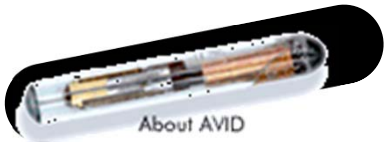
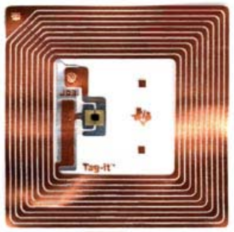
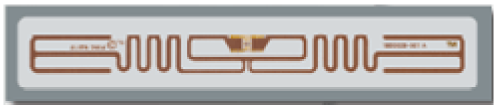
Identification Radiofréquence
Radiofrequency Identification

Pr. Tan Phu VUONG







Outline :

Introduction

Principles

Characterization and modeling of RFID Chips

Design of RFID tag antennas

Conclusion and perspectives

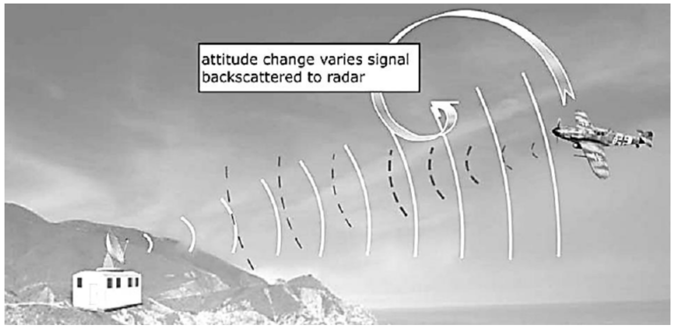
Introduction

1939-1945, during the second world war

• **First use of passive backscattering** by the German air force to identify aircraft using a ingenious maneuver

When the Luftwaffe pilots received indication that they were being illuminated by their radar, they would roll in order to change the backscattered signal reflected from their airplanes.

- The consequent modulation of the blips on the radar screen allowed the German radar operators to identify these blips as friendly targets.



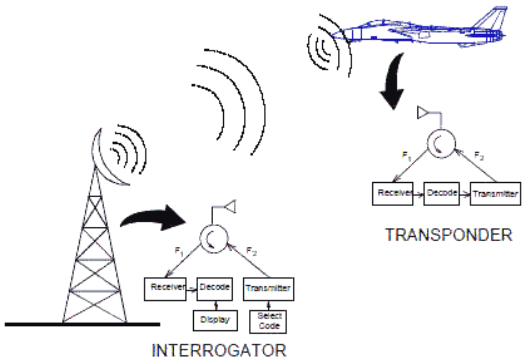
Variation of radar cross section is involved in this technique.

Introduction

- **First apparition of an active RFID system** to identify friends and foes (IFF).

The **US and Britain use IFF systems using an active beacon** on the airplane (the XAE and Mark I) in 1937/1938.

The **Mark III system**, is **widely used** by the Britain, the United States, and the Soviet Union **during the war**, used a mechanically tunable receiver and transmitter with **six possible identifying codes.**



Introduction

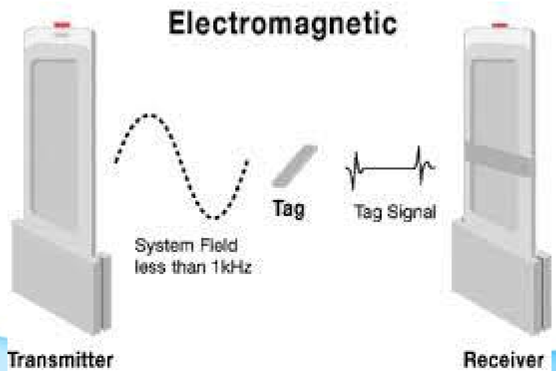
1946, after the war in soviet union

- The “thing” made by Léon Theremin : The first apparition of a passive RFID system.
- In 1946, a two foot wooden replica of the Great Seal of the United States is offered to Ambassador Averell Harriman (Moscow).
- In 1952, they discovered that the seal contained a microphone and a resonant cavity which could be stimulated from an outside radio signal.

