CHAPTER 1

Overview of RFID Technologies

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About the author

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Electrical sensors

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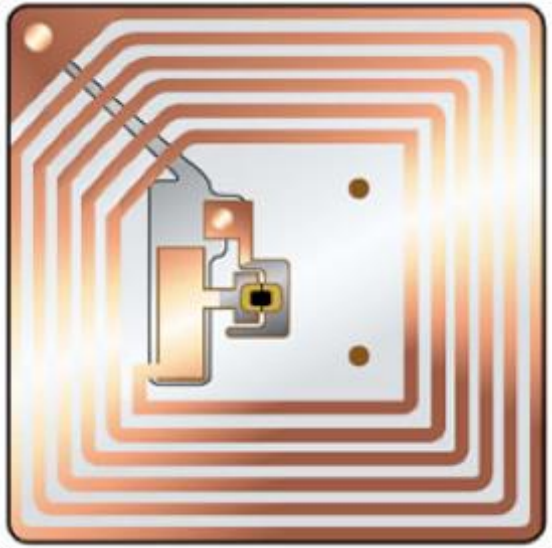
- Chair for electrical measurements

2001-2002 DAAD scholarship at the Lehrstuhl für Agrarsystemtechnik, TU München in Freising-Weihenstephan, beim prof. Hermann Auernhammer

2006-2016 BioSense Centre of the FTN, now BioSense Institute

Overview

- RFID technology overview
- Passive tag RFID technology
  - Inverse RF tags
- Active tag RFID technology
- Sensors based on RFID
  - Applications in agriculture
  - Batteryless RFID sensors



- *** - presentation of some original research

RFID technology overview

- Two parts: tags and interrogators

- Tags (labels) attached to objects to identify them
  - Substrate
  - Microchip (memory, processing, modulation, demodulation)
  - Antenna

- Active (periodically transmit ID signal)
- Battery-assisted passive (transmit only when invoked)
- Passive (harvest or modulate energy)

RFID technology overview

- Interrogators send signals to tags and read response

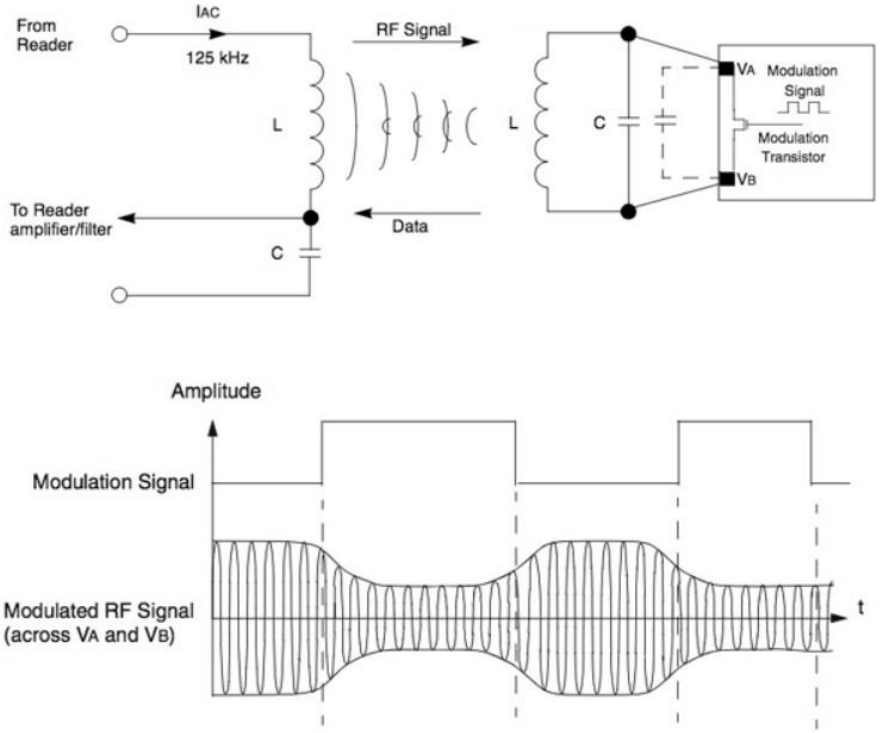
- Active Reader Passive Tag (ARPT) – “passive tag RFID”

- Passive Reader Active Tag (PRAT)
- Active Reader Active Tag (ARAT)
- Battery-Assisted Passive (BAP)

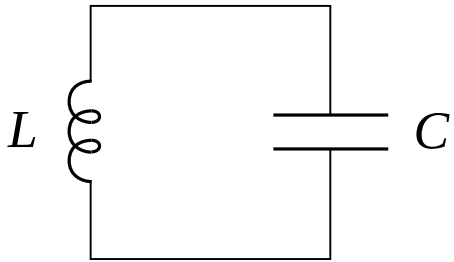
} – “active tag RFID”

