RFID: Technology and Applications

Outline

- Overview of RFID
  - Reader-Tag; Potential applications
- RFID Technology Internals
  - RF communications; Reader/Tag protocols
  - Middleware architecture; EPC standards

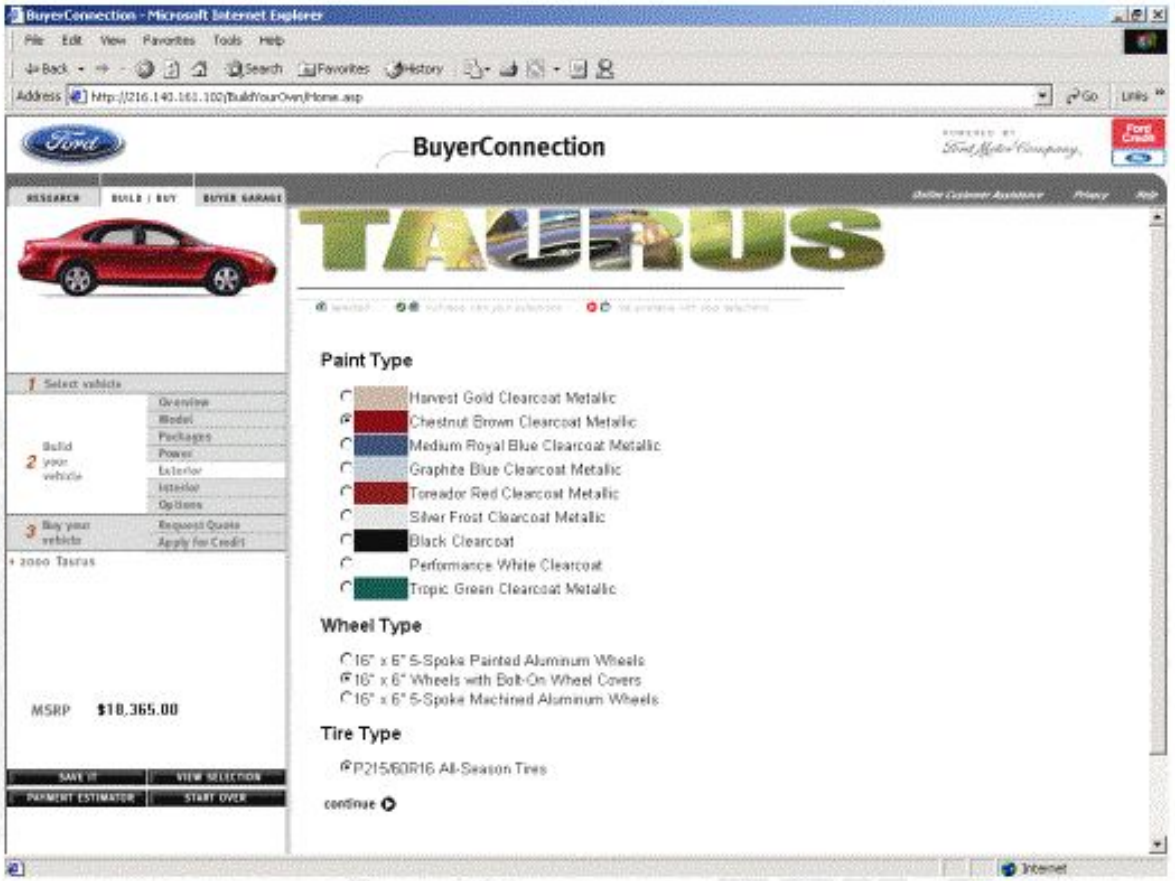
Product Marketing – 75 years ago

You can have
any color,
as long as its
black !

Product Marketing - Today

Add consumer flexibility, courtesy of robotics, computers …

Customer window into final stage of manufacturing



Effect on manufacturing

- Need to ensure error-free, custom assembly
- Need inventory of components for the various customization options

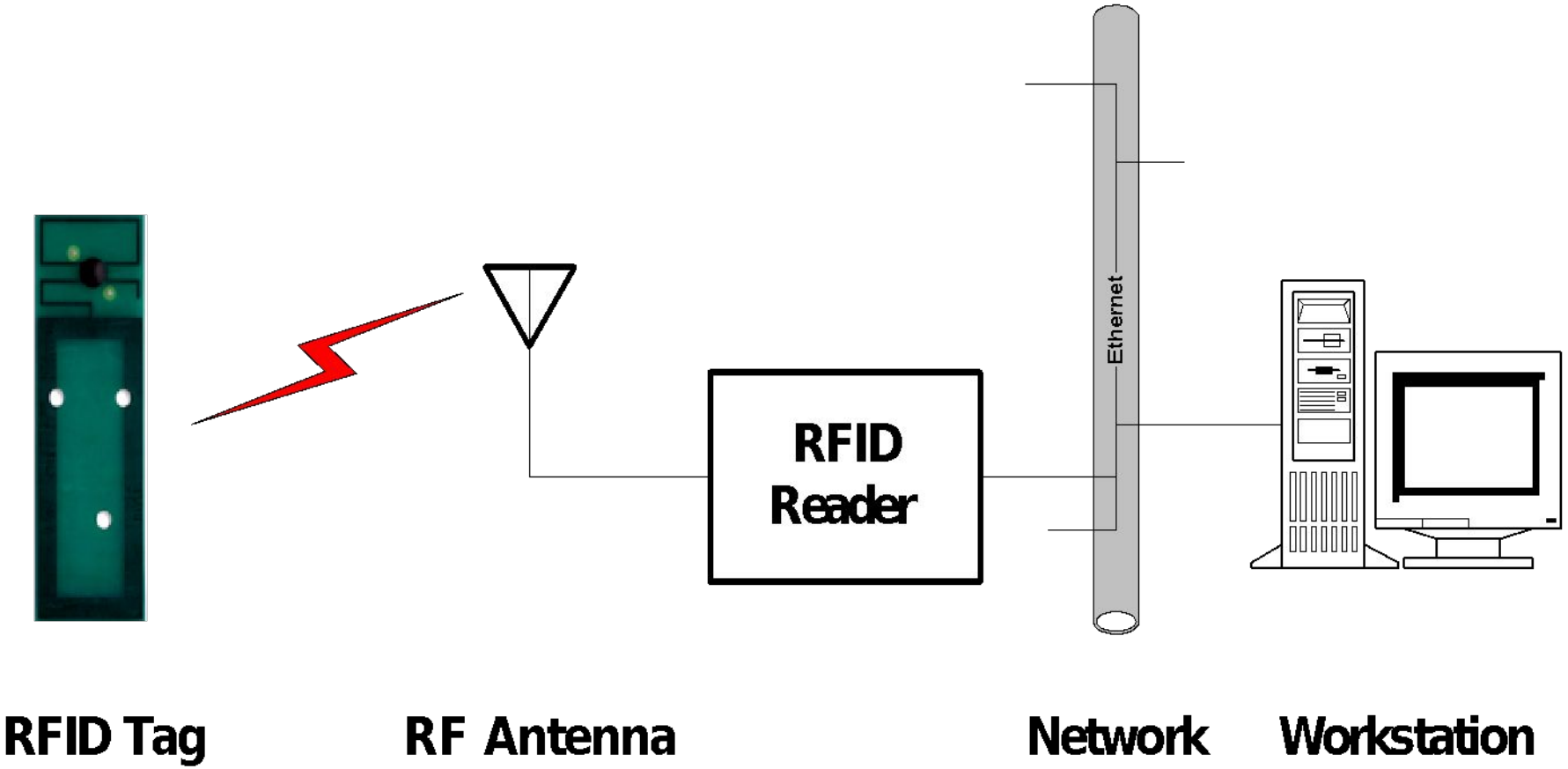
- Critical Issues
  - Assembly process control
  - Inventory management
  - Supply chain integration
  - Customer insight