Introduction

Evolution of the RFID technology in the 20th century

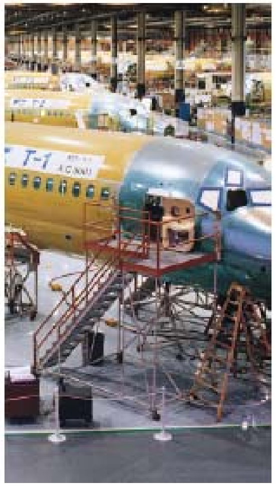
- 1939-1945: First concepts of passive backscattering and IFF
- 1946: The “thing” by Léon Theremin
- 1948: Harry Stockman published "Communication by Means of Reflected Power.
- 1960s: First commercial applications. Companies Sensormatic, Checkpoint and Knogo develop Electronic Article Surveillance (EAS) also called “1-bit tags”.
- 1970s: Patents are flourishing. Academic institutions, government laboratories companies and independent researchers are all working to develop RFID technology (toll collection, animal and vehicle tracking,

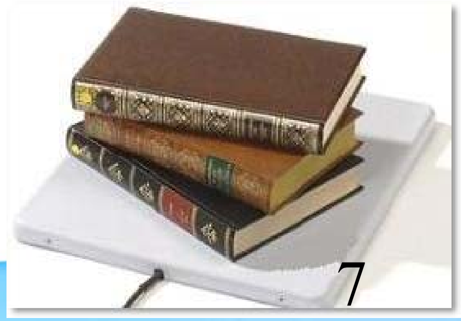


Introduction

Evolution of the RFID technology in the 20th century

- 1980s: Commercial Expansion. RFID technology is fully implemented in transportation systems, animal tagging, and business applications.
- 1990s: RFID uses are so widespread that standards begin to emerge.

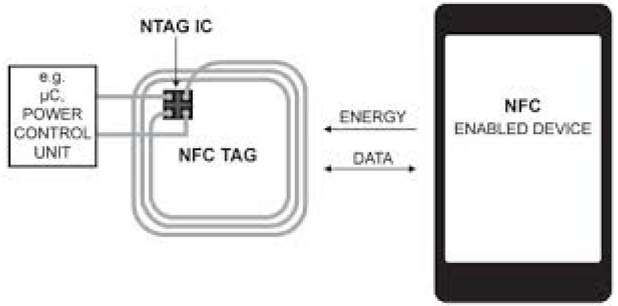


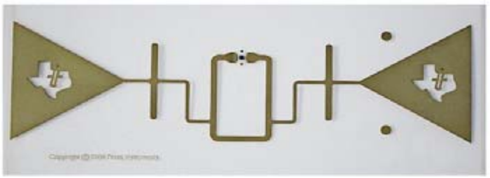


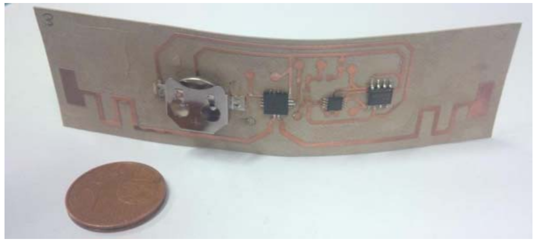
Introduction

Evolution of the RFID technology in the 20th century

- 2000s: Cost, performance, authentication and power consumption improvement.
- Since 2010: emergence of RFID sensors.