- BAP and ARAT are more similar to ARPT then to PRAT

Interrogation and response



Important remark



$$f = \frac{1}{2\pi\sqrt{LC}}$$

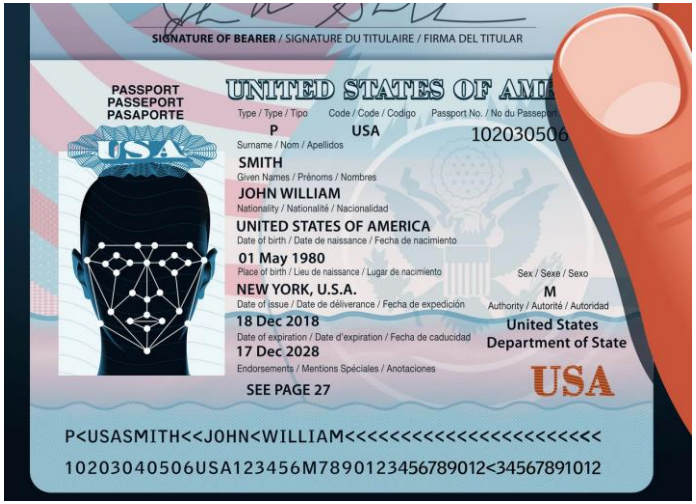
- Size matters!
- Smaller tags – smaller *C* and *L* – operate on higher frequencies

RFID technology overview

- Low-frequency (120–150 kHz)
  - Unregulated
  - Range <10 cm
  - Low data rates, <1 kbits/s
  - Animal identification, factory data collection
  - Tag price: 1-10 €

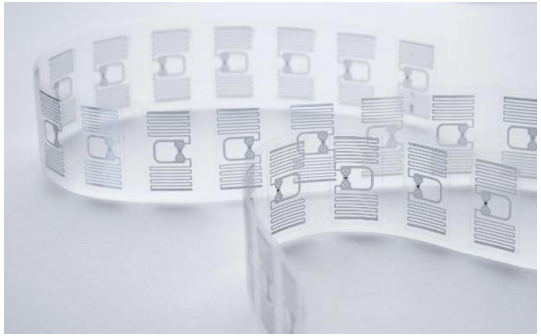
RFID technology overview

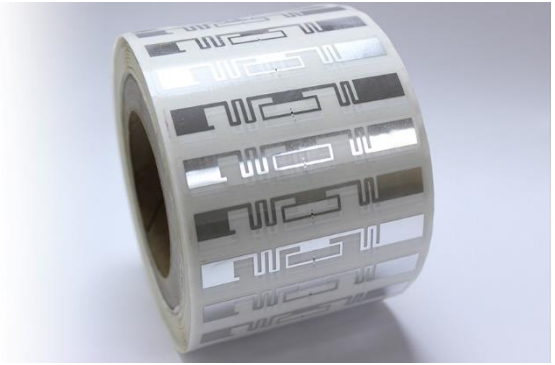
- High-frequency (13.56 MHz)
  - ISM band
  - Range 0.1–1.5 m
  - Low data rates, 25 kbits/s
  - Smart cards, memory cards
  - Tag price: 0.05-50 €



RFID technology overview

- Ultra-high-frequency (865–868 MHz EU 902–928 MHz North America)
  - ISM band
  - Range 1–12 m
  - Moderate data rates, 100 kbits/s
  - Smart cards, memory cards, anti theft
  - Tag price: 5-10 €
- Most passive tags are of this type





RFID technology overview

- Microwave (2450–5800 MHz and 3.1–10 GHz)
  - ISM band
  - 2450–5800 MHz: 1–2 m - 802.11 WLAN, Bluetooth
  - 3.1–10 GHz up to 200 m
  - High data rates, 10 Mbits/s
  - Tag price: 25 €
- Most active tags are of this type

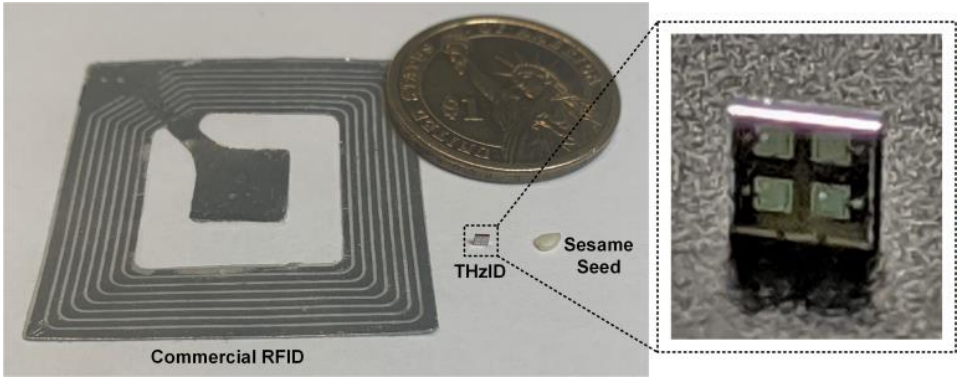
RFID technology overview

- mm-wave (2.45 and 5.8 GHz)
  - ISM band
  - 10–200 m (with use of retro directive backscatter)
  - High data rates, 50+ Mbits/s
  - Miniaturization, IoT, Implants
  - Tag price: 50+ €