- One solution: RFID

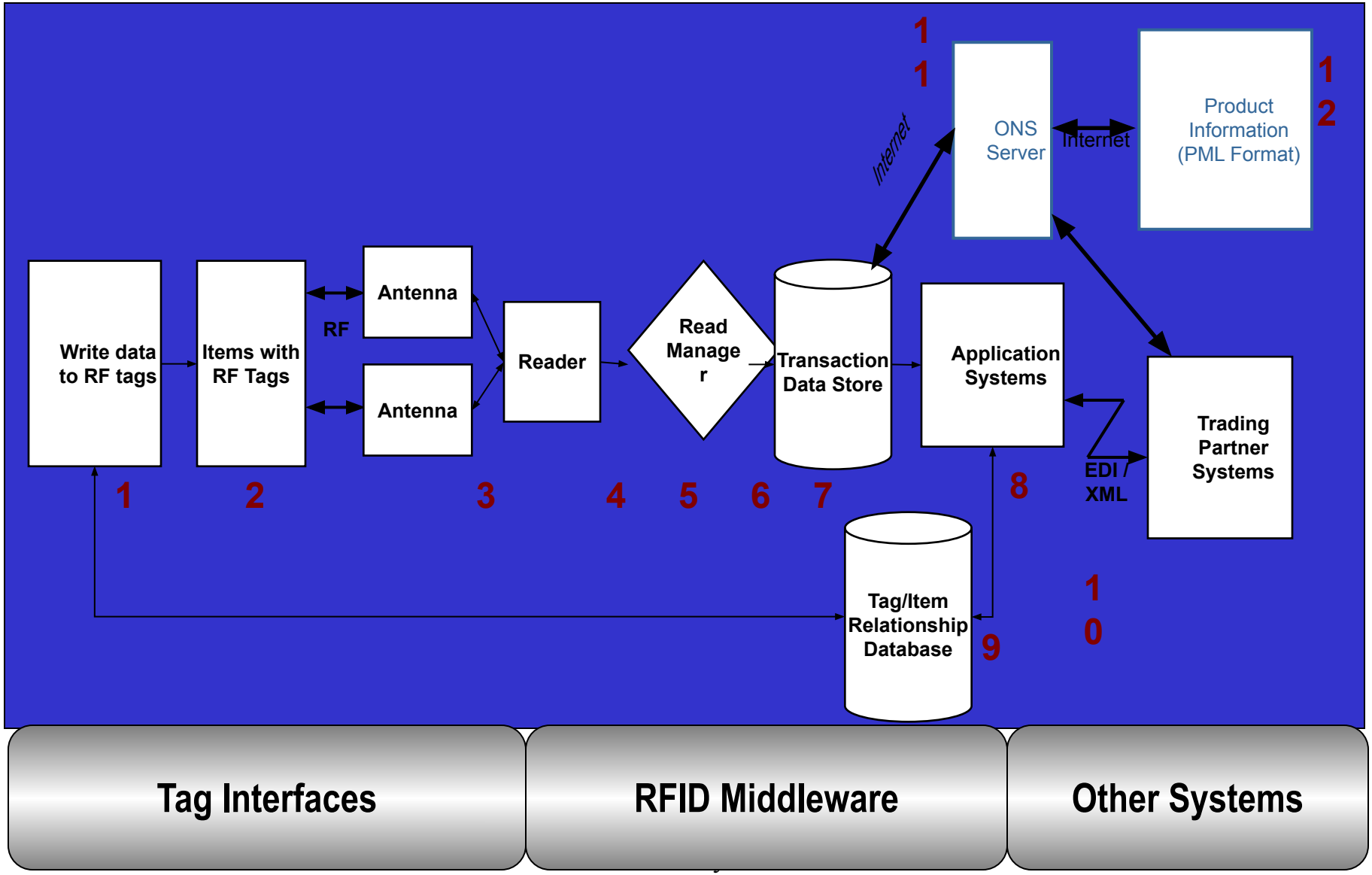
What is RFID?

- 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.
- Other ADC technologies: Bar codes, OCR (Optical character recognition).

