

Mobile Tagging

CSE 162 – Mobile Computing

Hua Huang

Department of Computer Science and Engineering

University of California, Merced

Tagging the physical world

- When tags are attached to or linked to physical objects, they provide a way to audit physical spaces and processes.



History of Barcode

- 1920's most complex business existed in the grocery store.
- Herman Hollerith built the “Hollerith Machine.”



Groceries

- Consumers would get their cards punched depending on selected products.
- Pay for their selection at counter.
- Customer would receive groceries on a conveyor belt.
- Although the idea was ahead of time, it lead to the development of barcodes that are used in the modern supply chain.

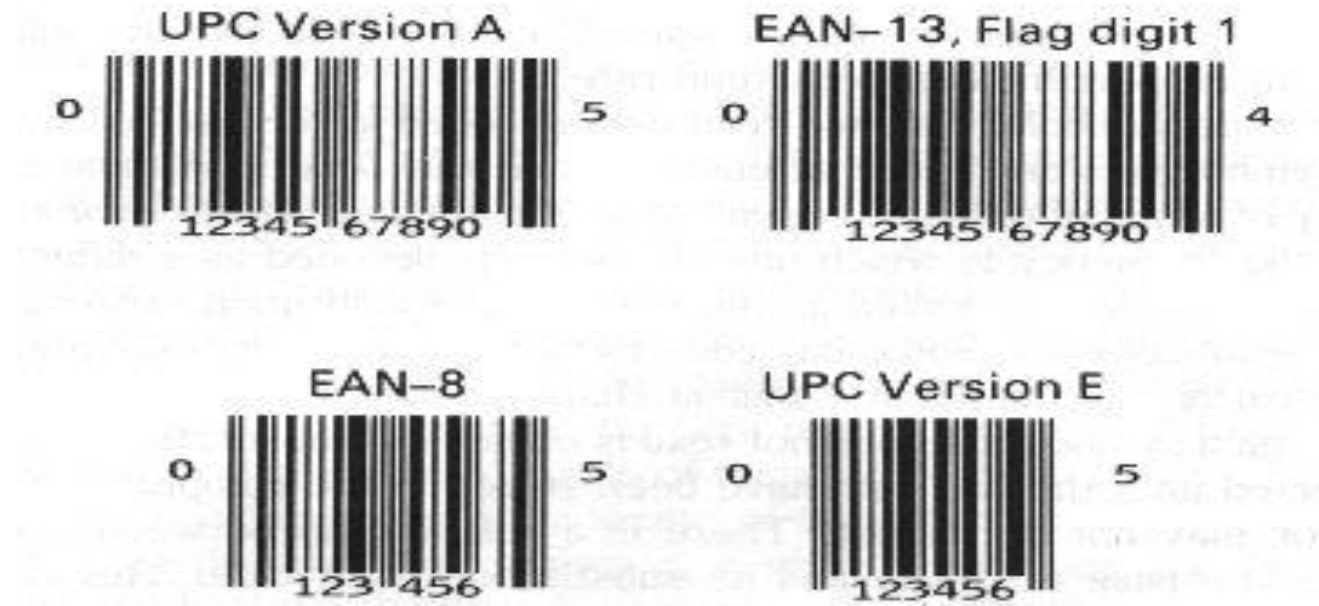
Barcode

- UPC (Universal Product Code)



- broadly accepted.
- Succeeded well in the marketplace resulting in the creation of EAN(European Article Numbering) and JAN (Japanese Article Numbering).

Other Barcodes



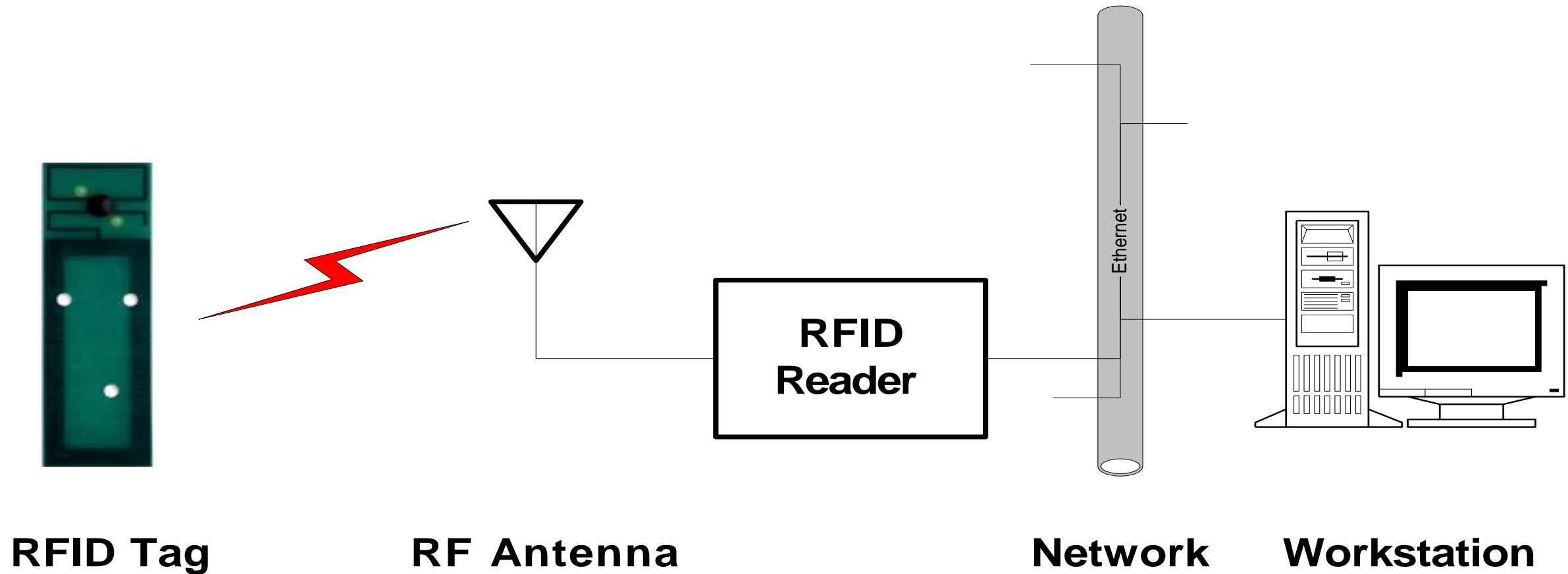
Barcodes

- Drawbacks:
 - Limited in terms of information capacity.
 - Easily damaged or lost.
 - Need for human in the loop