Source: Wikipedia

TFID – 2020

- MIT produced 1.6 mm^2 THz tag
- Actually it is 260 GHz
- No external antenna
- 2×2 antenna array backscatter communication
- Range: 5 cm



Ruonan, Han et al. (2021). "MOS THz-ID: A 1.6-mm² Package-Less Identification Tag Using Asymmetric Cryptography and 260-GHz Far-Field Backscatter Communication". 2021 IEEE International Solid- State Circuits Conference.

Passive RFID technology

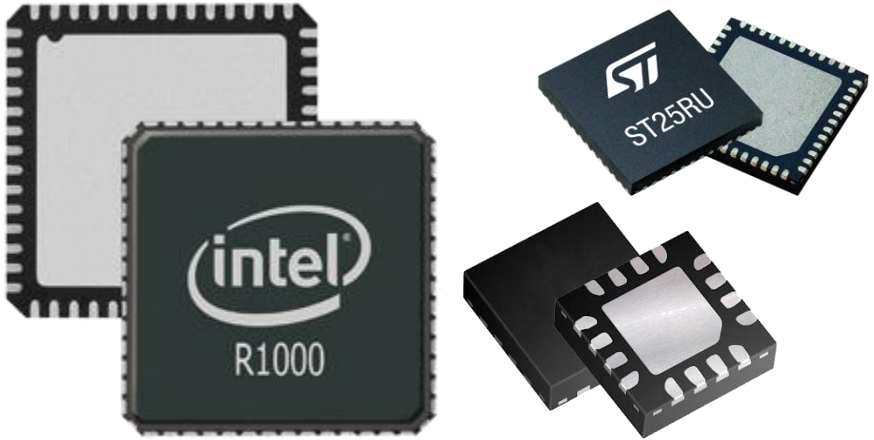
Analogue

- Antenna only – RF tags (no ID)

Digital

- ID and other data sent – requires a chip
- Data imprinted into signal via modulation

Memory onboard RFID tags

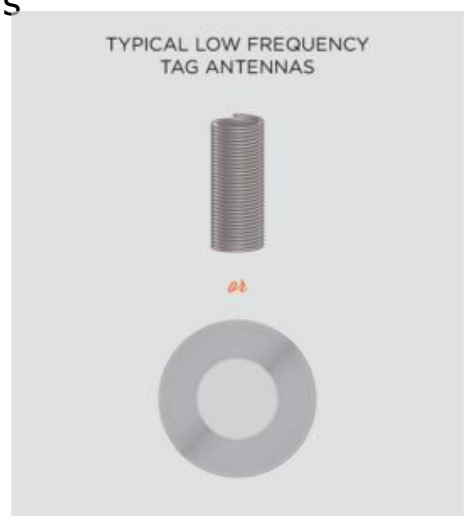


- Comprise 4 segments:
  - TID (Tag identifier)
  - EPC (Electronic product code)
  - USER
  - RESERVED
- 32 bits to 2 kB
- Read only – unique serial number written during manufacturing
- Write once read many (WORM) – User can setup memory content once
- Read / write (R/W) – Unique ID is usually non-erasable, but secondary information can be rewritten many times

  (WE NEED THESE FOR SENSORS)

Antenna type 1

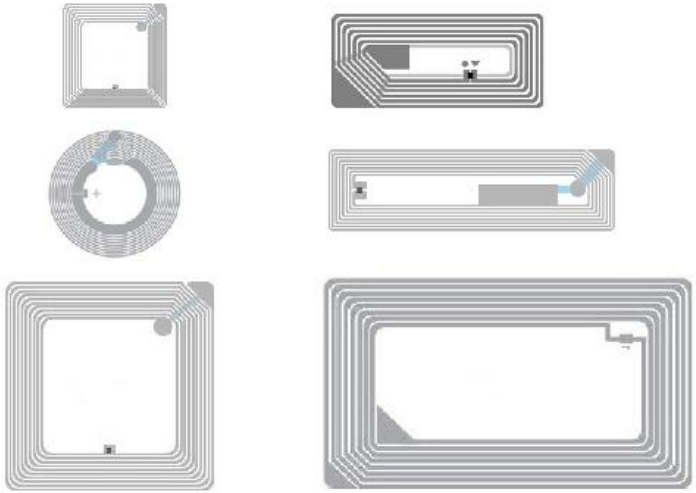
- Low-frequency (124 kHz – 135 kHz)
- Inductive coupling – proximity field for power
- Rounded winding
- Used for passive tags