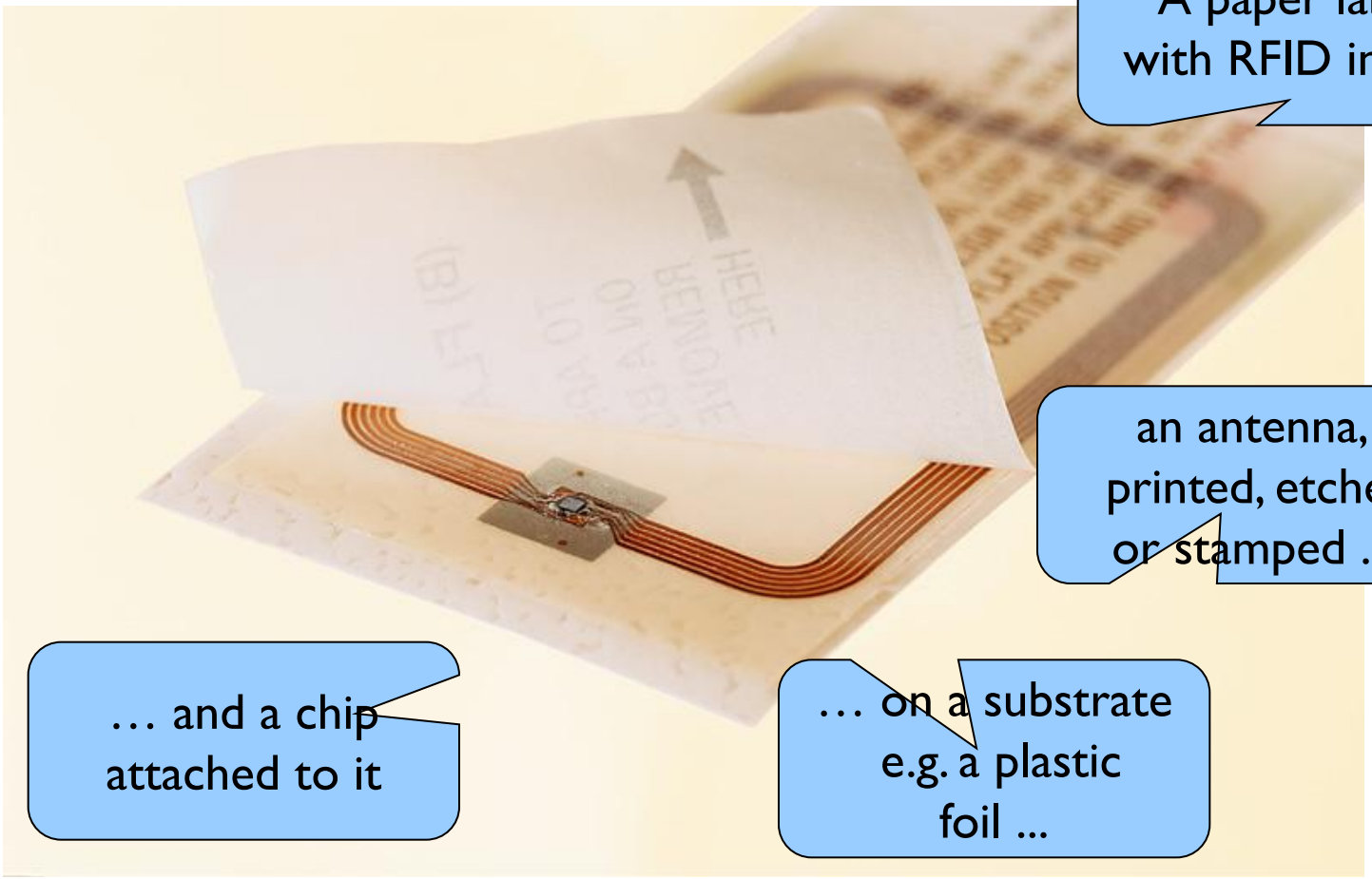
RFID system components



RFID systems: logical view

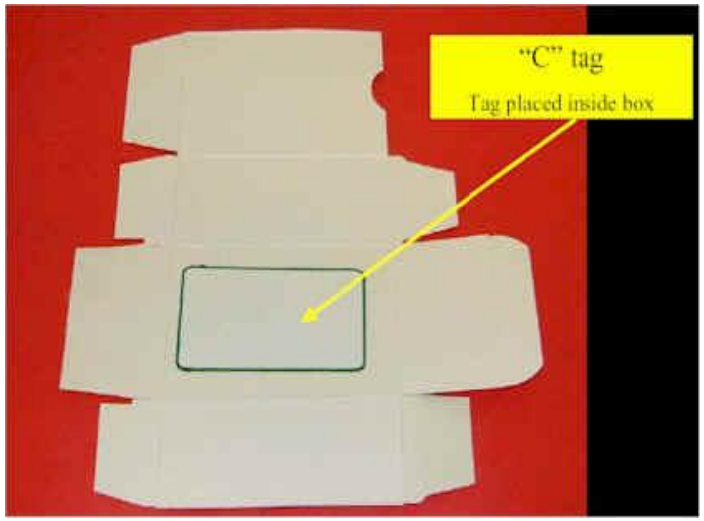


RFID tags: Smart labels



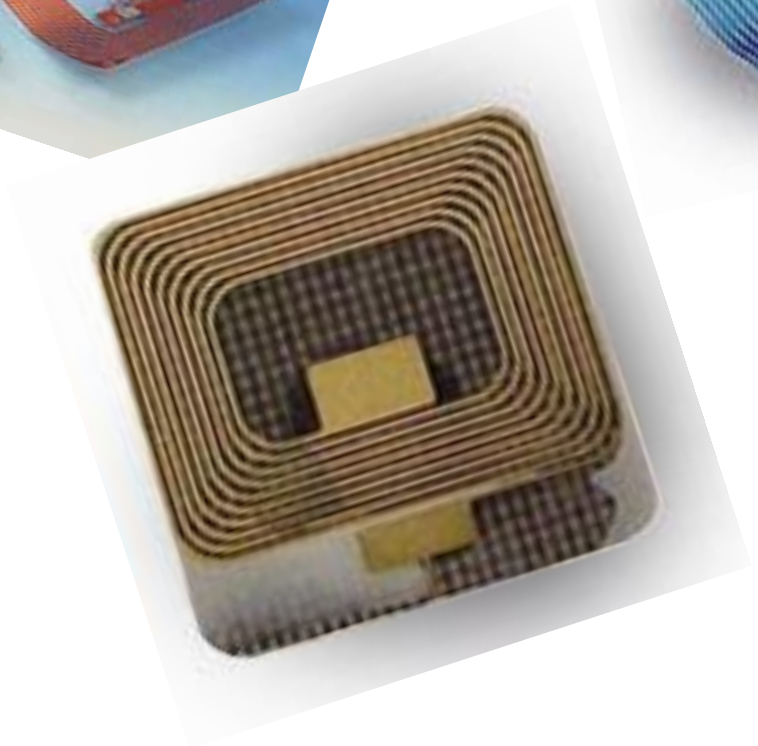
Source: **www.rfidprivacy.org**

Some RFID tags



Source: **www.rfidprivacy.org**

Real Tags



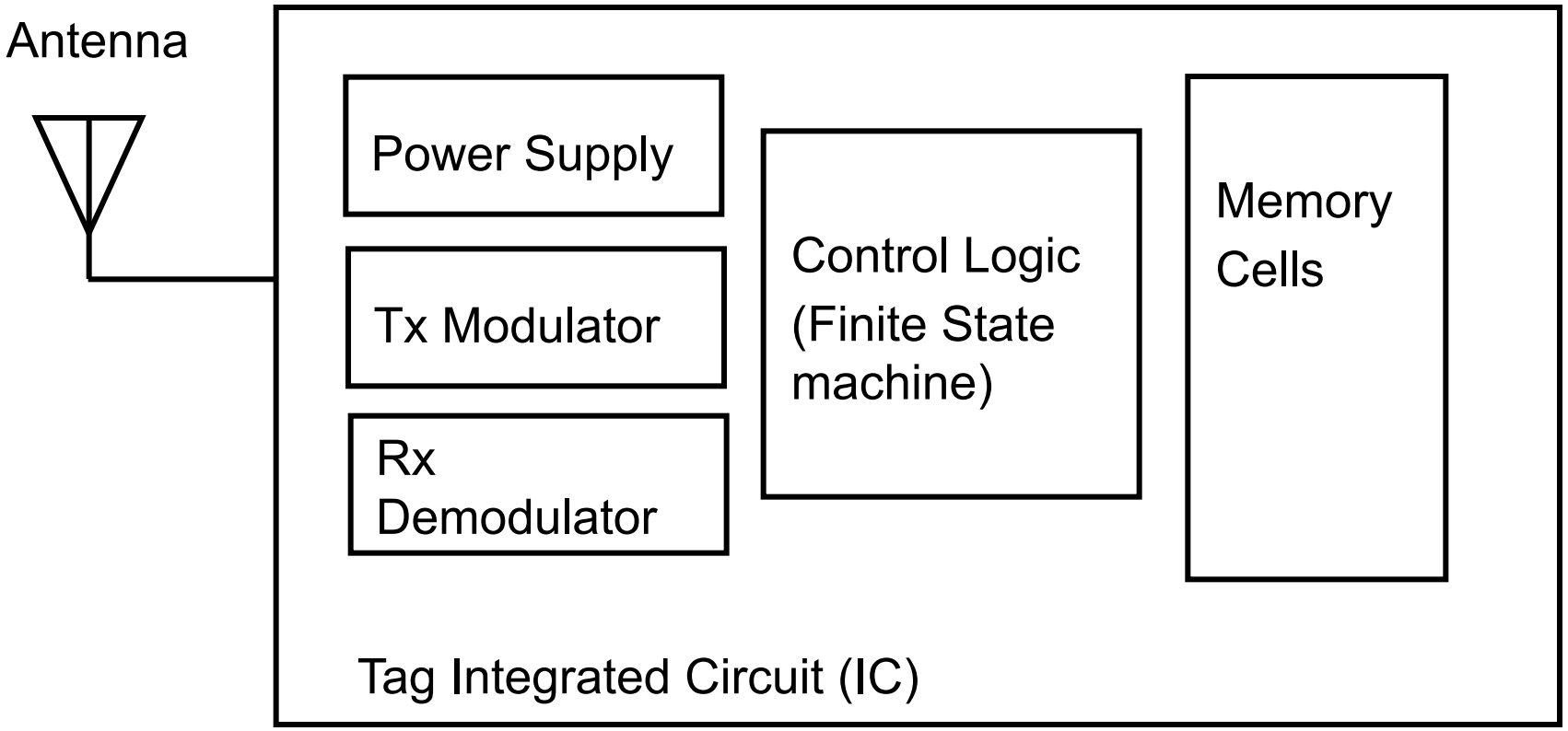
RFID tags

- 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
  - sensitive to interference (metal, noise, etc,) **IN CASE OF UHF**
- **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
  - better than passive tags in the presence of metal

RFID tags

- **Semi-Passive Tags**
  - Powers the microchip of the tag
  - Less sensitive to interference than passive tag (metal)
  -
- **Semi-Active Tags**
  - Power the transmitter part
  - Better than passive and semi-passive in a noisy environment
- **Near Field communication**
  - NFC is a short-range wireless technology that enables easy and convenient interaction between devices.
  - range few centimeter
  - combines the interface of a smartcard and a reader in one device
  - mobile devices with enabled NFC technology are already on the market
  - applications - mobile ticketing in public transport, mobile payment, smart poster, e-money...etc