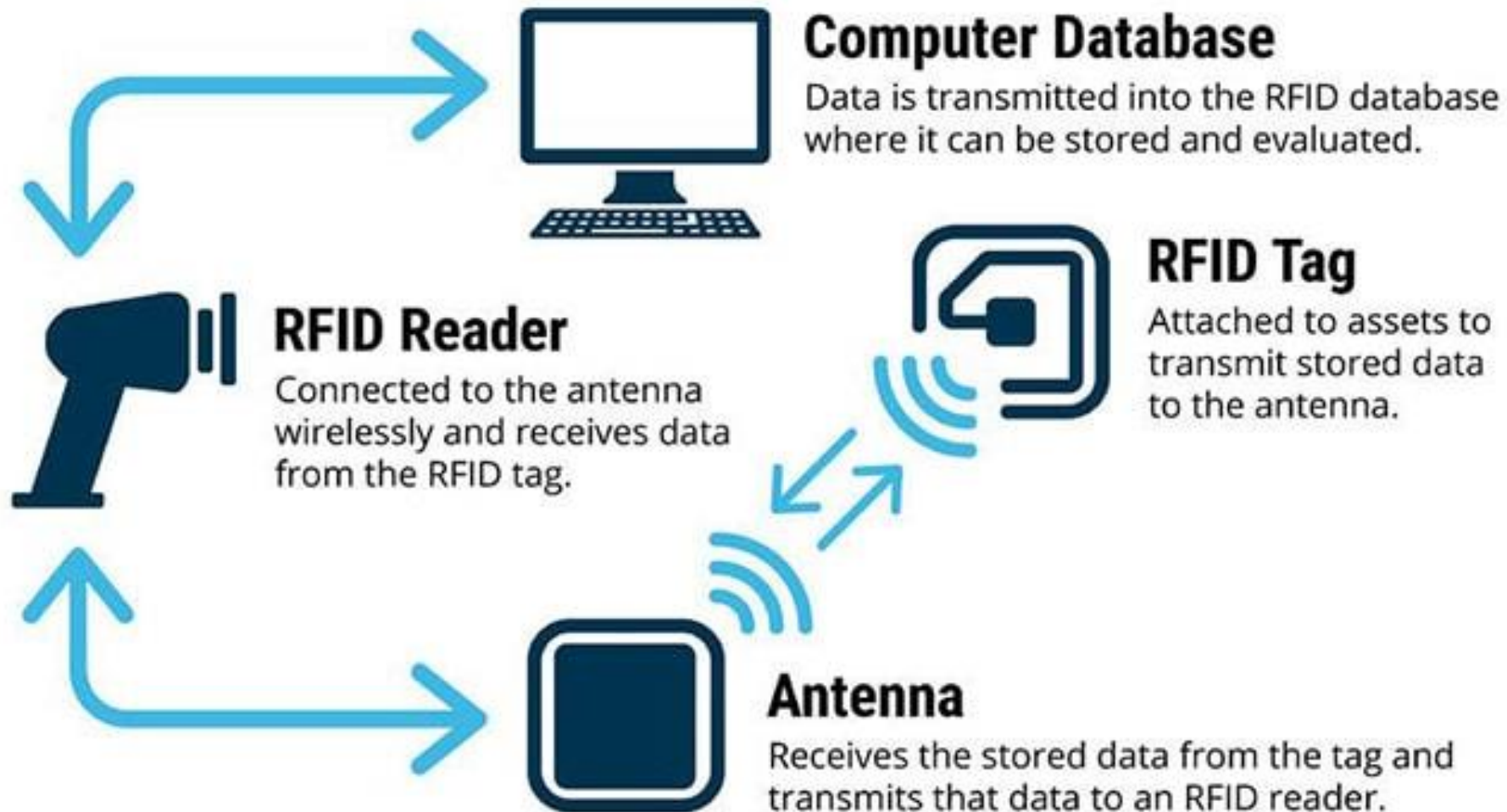
What is RFID?

- RFID = Radio Frequency IDentification.
- An ADC (Automated Data Collection) technology that:
 - uses radio-frequency waves to transfer data between a reader and a movable item to identify, categorize, track..
 - Is fast and does not require physical sight or contact between reader/scanner and the tagged item.
 - Performs the operation using low cost components.
 - Attempts to provide unique identification and backend integration that allows for wide range of applications.

RFID system components



How RFID works



RFID system components

- There are three parts to a RFID system:

RFID Tag

- Programmed with information

Antenna

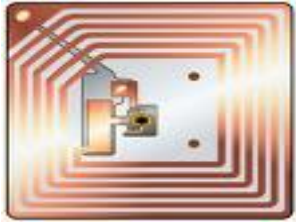
- Provides a means of communication and energy to communicate with RFID tag