Antenna type 2

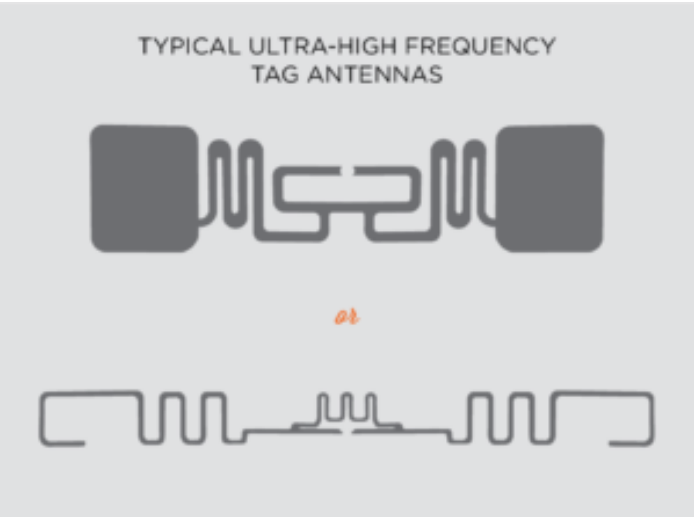
- High-frequency (13.56 MHz)
- Inductive coupling – proximity field to gain power
- Round or square windings
- Used for passive tags

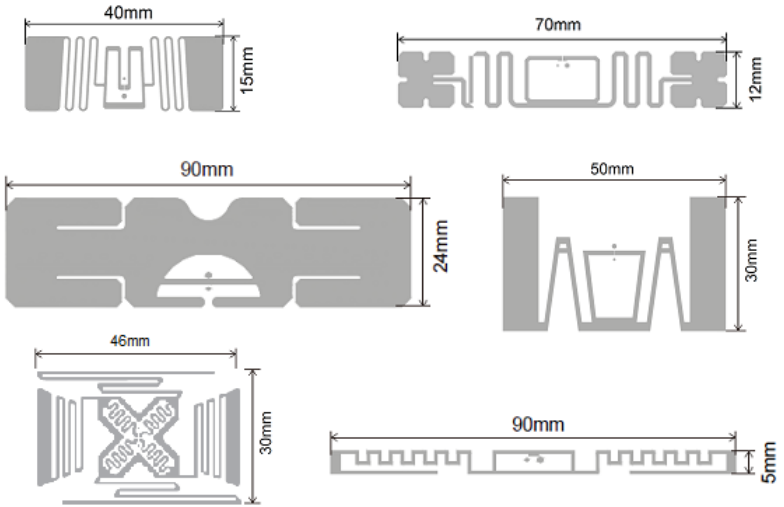
- In detection systems – destruction of the capacitor deactivates the tag



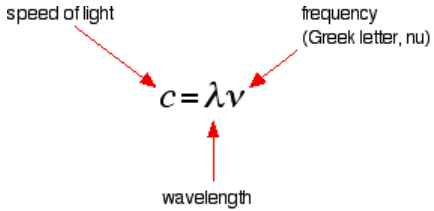
Antena type 3

- UHF (860 MHz – 960 MHz)
- Backscatter
- Dipole antenna





UHF Dipolne RFID tag antene



Half-Dipole

- Length equal to half wavelength
- Between 16 and 17 cm
- Increased resistance

Modified Half-Dipole

- Length 9.2 cm
- Negative reactance requires modifications (extra inductance or capacitance)

Short Dipole

- Length 1/10 of the wavelength
- Even more compensation required

Antenna modifications – Fat tag

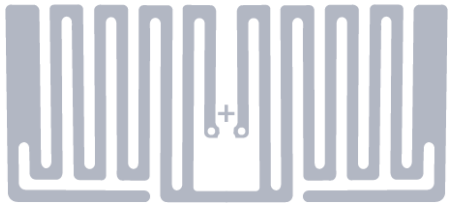
- Massive quantity of metal
- Fat conduction lines
- Substrate used as dielectric
- Huge capacitance, low inductance

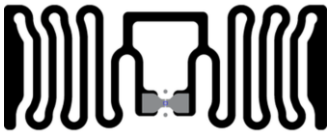
Antenna modifications – Tip loaded

- Similar to “Fat” dipol, but only at the ends
- Added menders in the middle to increase inductivity (reduce frequency)