Tag block diagram



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

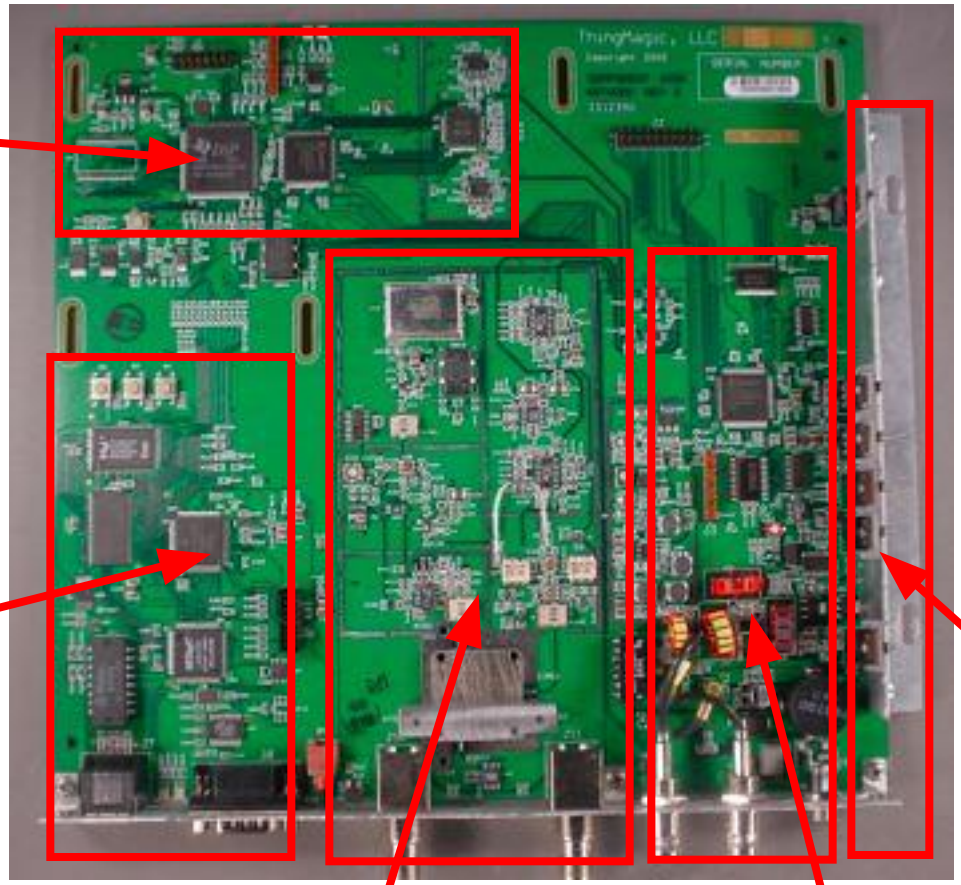
- Reader functions:
  - Remotely power tags
  - Establish a bidirectional data link
  - Inventory tags, filter results
  - Communicate with networked server(s)
  - Can read 100-300 tags per second

- Readers (interrogators) can be at a fixed point such as
  - Entrance/exit
  - Point of sale
- Readers can also be mobile/hand-held

