHF Class-1 Generation-1
- EPCglobal UHF Class-1 Gen-2 (Gen-2)
  - ISO 18000-6C standard
  - Item management standard
  - Retail standard

EPC Standards

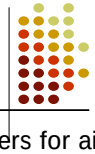
- Class 1
  - simple
  - passive
  - read-only
  - backscatter tag
  - memory
    - one-time
    - field-programmable
    - non-volatile
- Class 0
  - read-only
  - programmed at the time the microchip was made

EPC RFID Classes



- **Class 0 Tags – Read Only**
  E.g Matric
- **Class 1 Tags – WORM**
  E.g Alien
- **Class 0+ - Read/Write**
  E.g Matrics, Impinj
- **Class 2 – Read/Write**
- **Class 3 – Semi active, with sensors**
  E.g Alien, Powerpaper(EM)
- **Class 4 – Active Tag**

ISO Standards



- Standards for automatic identification and item management
- ISO 18000 series
  - air interface protocol
  - for systems likely to be used to track goods in the supply chain
  - cover the major frequencies used in RFID systems around the world
- 18000–1: Generic parameters for air interfaces for globally accepted frequencies
- 18000–2: Air interface for 135 KHz
- 18000–3: Air interface for 13.56 MHz
- 18000–4: Air interface for 2.45 GHz
- 18000–5: Air interface for 5.8 GHz
- 18000–6: Air interface for 860 MHz to 930 MHz
- 18000–7: Air interface at 433.92 MHz

Applications

- Logistics & Tracking
  - Item visibility and status
  - Anti theft/tamper evidence
  - Authentication
- Manufacturing
  - Shop floor tracking
  - Location tracking
  - Status control
  - Compliance
- Asset Tracking
  - Equipment movement
  - Calibration
  - Maintenance
- Healthcare
  - Patient dosing
  - Traceability
- Personnel Identification
  - Access control
  - Animal tagging
  - Car immobilisers
- Payment systems
  - Road tolls
  - Electronic tickets
  - Mass transit ticketing

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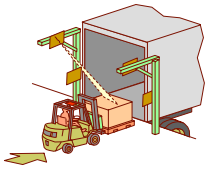
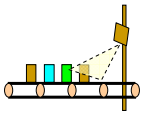
Usage Models



Dock Door

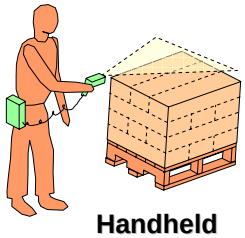


Conveyor Belt

Forklift

Container, Pallet, Munitions

Printers



Handheld

Smart Shelves

Point of Sale

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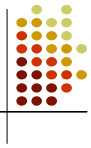
Patient Identification

- VeriChip's VeriMed Patient Identification product
  - received US FDA approval as a Class II Medical Device two years ago
  - RFID implant chip about the size of a rice grain that is injected in a person's triceps area
  - chip contains a unique identification number
    - serves as a pointer to relevant medical information held in an external database

Problems with RFID

- Cost
  - more expensive than a printed barcodes
  - host system and infrastructure capital cost
- External influences can interfere
  - metalwork
  - radio
- Lack of consistent standards
  - application numbering systems
  - lack of internationally agreed frequencies for RFID operation

Security and Privacy Issues

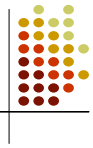


- Privacy concerns
  - ubiquitous tracking of anybody without consent
  - stealth tracking and profiling
  - tags can be hidden such that the individual is unaware of their presence
    - sewn up within garment
    - moulded within plastic or rubber
    - researchers have already developed tiny coded beads invisible to human eye that can be embedded in inks
      - should be ready for commercial use soon
      - could be used for currency and other document tagging
      - could be added to substances
        - automobile paint
        - explosives

Big Brother?

- If every product has an RFID
  - a distributor may be able to find out
    - what clothes you wear
    - where you buy them
    - how old they are
- Combined with credit card information
  - Would make it easy to profile you
- Experiments carried out by Wal Mart, Gillette etc
  - consumers are not ready to give up privacy in exchange for a shorter time spent at the cash registers
- Wal Mart didn't give up
  - announced to all its partners
    - they have to place RFID labels on their products

Maintaining Privacy

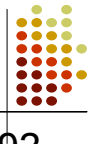


- Removing tags
- Encrypting information
- RSA Blocker Tags
  - similar in size and appearance to RFID tags
  - can “spam” any reader that attempts to scan tags
    - without the right authorization
    - confuses the reader
- Kill Switches
  - RFID tags can include a “Kill Switch” or fuse
    - Blowing the fuse disables the tag
  - consumer may be given an option of disabling the RFID tag before leaving the store

Papers

- Stanford, V., "Pervasive computing goes the last hundred feet with RFID systems", Pervasive Computing, IEEE, Volume 2, Issue 2, April-June 2003 Page(s):9 - 14
- D. R. Thompson, “RFID technical tutorial,” The Journal of Computing Sciences in Colleges, vol. 21, no. 5, pp. 8-9, May, 2006.
- Useful articles on RFID, Nearfield, and Semacodes on wikipedia

RFDump



- Open source software tool for RFID ISO-15693 and ISO-14443 readers (13.56 MHz)
  - Read/write data on RFID tags
  - Integrated cookie feature
    - Add cookie to tag and automatically increment counter when tag is in range of reader
    - Track number of times shopper enters reader field or picks up item
  - www.rf-dump.org