Antenna modifications – Meander antennas

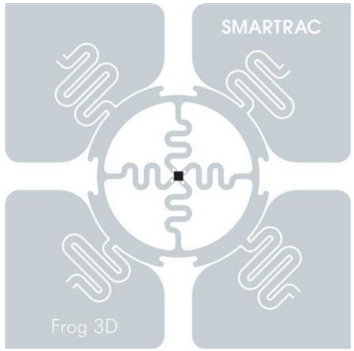
- Using meander to squeeze in as much wire as possible
- Meanders reduce frequency
- Number of meanders is more important then their shape (explosion of patents)



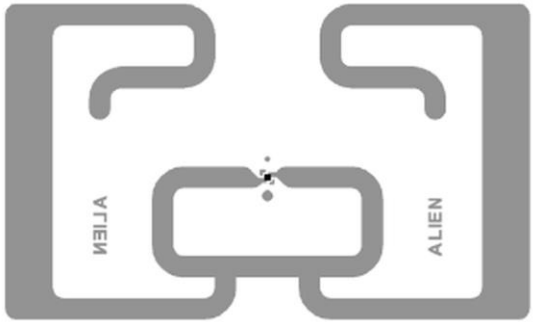


Some non-typical antenna shapes

- “Smartrack Frog”



- “Alein spider”

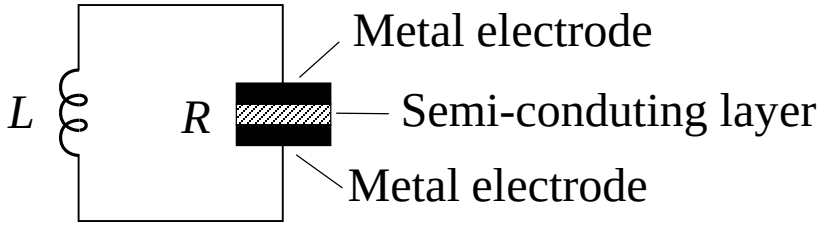


Speaking of non-typical… Iverse RF tags

- Normal scenario of operation: RF tag is active until no longer needed (destroyed)
- The challenge: How to make an RF tag inactive until you need to activate it
- Additional challenge: Can you make it recurrent?

Inverse RFID –concept #1

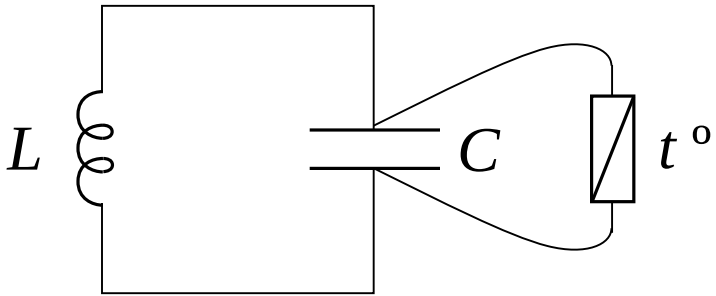
- Create the capacitor from a conductor by burning it with a strong current



- Issue: reliability – destructive phenomena are difficult to control

Inverse RFID –concept #2

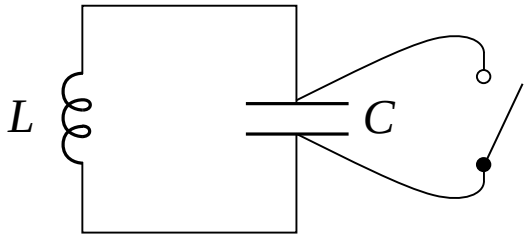
- Bridge the capacitor with a thermo-fuse