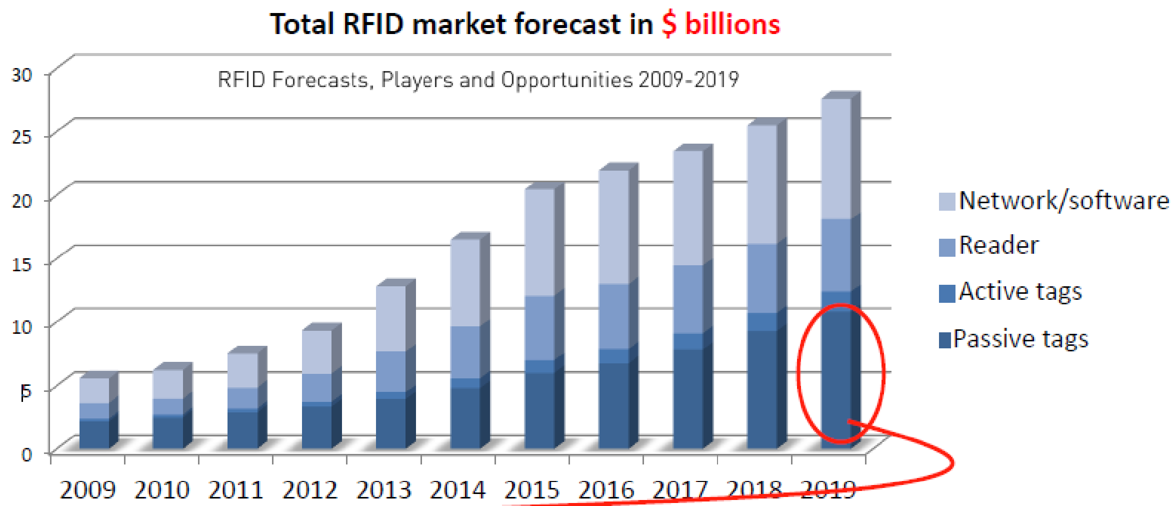


IMEP-LAHC

The market

Socio-economic positioning

- RFID Forecasts, Players and opportunities 2009-2019



Electronics on flexible substrate (2006 - ...)

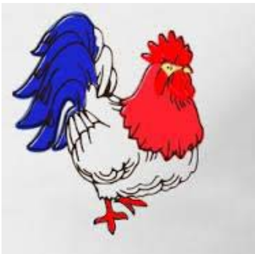
TAGEOS

Developpement of novel realization process of RFID tags on paper

Market shares by applications

- The global market for RFID 2010-2020

R&D



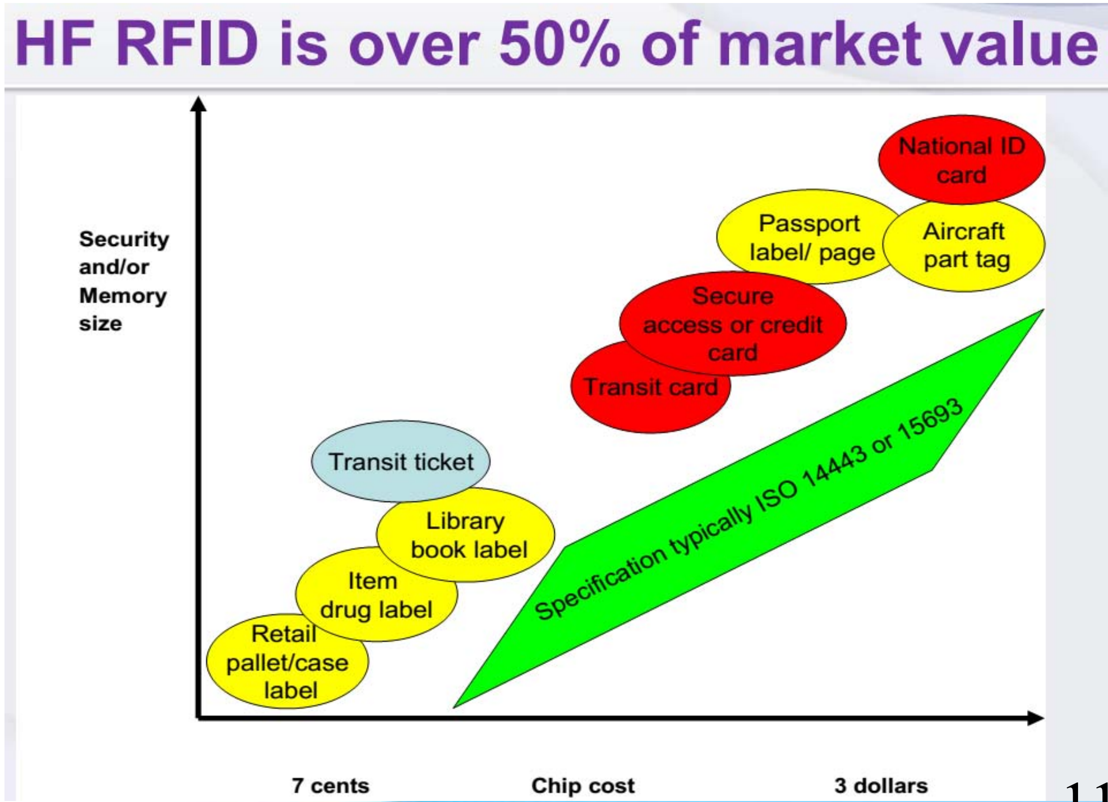
RFID is $5.6 billion in 2010 but fragmented