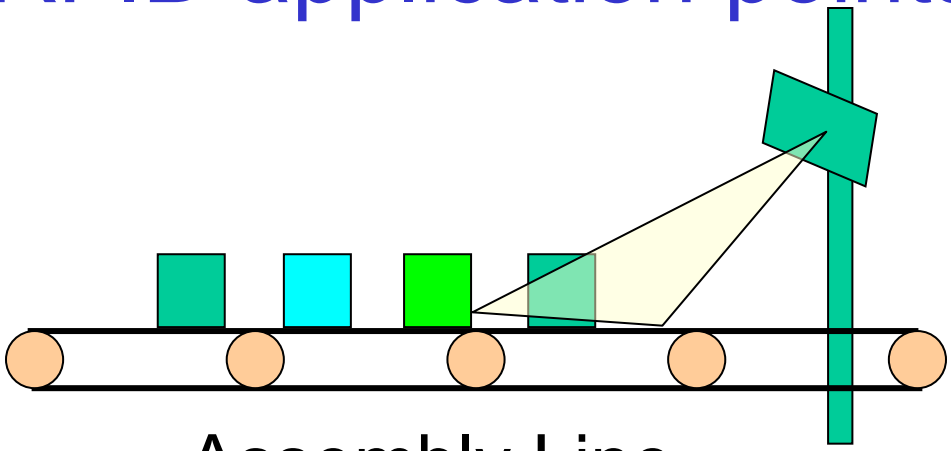
Some RFID readers

Source: **www.buyrfid.org**

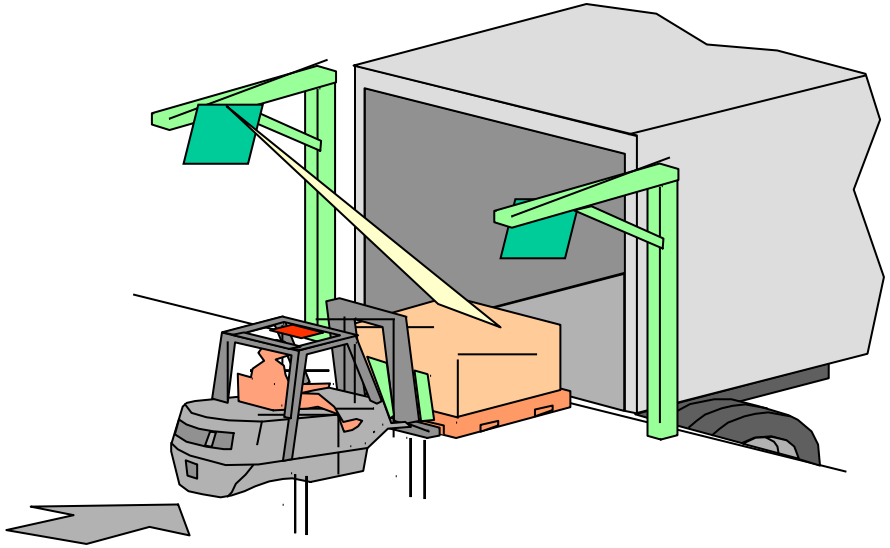
Reader anatomy

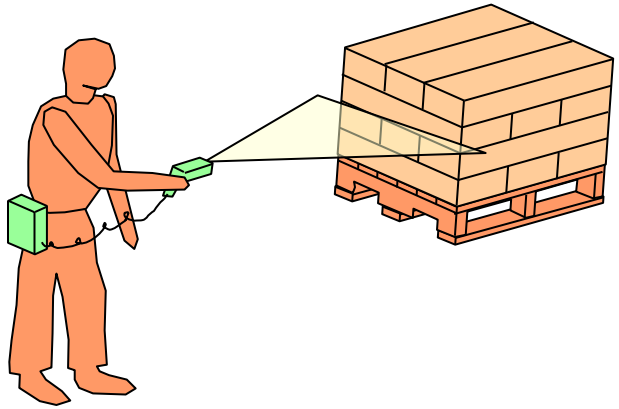


RFID application points



- Assembly Line





- Handheld Applications

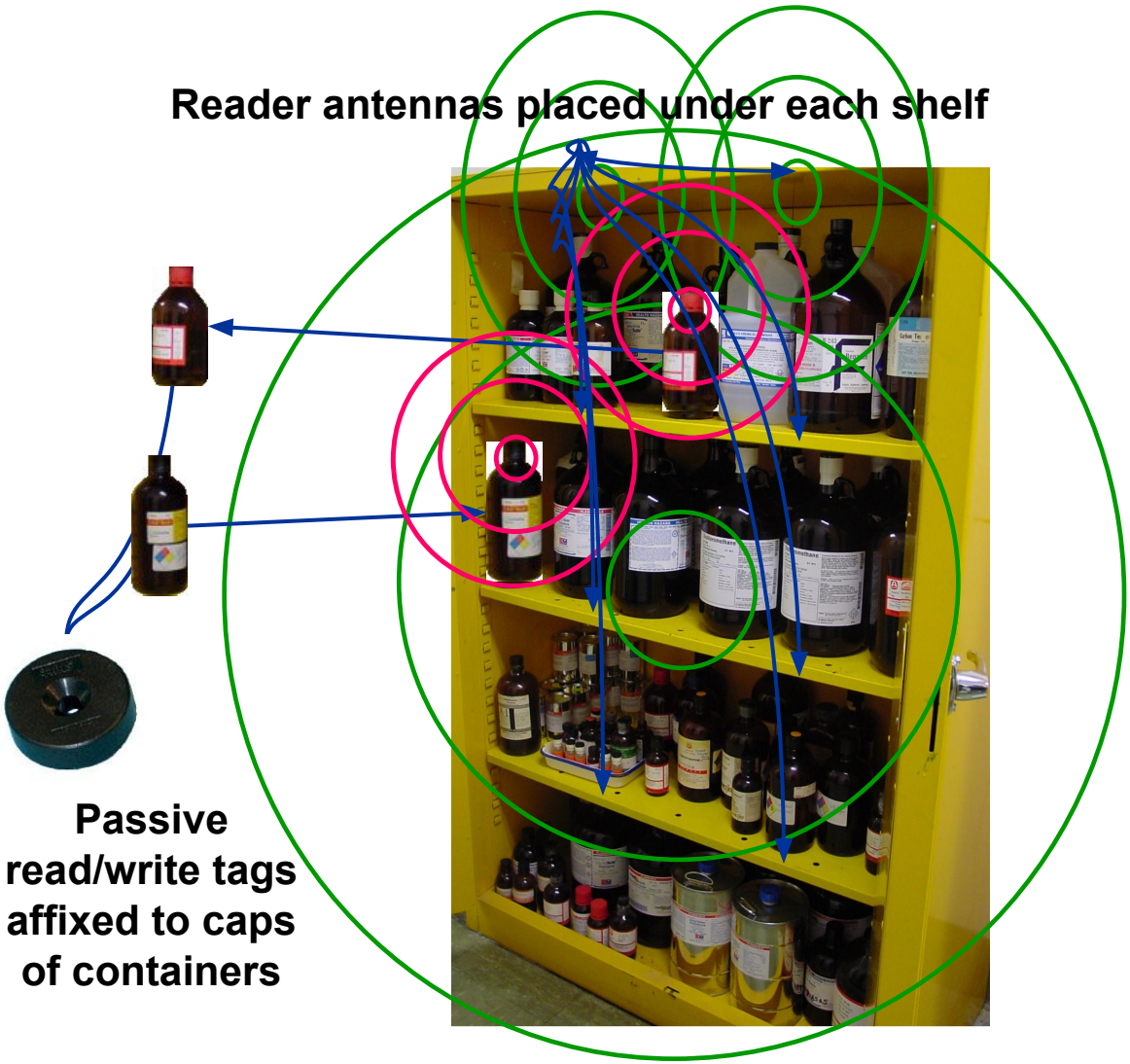
RFID applications

- Manufacturing and Processing
  - Inventory and production process monitoring
  - Warehouse order fulfillment
- Supply Chain Management
  - Inventory tracking systems
  - Logistics management
- Retail
  - Inventory control and customer insight
  - Auto checkout with reverse logistics
- Security
  - Access control
  - Counterfeiting and Theft control/prevention
- Location Tracking
  - Traffic movement control and parking management
  - Wildlife/Livestock monitoring and tracking

Smart groceries

- Add an RFID tag to all items in the grocery.
- As the cart leaves the store, it passes through an RFID transceiver.
- The cart is rung up in seconds.

Smart cabinet



1. Tagged item is removed from or placed in "Smart Cabinet"
2. "Smart Cabinet" periodically interrogates to assess inventory
3. Server/Database is updated to reflect item's disposition
4. Designated individuals are notified regarding items that need attention (cabinet and shelf location, action required)

Source: **How Stuff Works**

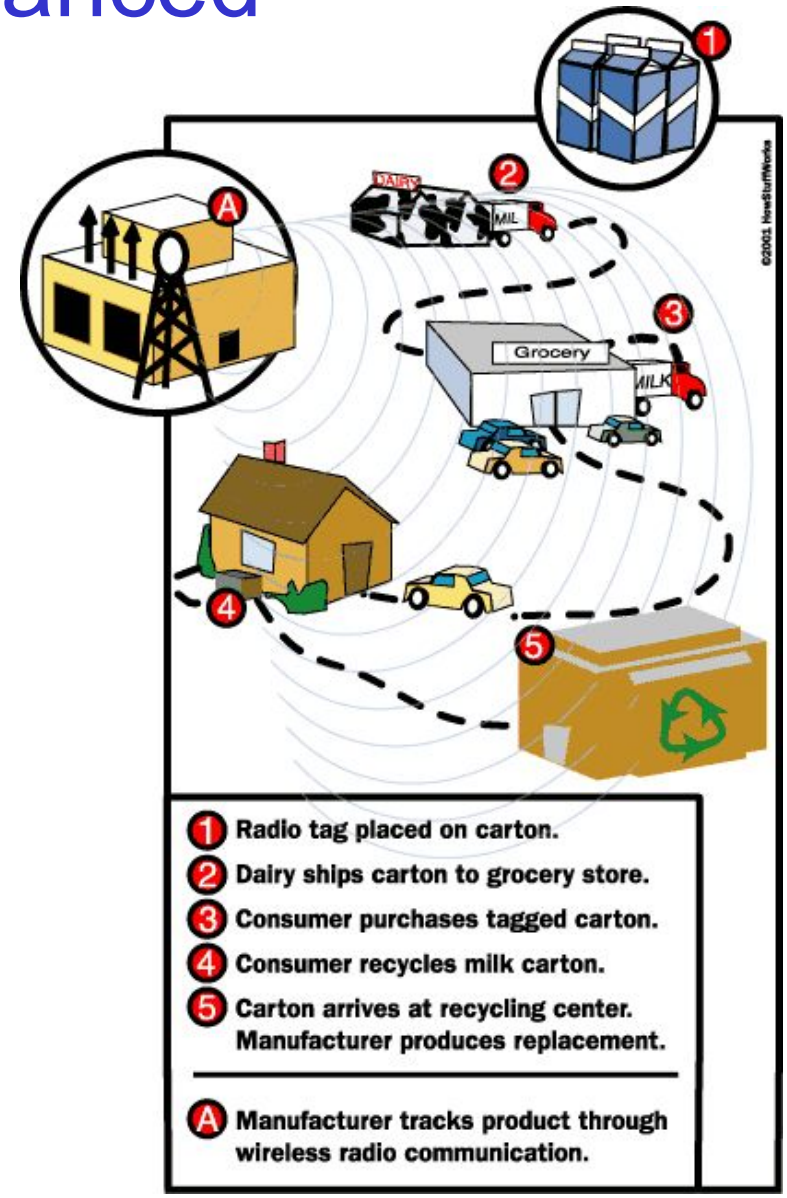
Smart fridge

- 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

Smart groceries enhanced

- Track products through their entire lifetime.



Source: **How Stuff Works**

Some more smart applications

- "Smart" appliances:
  - Closets that advice on style depending on clothes available.
  - Ovens that know recipes to cook pre-packaged food.
- "Smart" products:
  - Clothing, appliances, CDs, etc. tagged for store returns.
- "Smart" paper:
  - Airline tickets that indicate your location in the airport.
- "Smart" currency:
  - Anti-counterfeiting and tracking.

- "Smart" people ??

RFID advantages over bar-codes

- No line of sight required for reading
- Multiple items can be read with a single scan

- Each tag can carry a lot of data (read/write)
- Individual items identified and not just the category

- Passive tags have a virtually unlimited lifetime
- Active tags can be read from great distances