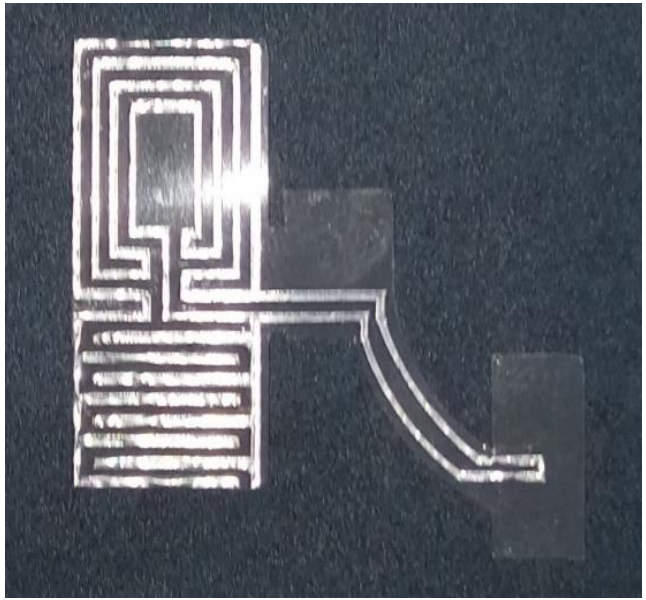


- Issue: slow

Inverse RFID –concept #2

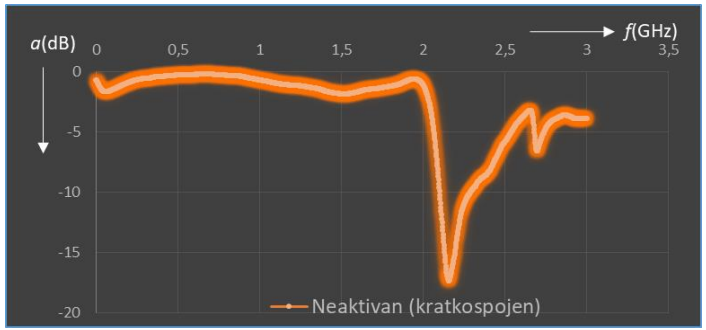
- Bridge the capacitor with a contact switch

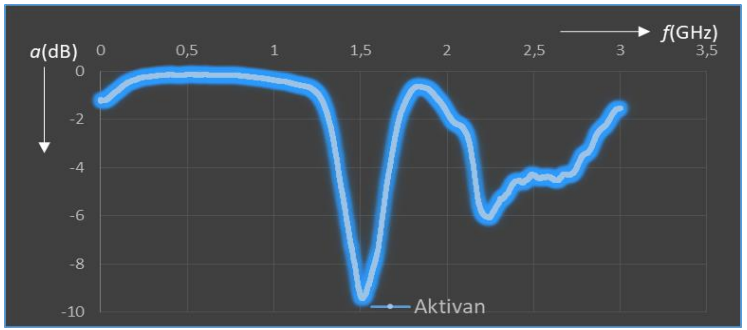




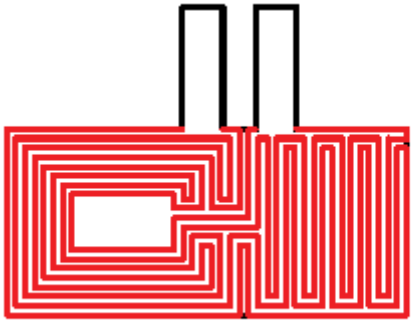
- Comb capacitor – single side printing
- Patented solution in 2021

Testing and improving





- Later made reversible



Active RFID technology

- Use energy from battery to constantly beacon its status
- Can be useful in some applications
- Energy very demanding
- Topic for another day

Sensors based on RFID

- Analogue – use physical quantity to modify frequency response (require a spectral analyzer)

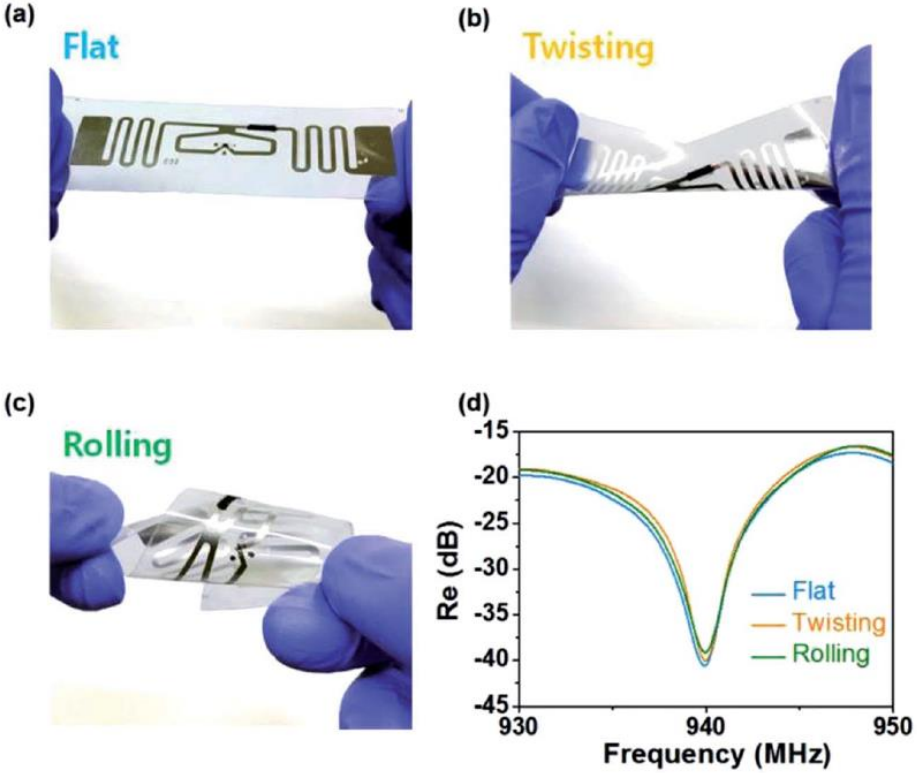
- Digital – have A/D converters, modify memory content
  - Passive – only one memory value
  - Active – measurement history