Over 1000 suppliers: top ten have half the business
Largest include these (double counting in the sales)
Gemplus –RFID cards & passports $500 million+
NXP – chips $500 million
ACS – Non stop road tolling and transport card system integrators $500 million
Assa Abloy – secure access, livestock$400 million
Savi – military & heavy logistics systems integration $200 million
Smartrac - Passport inlays $150 million
Allflex – livestock tags $110 million

The market

Market shares by applications

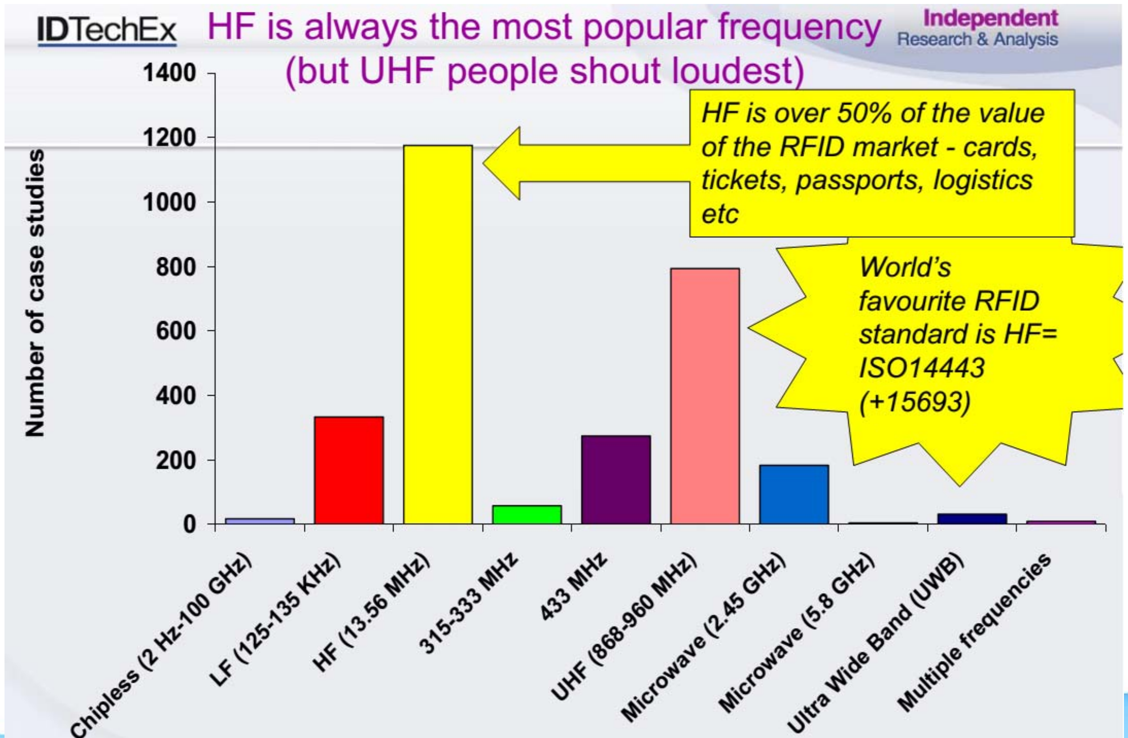
- The global market for RFID 2010-2020



The market

Market shares by applications

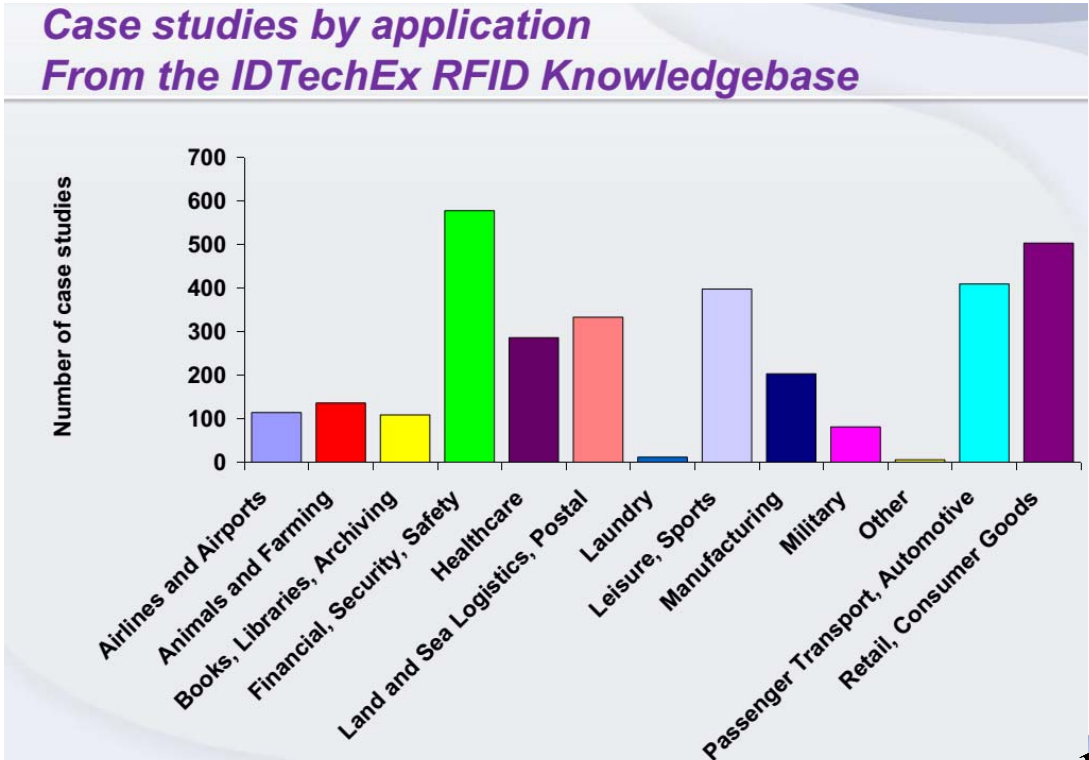
- The global market for RFID 2010-2020



The market

Market shares by applications

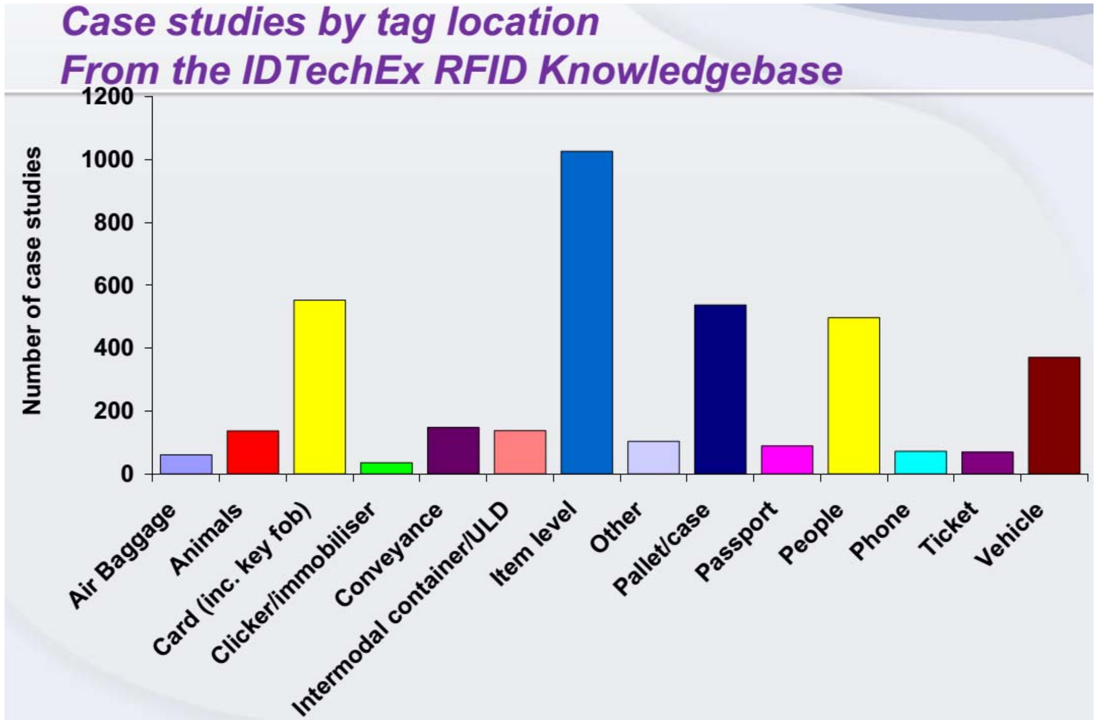
- The global market for RFID 2010-2020



The market

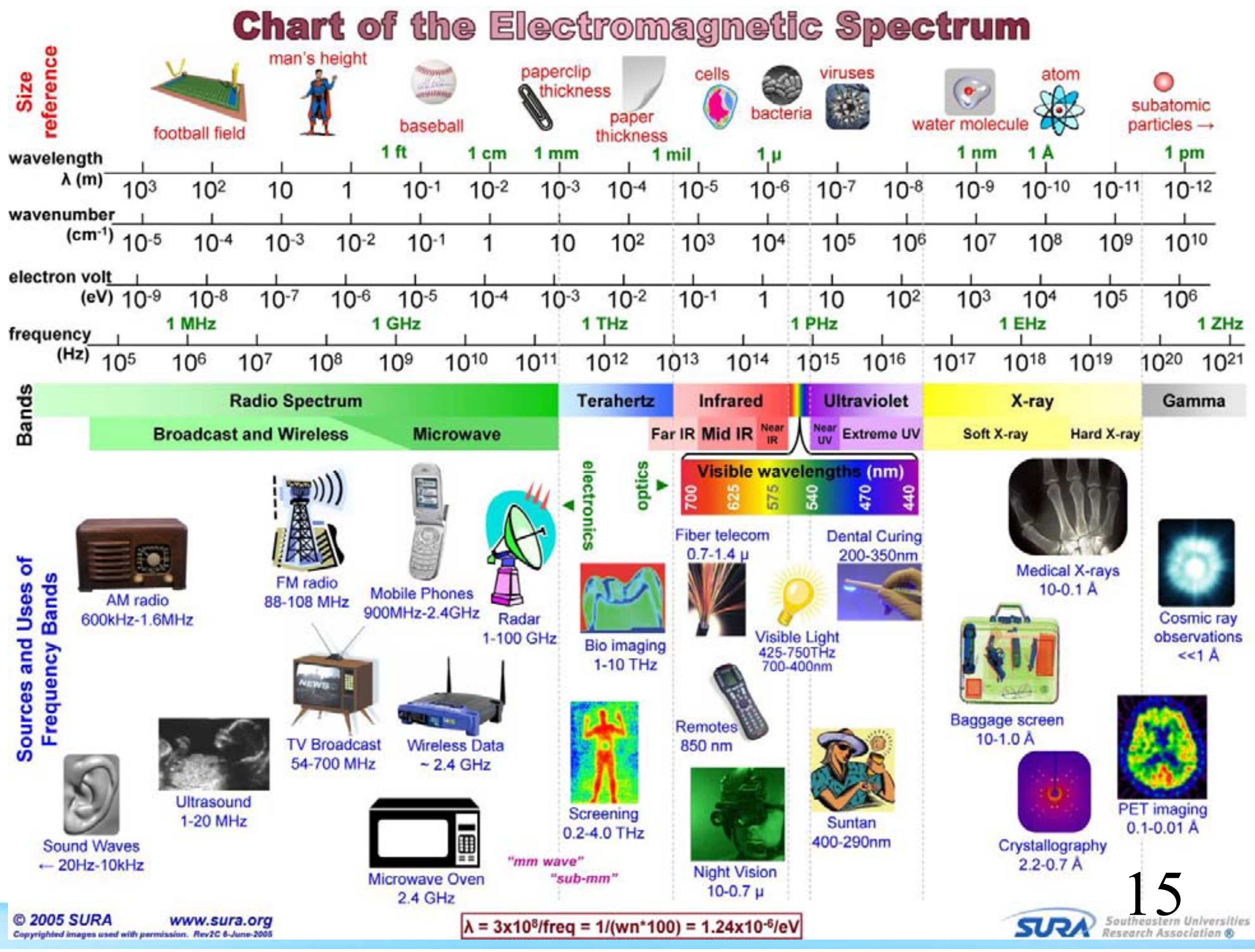
Market shares by applications

- The global market for RFID 2010-2020



The technologies

- **The electromagnetic spectrum**



The technologies

- **Tentative of classification**

Categories

- **Passive**
- **Semi-Passive**
- **Active**
- **Semi-Active**

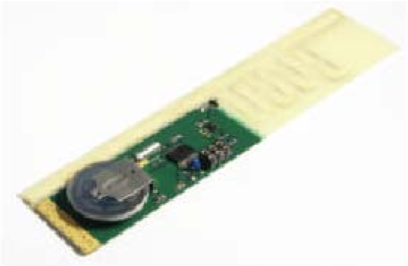
Frequency

- **Low**
- **High**
- **Very High**
- **Ultra High**

– **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

- **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)