- Can be combined with barcode technology

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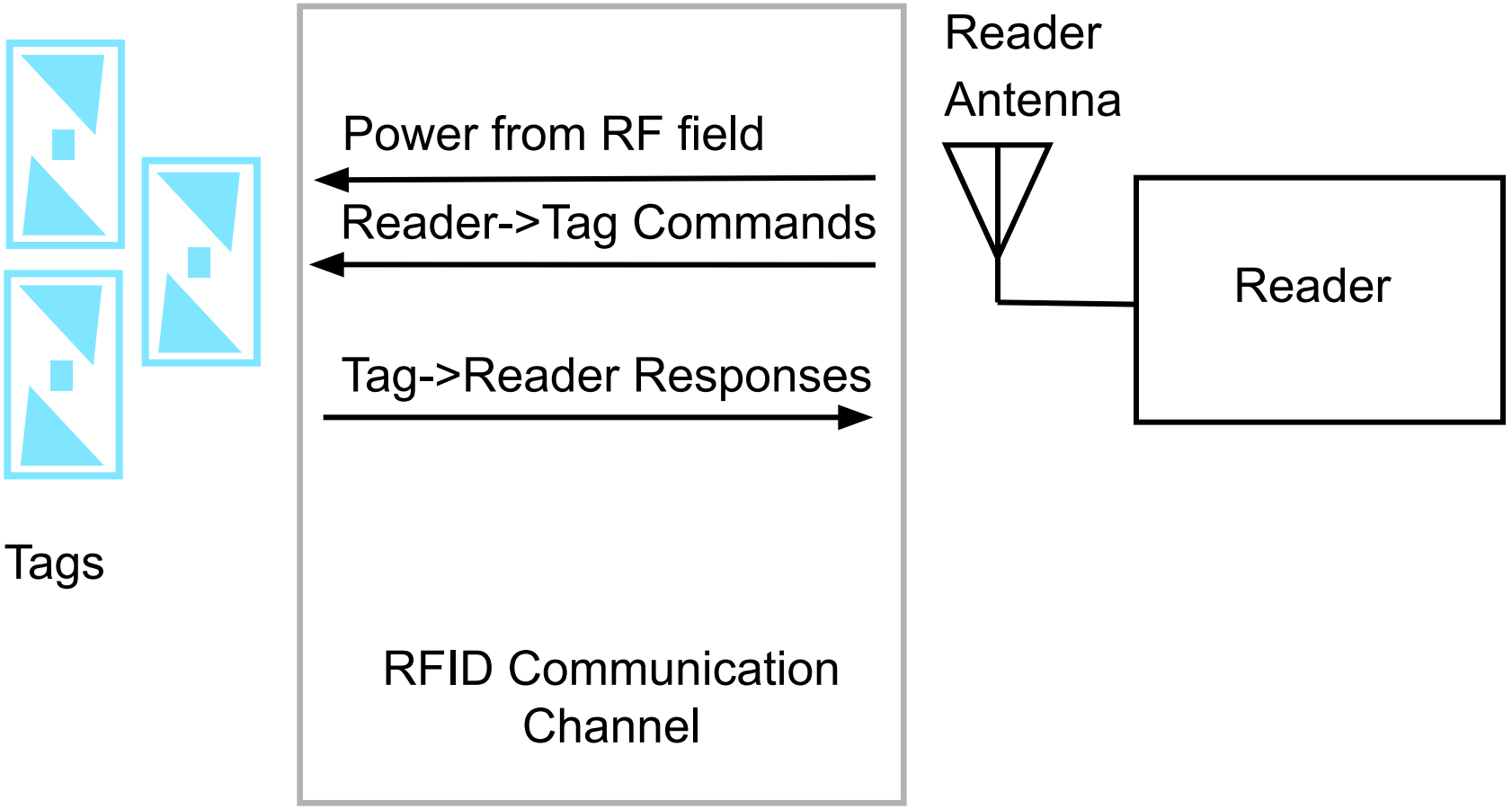
RFID communications