RFID Reader

- Has a decoder to interpret the data

Work station

- Data management



RFID vs. Bar Codes

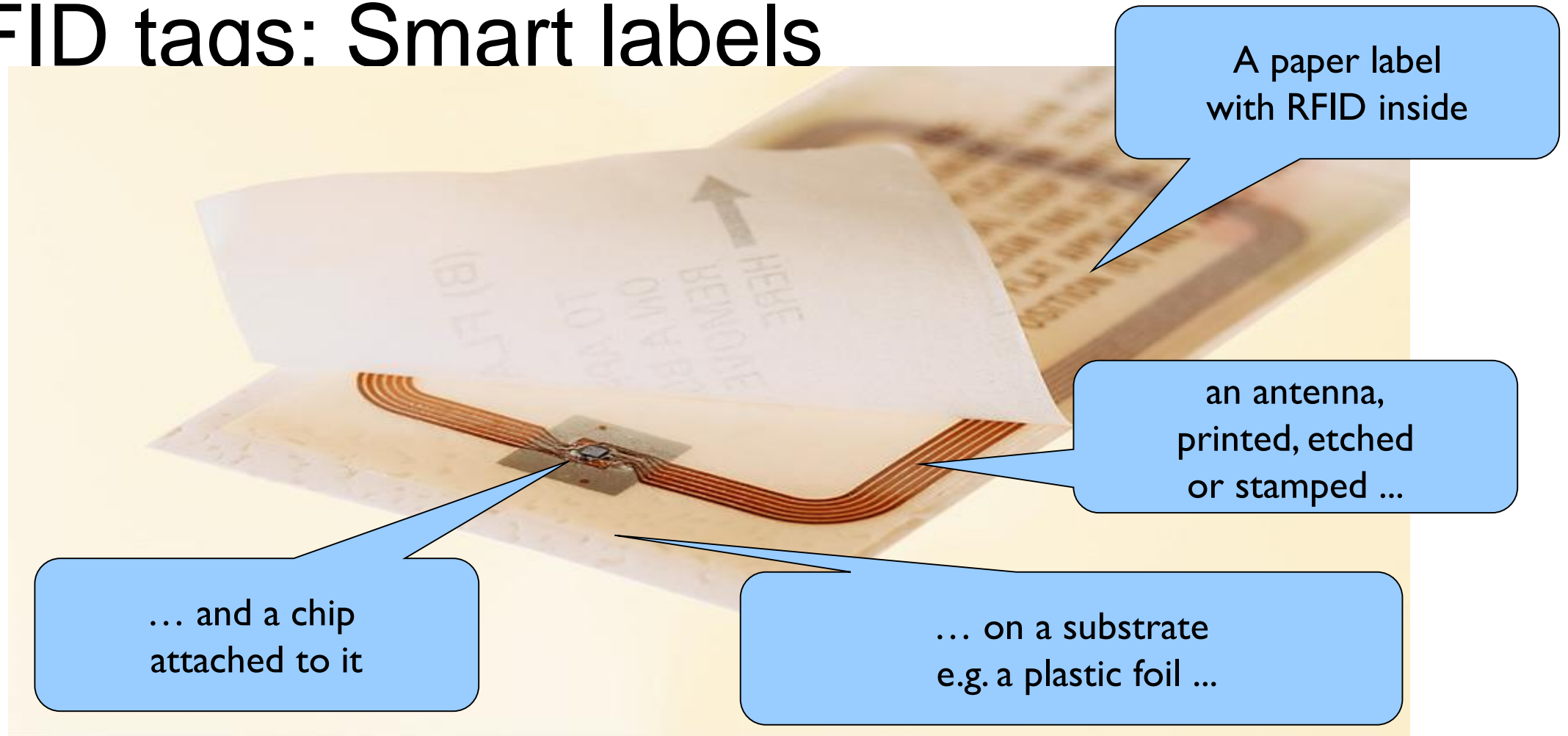


- How is RFID different from Bar Codes?
 - Tag does not need to be on the surface of the object because they do not need a direct line of sight, tags can be embedded or hidden.
 - Tags are applicable in harsh environments, such as outdoors, around chemicals, moisture and high temperatures.
 - RFID tags can be read at a rate of forty or more tags per second; Bar Codes usually take half a second or more per bar code.
 - RFID tags can be read at distances up to 300 feet; Bar Codes no more than 15 feet.
 - RFID Tags can be re-programmed; Bar Codes do not have the read/write capability

RFID vs. Bar Codes

	Manual Process	Bar Code	RFID
Data Accuracy	Least Accurate	Most Accurate	More Accurate
Data Collection Time/Labor	Most Time/Labor	Some Time/Labor	Least Time/Labor
Data Input Time/Labor	Most Time/Labor	Some Time/Labor	Least Time/Labor
Equipment Costs (tags, readers/scanners)	N/A	Some	More
Can Track Assets Out of Line of Sight	No	No	Yes
Amount of Data Storage on Tag	N/A	Less	More
Two way communication	No	No	Yes
Ability to Reprogram Tags	N/A	No	Yes

RFID tags: Smart labels



Passive Tags

Have no internal power supply,

Power supplied by the reader



Cost	Less Expensive--Few Cent to a Few Dollars
Size	Smaller
Power	Reader
Maintenance	None
Read Distance	A few feet
Life	Up to 20 years
Memory	Around 16K

Active Tags



Have their own internal power source,

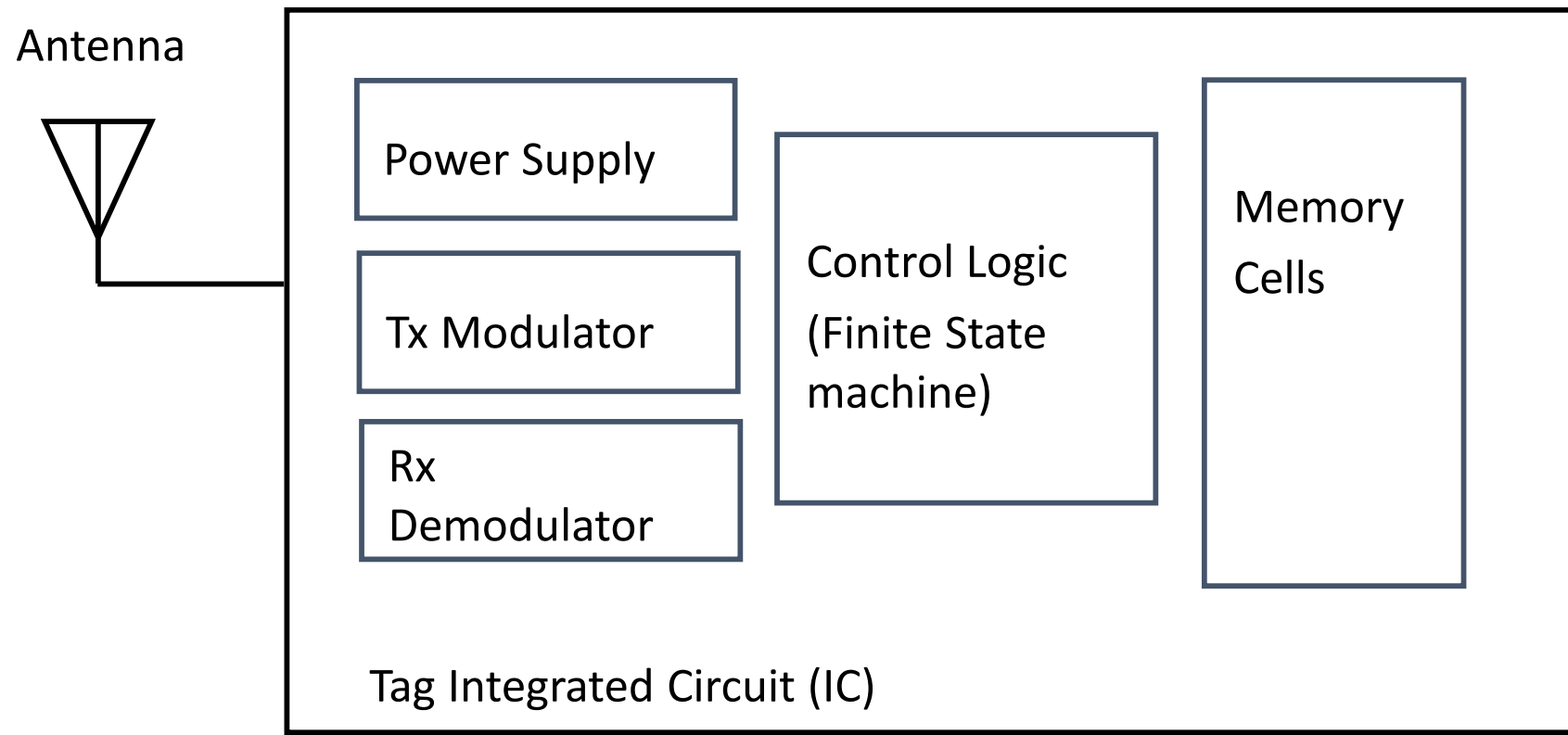
Can have a replaceable battery

Cost	More expensive--often \$20 or more
Size	Larger
Power	Provided by Battery
Maintenance	Replacement Required
Read Distance	Up to 100s of feet
Life	Depends on battery life
Memory	As high as 512K