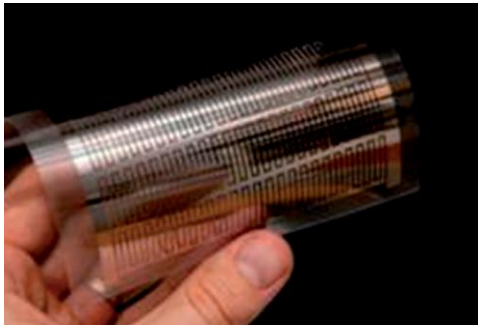
Analogue sensors

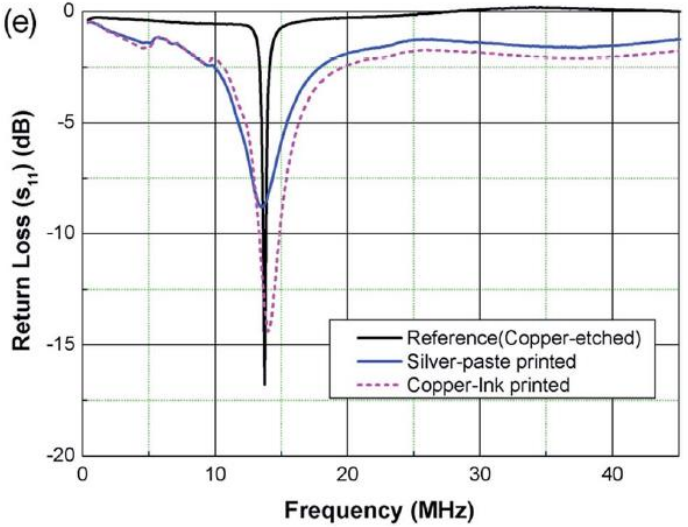
- UHF dipole antenna is made of materials that change ε_r or μ_r when exposed to some physical quantity (temperature, humidity, pressure, concentration of some chemical compound etc.)
  - Resonant frequency is changing

- Modification of resistance also possible – dampening of oscillations
  - Resonant frequency the same, but with smaller or higher peak
  - Best technology carbon nano-tubes
  - Issue of detector proximity

Example characteristics







Digital sensors

- Response in a digital format – invariant to geometry
- Complex chip structure
- The smaller – the more efficient
- 32 bits – ID + one value
- 2 kB – ID + series of values

Applications

RFID Sensors

Healthcare	Food Quality	Agriculture	Automotive	Structural Health Monitoring	Space	Wereable & Implantable	Localization & activity monitoring
							
▪ Body temperature monitoring ▪ Blood glucose monitoring ▪ Activity and gesture sensing ▪ Sleep disorders	▪ Meat, fish, vegetable freshness monitoring ▪ Expiration date monitoring	▪ Soil moisture monitoring ▪ Precision irrigation ▪ Agro-food supply chain monitoring ▪ Vineyard monitoring ▪ Cold chain monitoring	▪ Automatic production monitoring ▪ Security of infants ▪ Tire pressure sensors ▪ Vehicles road distance	▪ Metal and concrete crack monitoring ▪ Structural damage detection ▪ Monitoring of structural movements ▪ Corrosion monitoring	▪ Temperature monitoring ▪ CO_2 monitoring ▪ Battery level monitoring	▪ human movements ▪ Heart & breath frequency monitoring ▪ monitoring body areas and vascular prosthesis	▪ human movements ▪ Heart & breath frequency monitoring ▪ monitoring body areas and vascular prosthesis

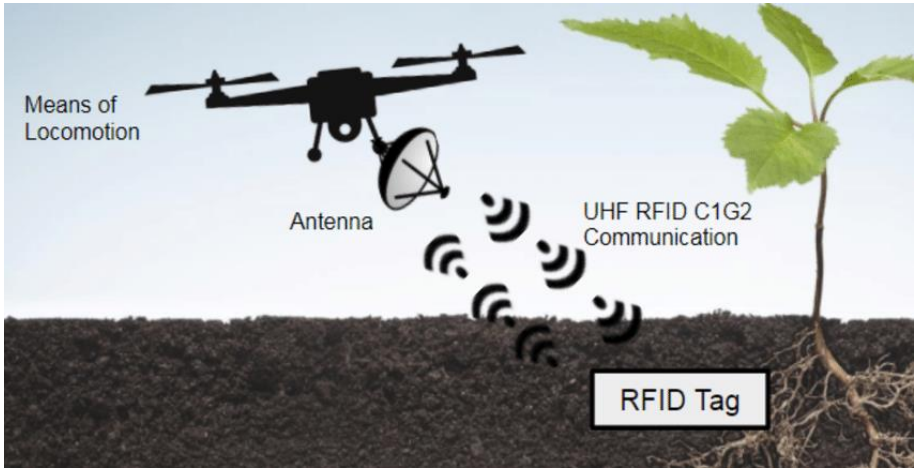
Applications in agriculture

- Animal tracking on farms
- Product traceability (cold chain, food supply, etc.)
- Precision irrigation
- Plant health and nutrition monitoring (for multi-seasonal plants)