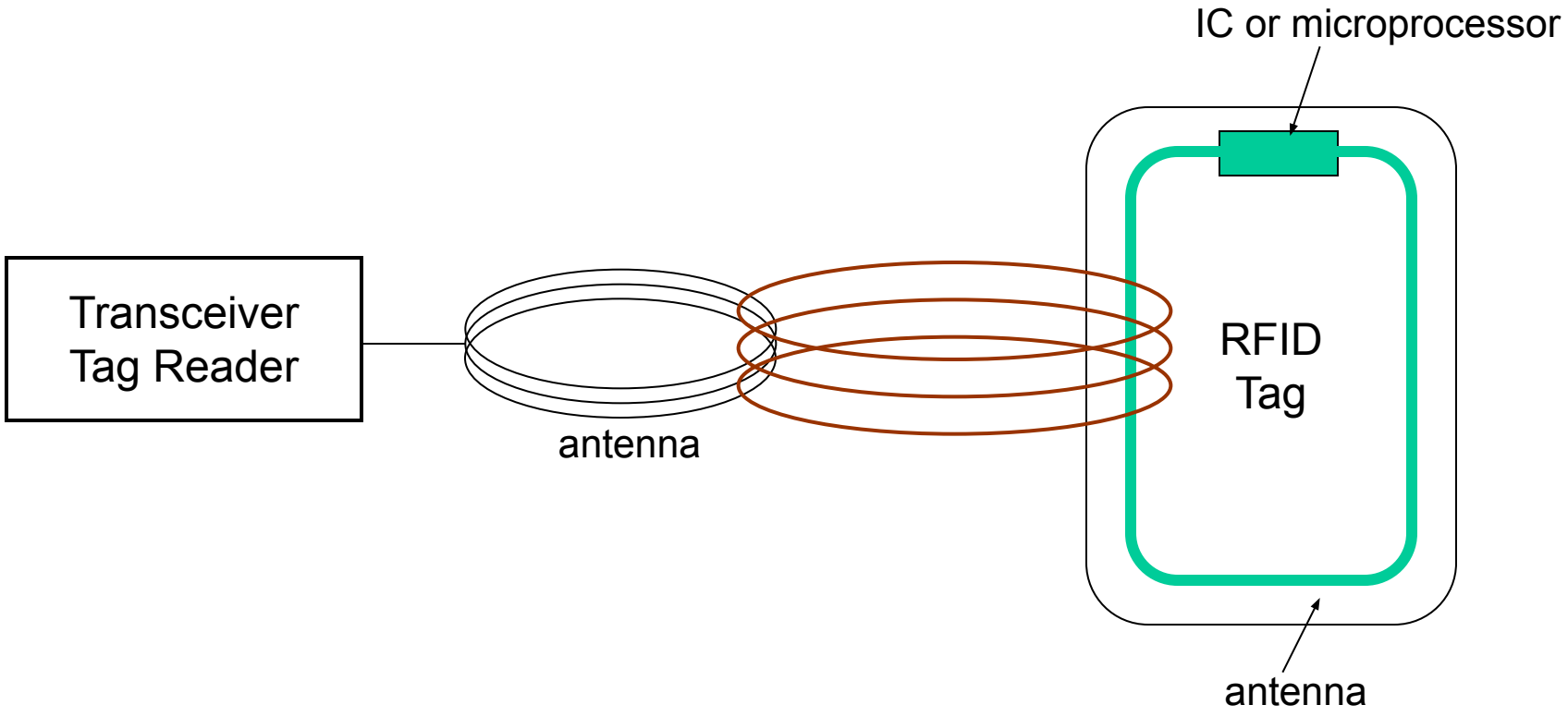
RFID communication

- Host manages Reader(s) and issues Commands

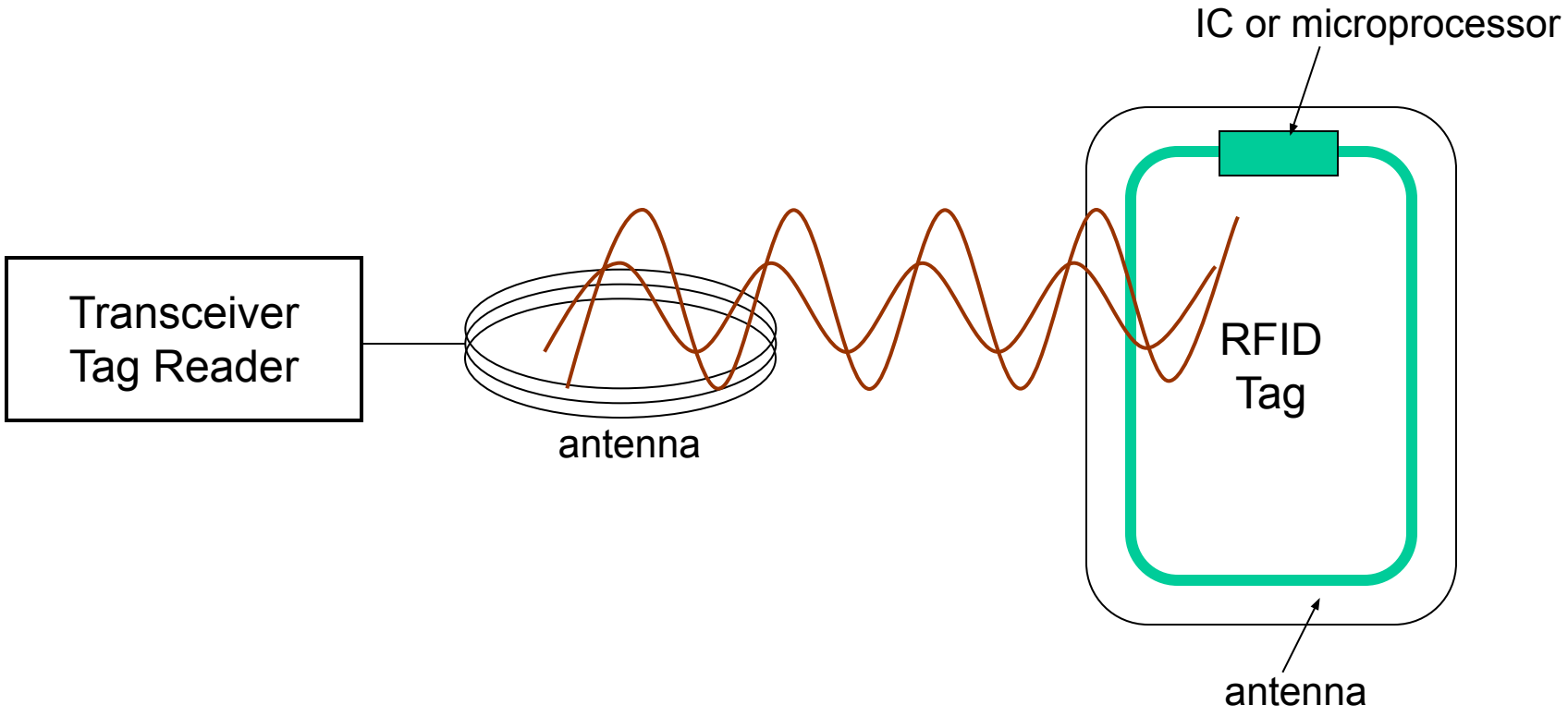
- Reader and tag communicate via RF signal
- Carrier signal generated by the reader
- Carrier signal sent out through the antennas
- Carrier signal hits tag(s)
- Tag receives and modifies carrier signal
  - "sends back" modulated signal (Passive Backscatter – also referred to as "field disturbance device")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

- Reader decodes the data
- Results returned to the host application

Antenna fields: Inductive coupling



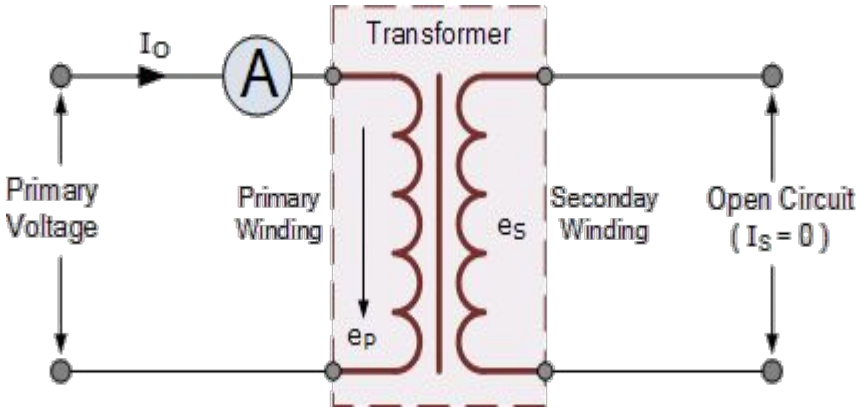
Antenna fields: Propagation coupling

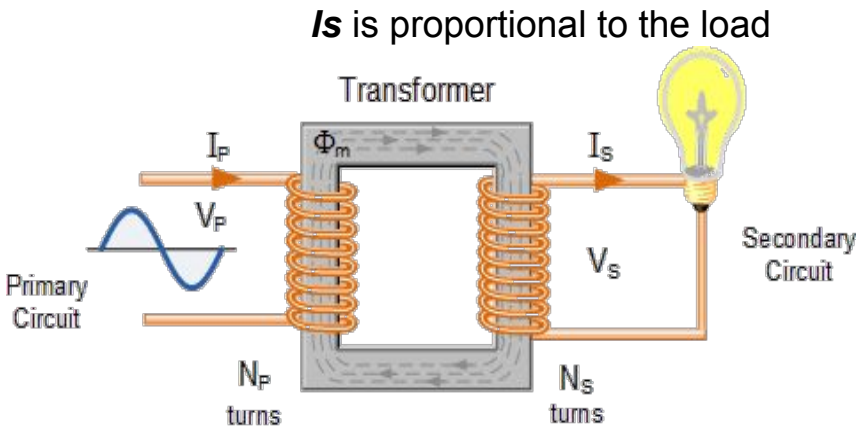


Operational frequencies -
https://rfid4u.com/rfid-frequency/

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

Principle of RFID





- Based on the transformer principle
- Electromagnetic induction
- *Is* induces a voltage back into the primary coil α to its strength.
- is also called as back emf (electromotive force), can be sensed by suitable electronics

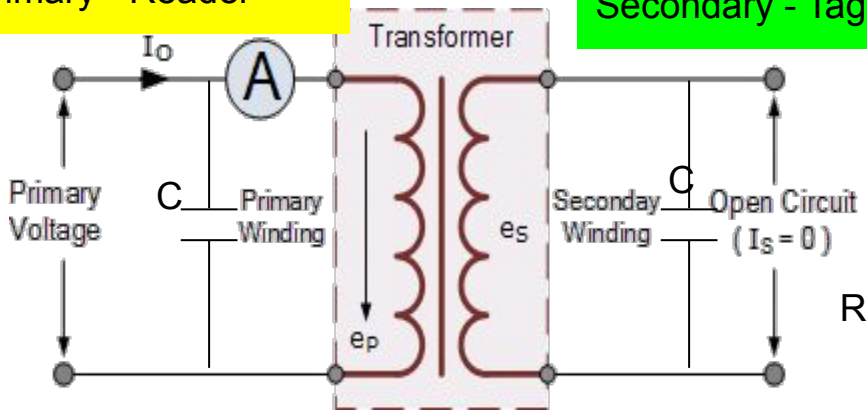
Principle of RFID

Connecting a load - Logic 1

Taking off the load - logic 0

Primary - Reader

Secondary - Tag



If the load resistance is changed the voltage at the primary corresponding to the Resonant Frequency drops sharply

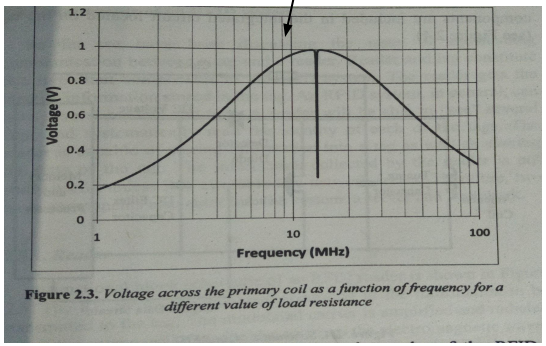
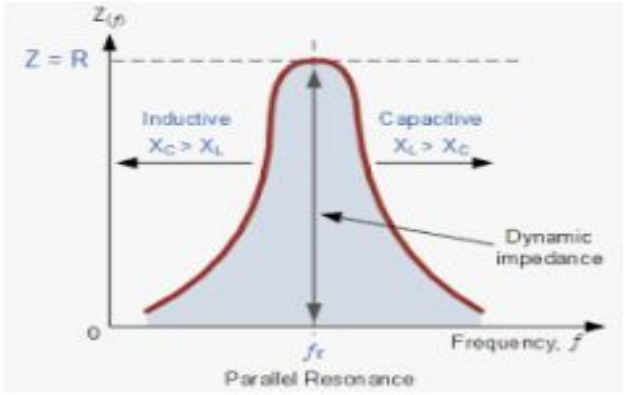
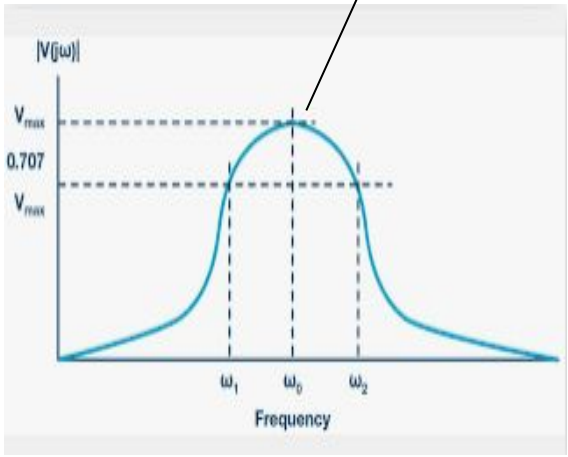