RFID tags

- Tags can be attached to almost anything:
 - Items, cases or pallets of products, high value goods
 - vehicles, assets, livestock or personnel
- **Passive Tags**
 - Do not require power – Draws from Interrogator Field
 - Lower storage capacities (few bits to 1 KB)
 - Shorter read ranges (4 inches to 15 feet)
 - Usually Write-Once-Read-Many/Read-Only tags
 - Cost around 25 cents to few dollars
- **Active Tags**
 - Battery powered
 - Higher storage capacities (512 KB)
 - Longer read range (300 feet)
 - Typically can be re-written by RF Interrogators
 - Cost around 50 to 250 dollars

Tag block diagram



Tag Attachments



- Embedded
 - Usually aimed for permanent or long-term implantation, such as animal traceability
- Attached
 - Designed to be attached on the surface of identified objects with permanent, semi-permanent or temporary attachment means
- Injected
 - Designed to have little contact or no contact with identified objects and can be easily removed
- Digested
 - Eastman Kodak has filed two patent applications for monitoring ingestion of medicine

RFID tag memory

- Read-only tags
 - Tag ID is assigned at the factory during manufacturing
 - Can never be changed
 - No additional data can be assigned to the tag
- Write once, read many (WORM) tags
 - Data written once, e.g., during packing or manufacturing
 - Tag is locked once data is written
 - Similar to a compact disc or DVD
- Read/Write
 - Tag data can be changed over time
 - Part or all of the data section can be locked

RFID readers

- Reader functions:
 - Remotely power tags
 - Establish a bidirectional data link
 - Inventory tags, filter results
 - Communicate with networked server(s)
 - Can read 100-300 tags per second
- Readers (interrogators) can be at a fixed point such as
 - Entrance/exit
 - Point of sale
- Readers can also be mobile/hand-held



Types of Readers



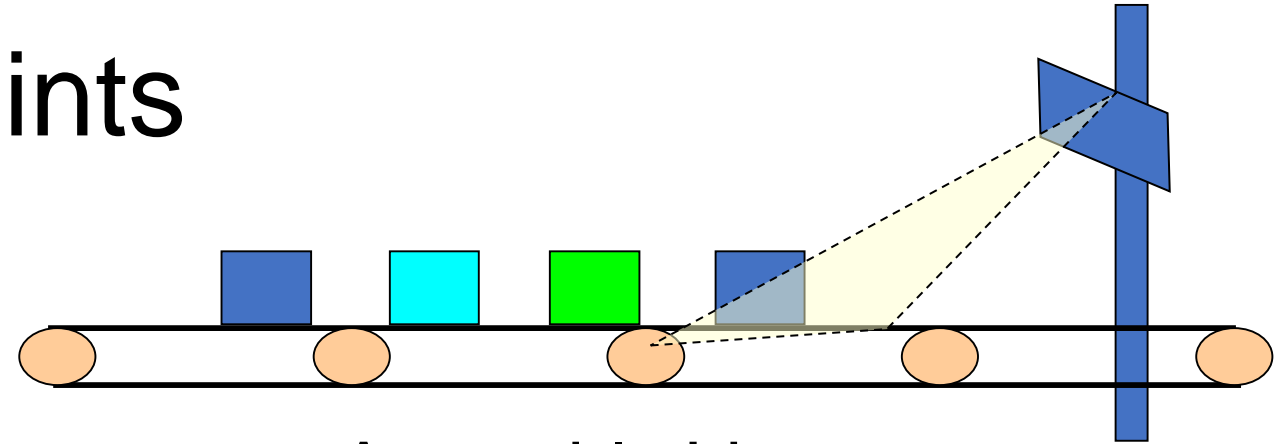
- Dumb
 - Can read only one type of tag using one frequency and one protocol
- Agile
 - can read tags at different frequencies or using different methods of communication
- Intelligent
 - Agile reader+ applications such as data filtering

Some RFID readers

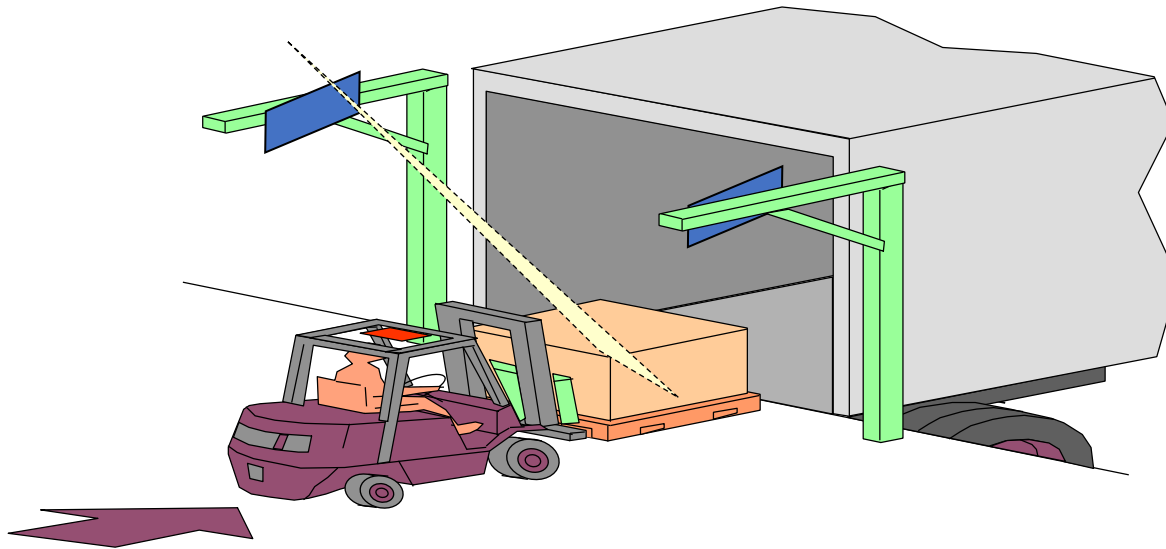


Applications

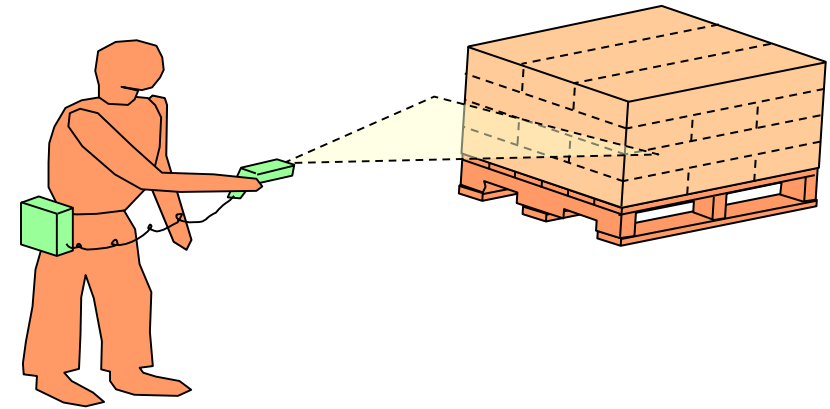
RFID application points



- Assembly Line



- Shipping Portals



- Handheld Applications

Smart groceries

- Add an RFID tag to all items in the grocery.
- As the cart leaves the store, it passes through an RFID transceiver.
- Check out in seconds.