- New applications include drones and robots for sensor readouts

Using robots to harvest information from RFID tags

- The idea was first introduced in storage industry



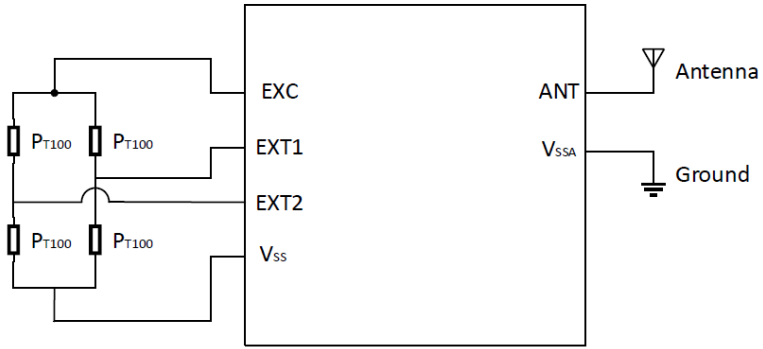
Using robots to harvest information from RFID tags

- Find the lost cargo in storage = find the lost sheep

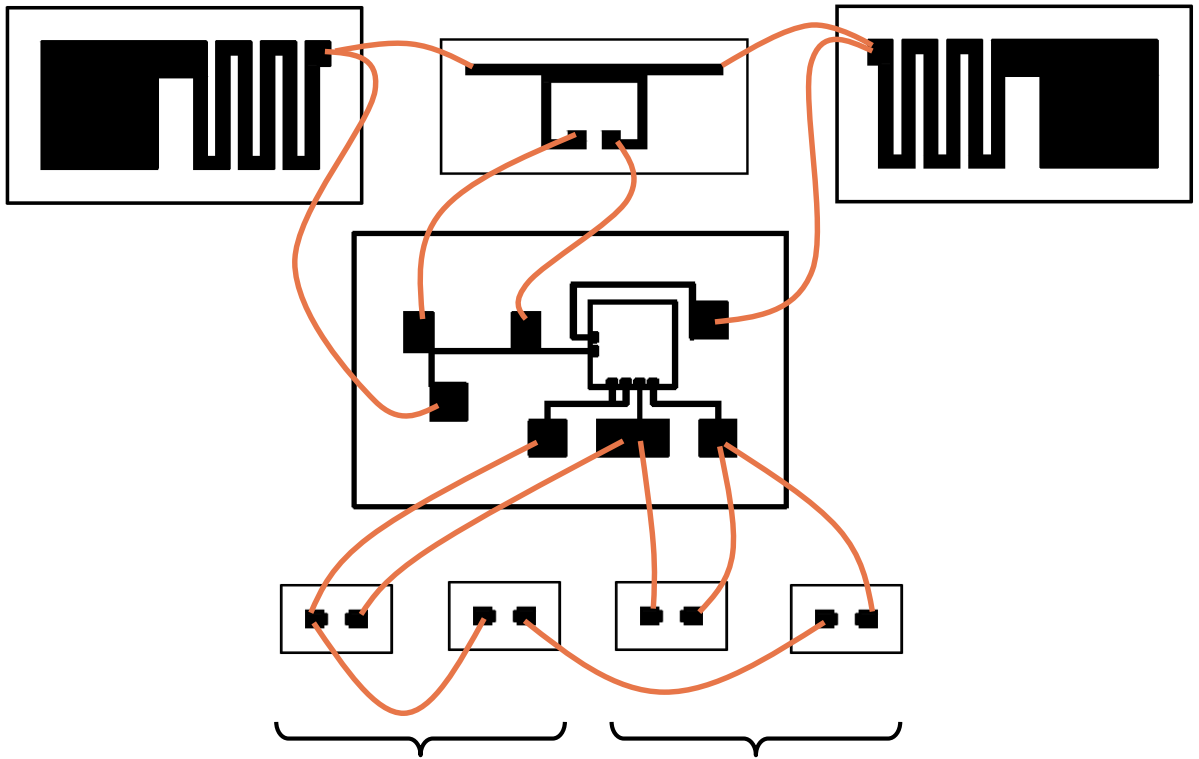
Any ideas for further applications?

Batteryless RFID sensors

- Differential leaf temperature measurements using baterryless passive RFID
- 0,5 ºC resolution
- Relative measurements
- Using multiplexing to add more sensors (one sensor per readout)



Modular sensor design



Thank you for your attention

https://smart4all-project.eu/

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