Figure 2.3. *Voltage across the primary coil as a function of frequency for a different value of load resistance*

Resonant Frequency



Parallel RLC Resonant Circuit



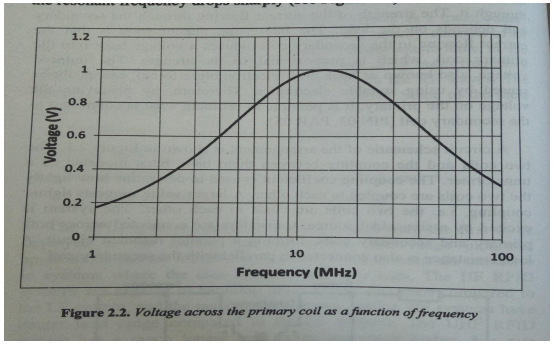


Figure 2.2. *Voltage across the primary coil as a function of frequency*

- The tag can convey any message back to the reader using RF signal.
- this can be achieved by switching in a load to represent a logical state 1 and taking off the load - logic 0.
- using load modulation, a tag is able to communicate with the reader and transfer its identity stored in the in a memory chip.
- A processor reads this information and modulates a load by operating the switch.

RFID Middleware

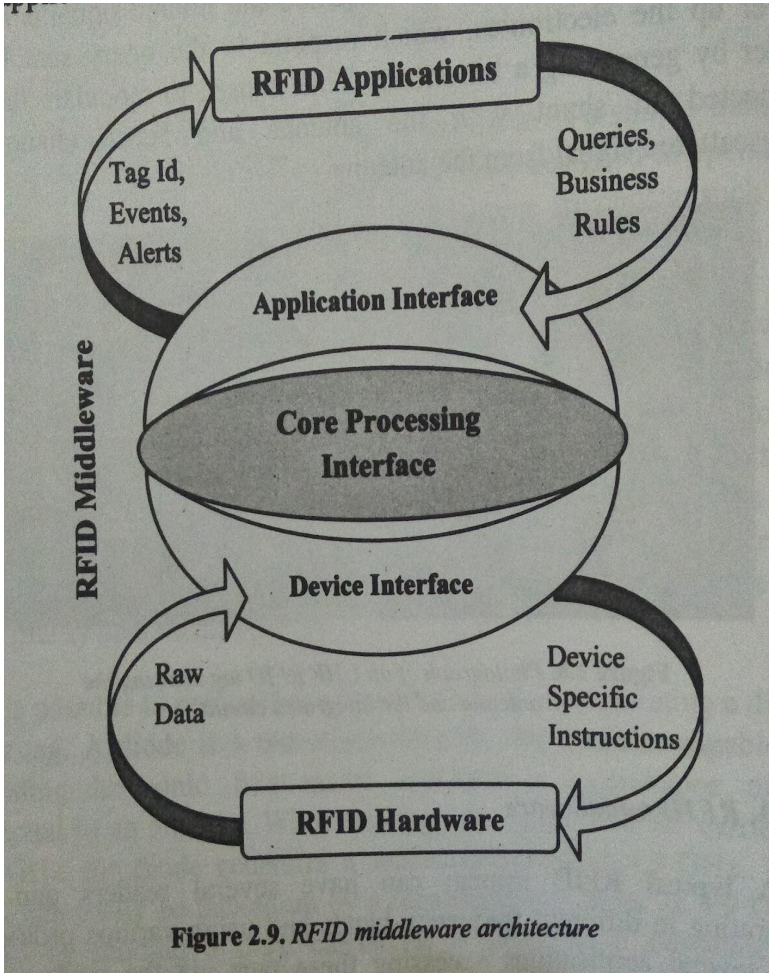


Figure 2.9. *RFID middleware architecture*

- Device Interface - enables RFID system to discover, manage and control readers and tags.
  - different make, distance are few parameter
- acts as a buffer between core processing and RFID hardware
- directing data to the correct reader
- adding new device, configuring them

RFID Middleware

Core processing interface:

1. decision making component
2. manages and manipulates the large amount of raw data before passing it to the API
3. processing is filtering - includes, removal of partial, erroneous, duplicate or redundant data
4. filtering reduces the large amount of data flowing into the API

API: form of a edgeware that is responsible for delivering RFID data to and from enterprise applications.

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
  - sensitive to interference (metal, noise, etc,) **IN CASE OF UHF**
- **Active Tags**
  - Battery powered
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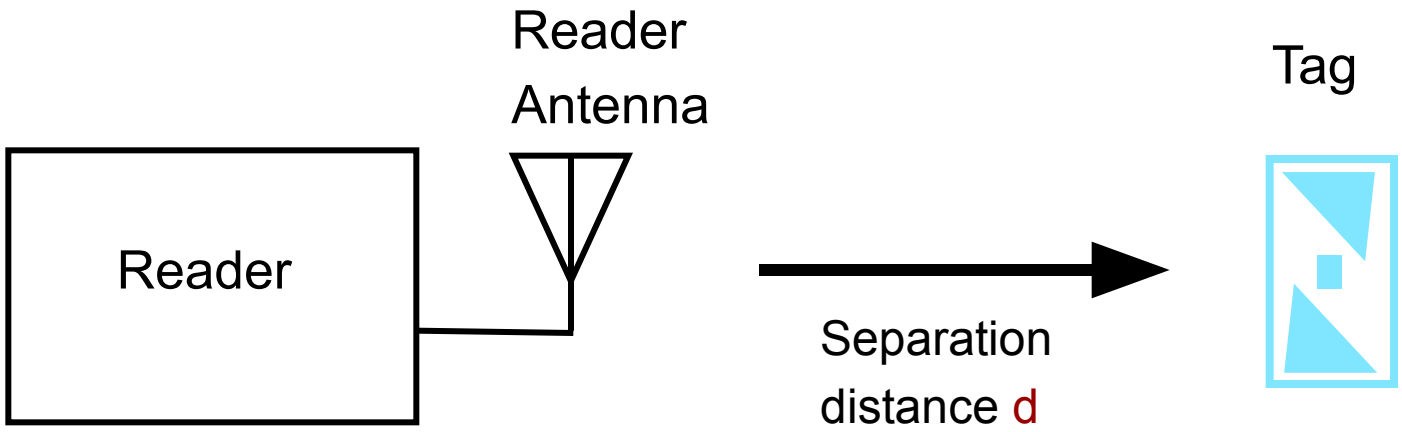
Reader->Tag power transfer



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

A: It depends-

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

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

Limiting factors for passive RFID

1. Reader transmitter power Pr (Gov't. limited)
2. Reader receiver sensitivity Sr
3. Reader antenna gain Gr (Gov't. limited)

4. Tag antenna gain Gt (Size limited)
5. Power required at tag Pt (Silicon process limited)
6. Tag modulator efficiency Et

Implications

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

- 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

Interferences - https://www.atlasrfidstore.com/rfid-insider/improve-rfid-read-range

- Different environmental conditions can affect the performance of UHF RFID systems.

- **UHF RFID tags** are strongly affected by objects containing metal (reflection of RF energy) or water (absorption of RF energy).

- If you don't choose the right tag for the object you wish to tag,
  - you may have greatly reduced read range or
  - you may not be able to read the tag at all.

Tag Placement:

- **Water, metal, fluorescent lighting, large machinery, and competing frequencies (other radio waves) may adversely affect UHF RFID read ranges.**

- The best way to maximize read range is to note the various possible forms of interference and attempt to mitigate that interference by testing, making changes to your system, and retesting.