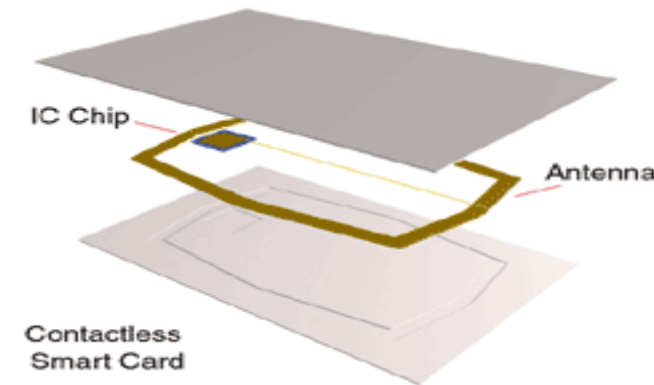


Smart fridge

- Recognizes what's been put in it
 - Recognizes when things are removed
 - Creates automatic shopping lists
 - Notifies you when things are past their expiration
-
- Shows you the recipes that most closely match what is available

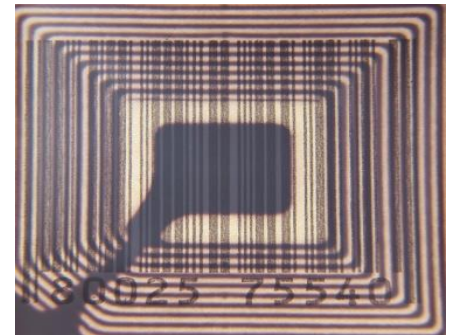
Access control and identification

- Cards for access to secure areas. Not only verifies identity but checks if certain requirements to enter have been met.
- Wristbands to provide access to unattended buildings.



Tracking people and objects

- Children in theme parks
- Protection of expensive objects
- Personnel activities inside a facility
- Inmates identification and tracking



Ticketing

- Trains, subways, buses, concerts, amusement parks, fitness facilities, ski resorts.
- Reduces counterfeit
- RFID tickets used in the Soccer World Cup in Germany in 2006. 4.8 millions Tickets sold with no counterfeiting problems.



Libraries

- From barcodes to RFID tags.
- Faster and automatic checkout and return.
- Faster inventory process.

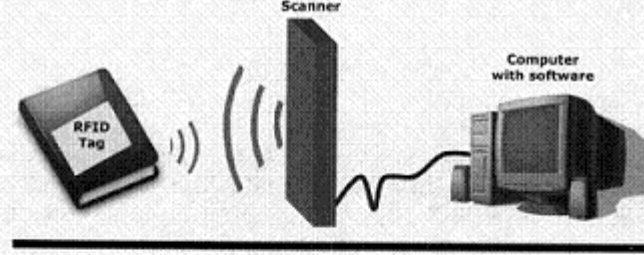


Figure 1. Components of an RFID system

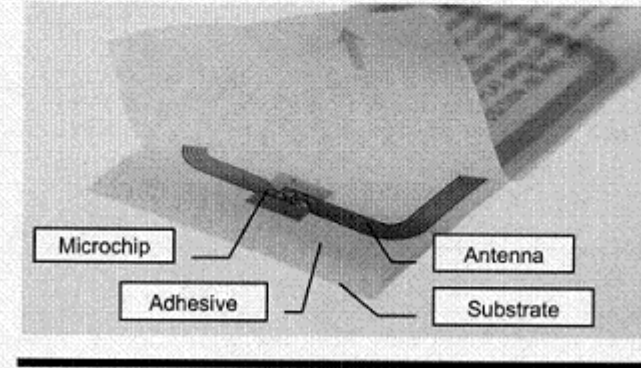


Figure 2. Typical RFID tag

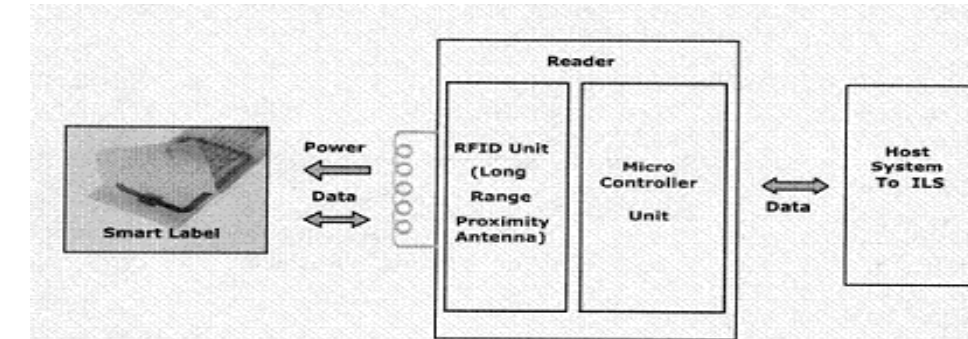
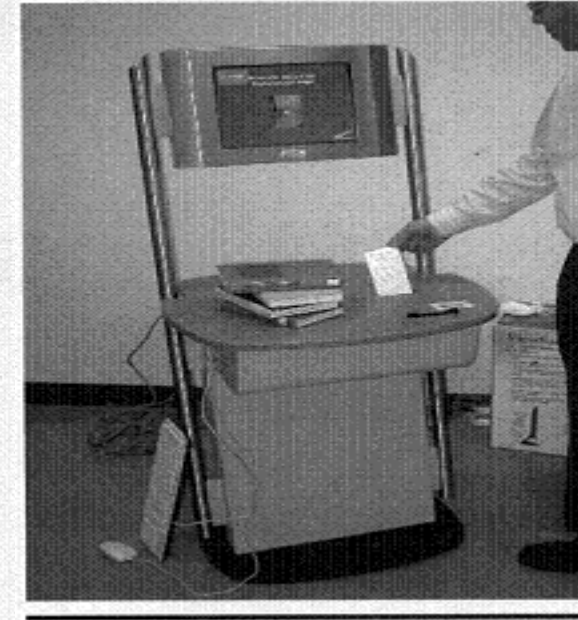


Figure 3. Information exchange for a typical RFID-based library (source: Libramation Library Systems)

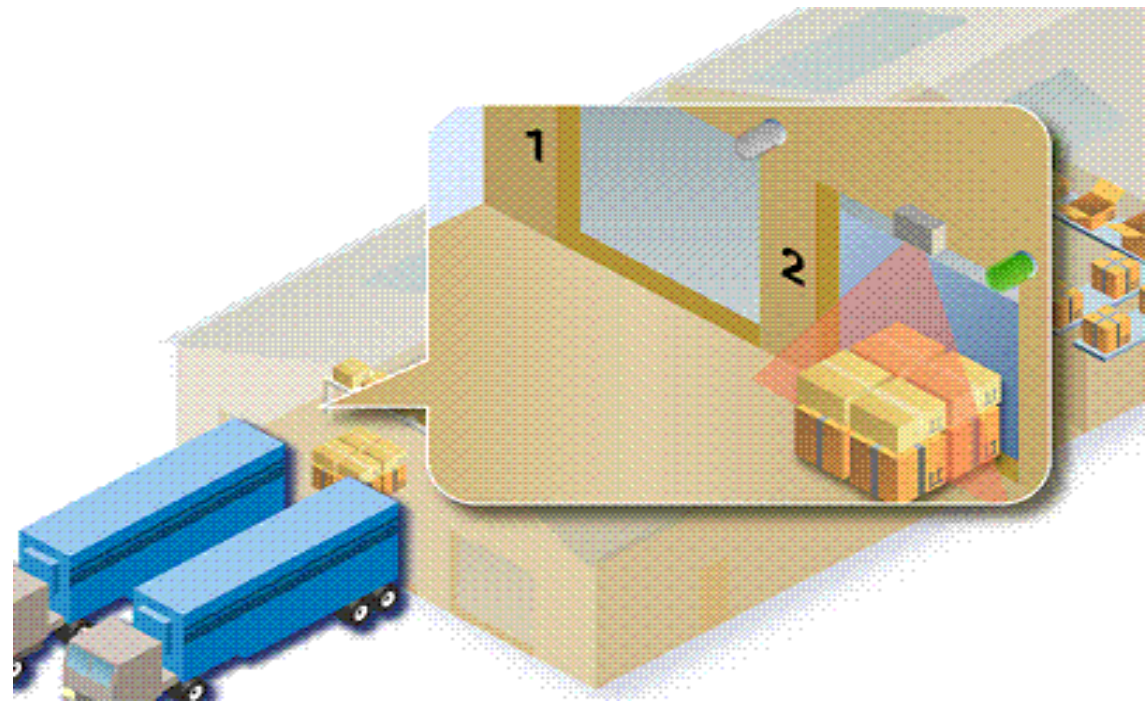
Production Line Control and Monitoring

- Car Body Production: Flow of information along the assembly line for process verification.
- Identify vehicles through assembly line prior to the execution of a given assembly task.



Distribution and transportation

- Receiving and check-in
- Put away and replenishment
- Order Filling
- Shipping
- Product and asset tracking



Vehicle Identification

- Fleet management
- Access to parking lots
- Railway industry
- Electronic toll collection



Baggage handling

- Replace bar code stick labels with RFID inlay stick labels.
- Many tags can be read at one time.
- Read-write capability is used to record information along the way as the bag makes its way through the handling system.



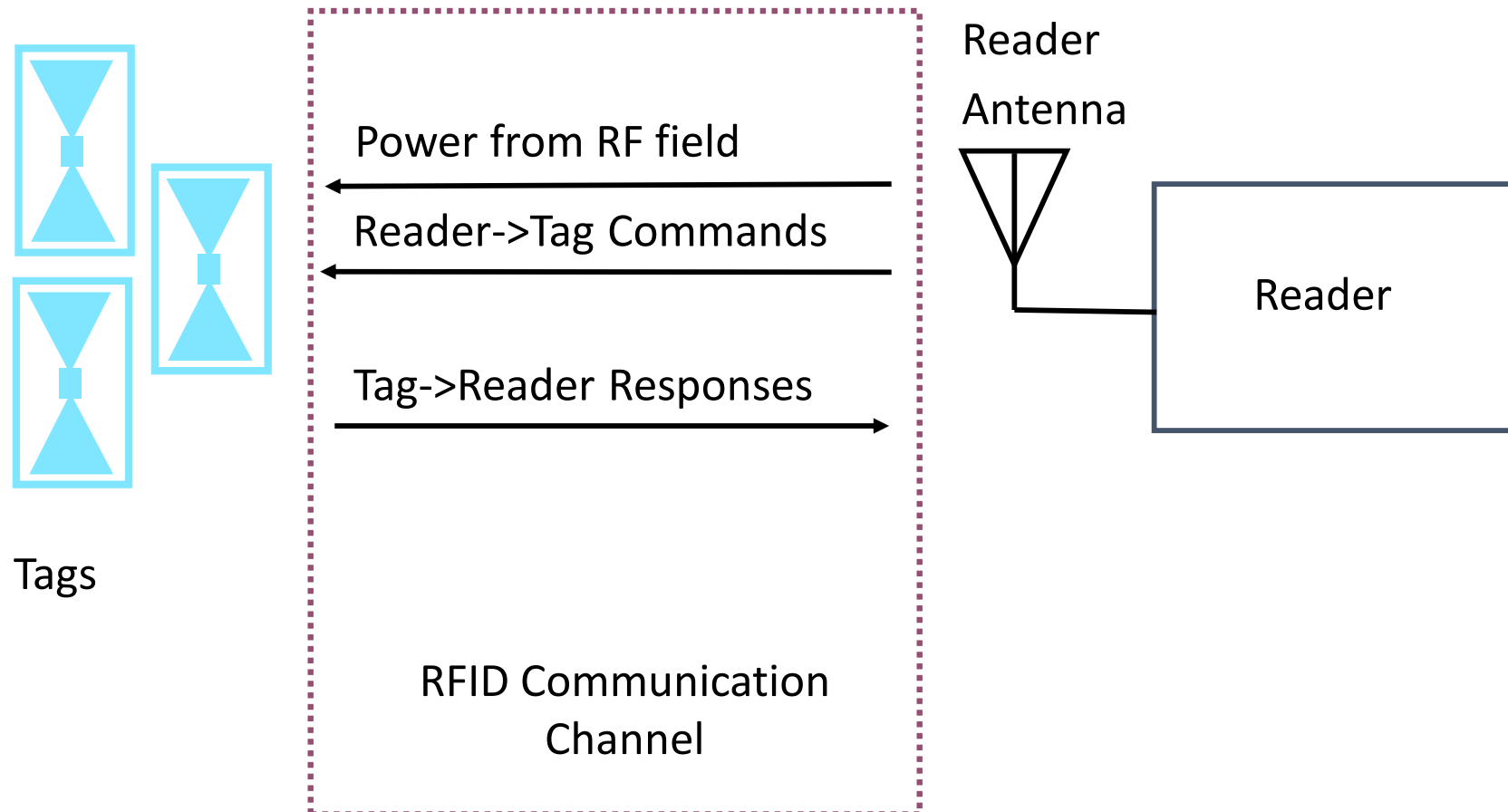
Animal Identification

- Livestock tracking
- Data critical for the safety of food supply
- Can also be used on pets.
- Ear tags, injectable tags, RFID tattoos



RFID Technology

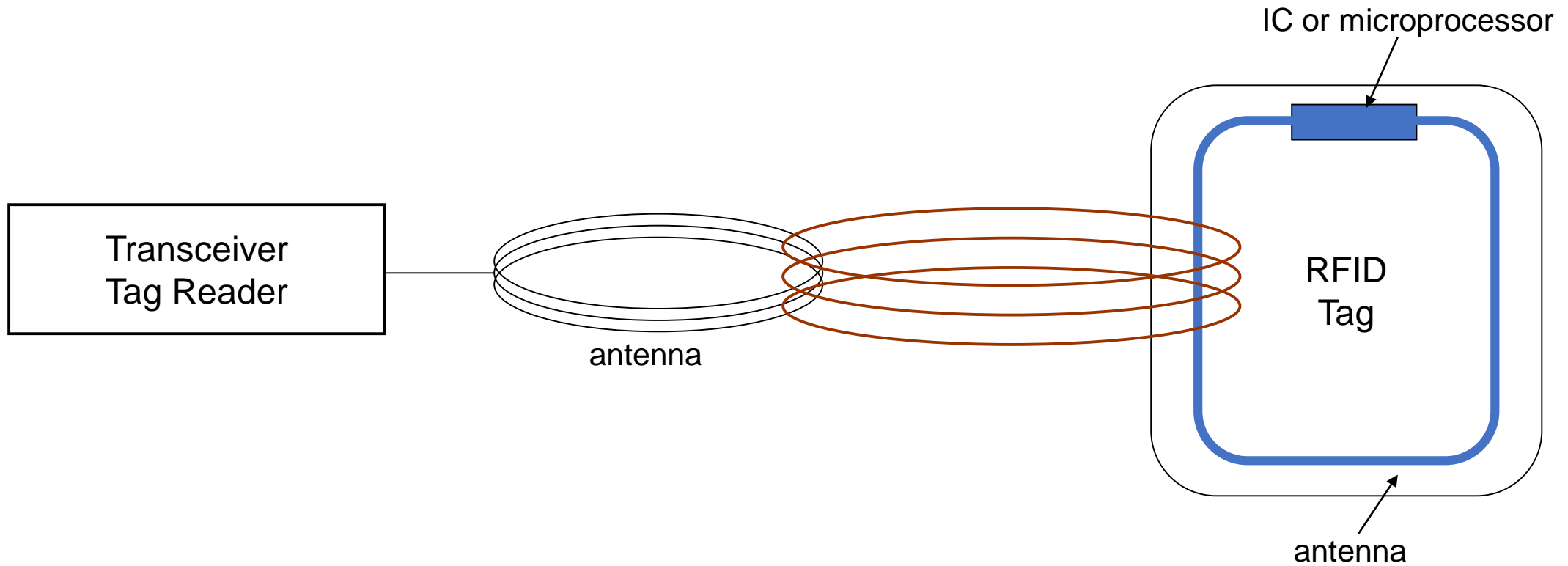
RFID communication



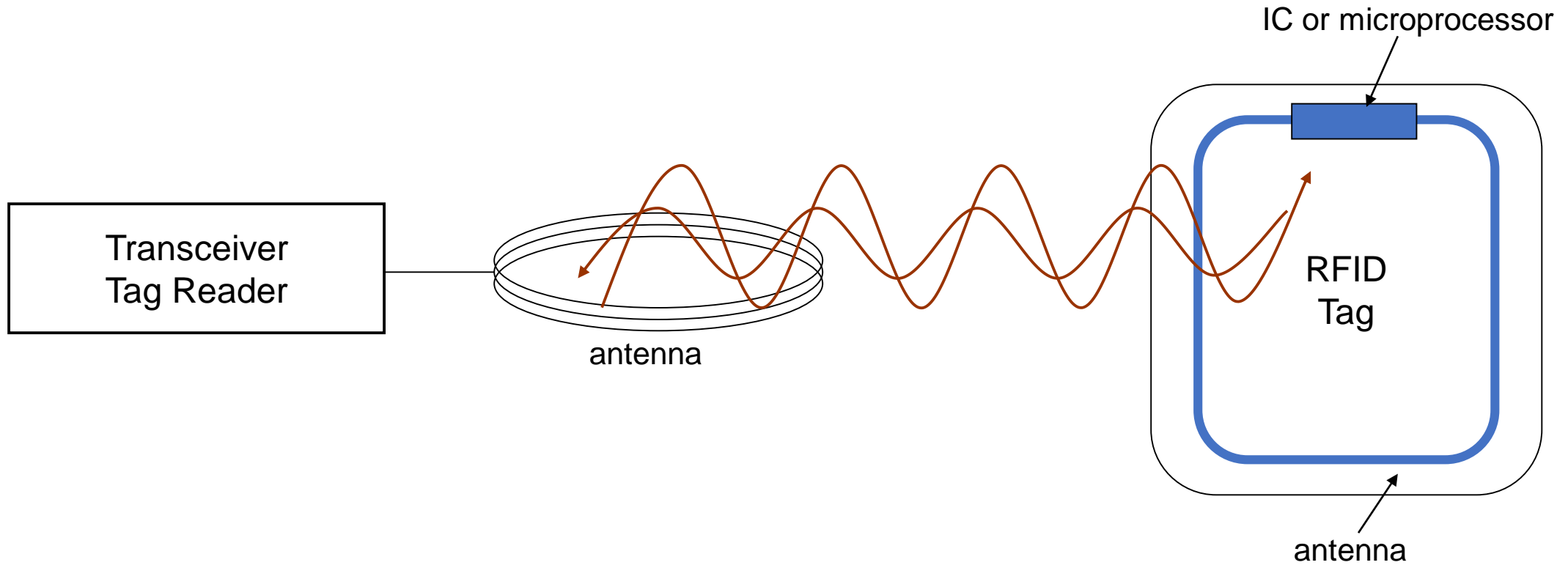
RFID communication

- Host manages Reader(s) and issues Commands
- Reader and tag communicate via RF signal
- Carrier signal generated by the reader and sent out through the antennas
- Tag receives and modifies carrier signal
 - “sends back” modulated signal (Passive Backscatter – also referred to as “field disturbance device”)
- Antennas receive the modulated signal and send them to the Reader
- Reader decodes the data

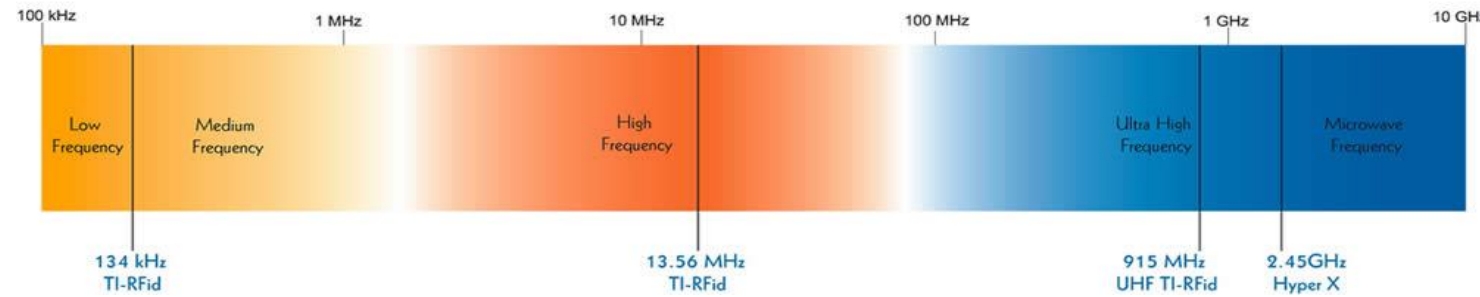
Antenna fields: Inductive coupling



Antenna fields: Propagation coupling



Frequencies

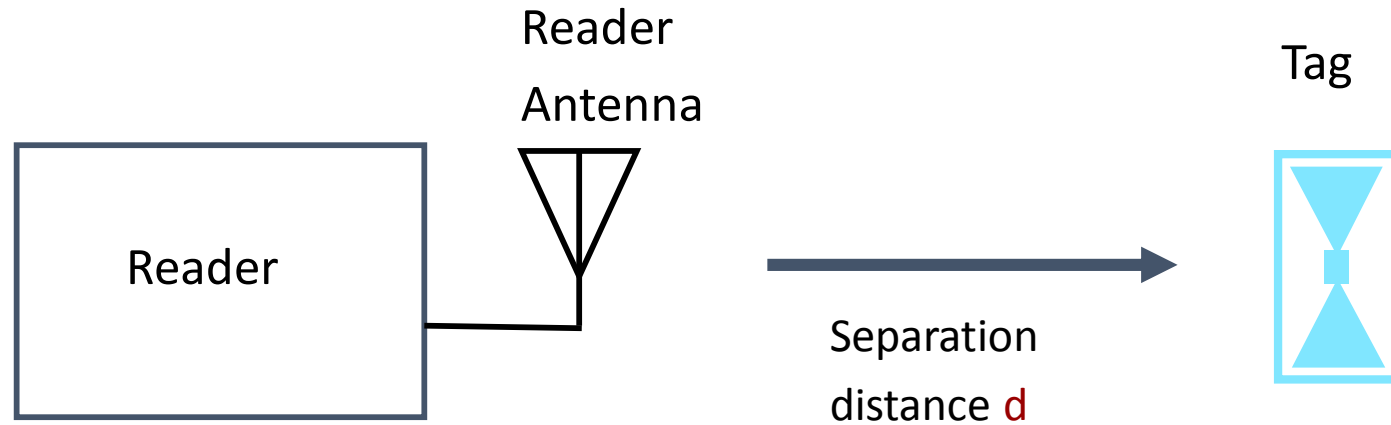


- Low Frequency (LF)
 - 125 KHz or 134KHz
 - Shorter read-range and read-rate
 - Less sensitive to interference
- High Frequency (HF)
 - 13.56 MHz
 - Greater read-range & higher read-speed than LF
- Ultra-High Frequency (UHF)
 - 860 to 930 MHz
 - Same cost as HF
 - Faster Data Transfer
 - Limited read ability
- Microwave
 - 2.45GHz or 5.8GHz
 - Highest data read speed
 - Most expensive
 - Limited read range (3ft)

Operational frequencies

Frequency Ranges	LF 125 KHz	HF 13.56 MHz	UHF 868 - 915 MHz	Microwave 2.45 GHz & 5.8 GHz
Typical Max Read Range (Passive Tags)	Shortest 1''-12''	Short 2''-24''	Medium 1'-10'	Longest 1'-15'
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitive coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling
Data Rate	Slower	Moderate	Fast	Faster
Ability to read near metal or wet surfaces	Better	Moderate	Poor	Worse
Applications	Access Control & Security Identifying widgets through manufacturing processes or in harsh environments Ranch animal identification Employee IDs	Library books Laundry identification Access Control Employee IDs	supply chain tracking Highway toll Tags	Highway toll Tags Identification of private vehicle fleets in/out of a yard or facility Asset tracking

Reader to Tag power transfer



Q: If a reader transmits P_r watts, how much power P_t does the tag receive at a separation distance d ?

A: It depends-

UHF (915MHz) : Far field propagation : $P_t \propto 1/d^2$

HF (13.56MHz) : Inductive coupling : $P_t \propto 1/d^6$

Limiting factors for passive RFID

1. Reader transmitter power P_r (Gov't. limited)
2. Reader receiver sensitivity S_r
3. Reader antenna gain G_r (Gov't. limited)
4. Tag antenna gain G_t (Size limited)
5. Power required at tag P_t (Silicon process limited)
6. Tag modulator efficiency E_t

Implications

- Since $P_t \propto 1/d^2$, doubling read range requires 4X the transmitter power.
- Larger antennas can help, but at the expense of larger physical size because $G\{t,r\} \propto \text{Area}$.
- More advanced CMOS process technology will help by reducing P_t .
- At large distances, reader sensitivity limitations dominate.

RF effects of common materials

Material	Effect(s) on RF signal
Cardboard	Absorption (moisture) Detuning (dielectric)
Conductive liquids (shampoo)	Absorption
Plastics	Detuning (dielectric)
Metals	Reflection
Groups of cans	Complex effects (lenses, filters) Reflection
Human body / animals	Absorption, Detuning, Reflection

Collision avoidance in RFID: Singulation

- Singulation is a method by which an RFID reader identifies a tag with a specific serial number from a number of .
 - Otherwise if multiple tags respond simultaneously to a query, they will jam each other.
 - E.g., when scanning a bag of groceries, potentially hundreds of tags might be within range of the reader.
- To read data from each and every tag
 - All the tags need cooperate with the tag reader and follow the same anti-collision protocol, called singulation protocol

Collision avoidance: ALOHA

- tags detect when a collision has occurred, and attempt to resend after waiting a random interval.
- Pros: simple
- Cons: when tags are dense, the network can reach congestion collapse.

Collision avoidance: Tree Walking

- Assume the reader is looking for tag with ID 010101
- The reader asks all tags with a serial number that starts with 0 to respond. If more than one responds, the reader might ask for all tags with a serial number that starts with 01 to respond, and then 010.
- It keeps doing this until it finds the tag it is looking for.
- Pro: can optimize the search order
- Con: leak information
 - everyone can determine all but the last bit of ID