IMEP-LAHC

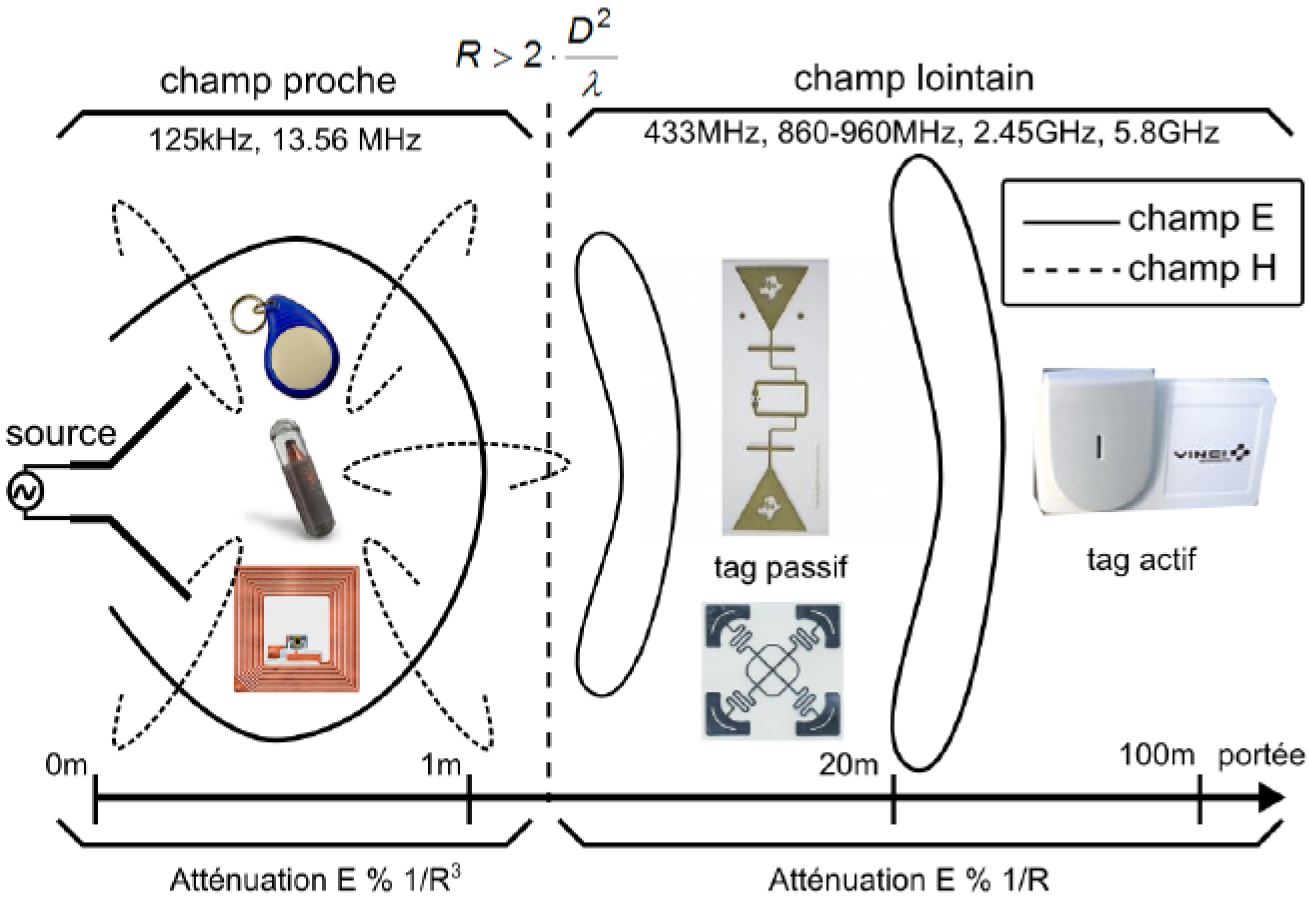
The technologies

- **Tentative of classification**

	Frequency	Distance	Example Application
LF	125khz	Few cm	Auto-Immobilizer
HF	13.56Mhz	1m	Building Access
UHF	900Mhz	~7m	Supply Chain
µwave	2.4Ghz	10m	Traffic Toll

The technologies

- **Tentative of classification**



Introduction

What is **RFID** ?

What is **passive UHF RFID** ?

Radio Frequency Identification:

- RFID is an Automatic Data Capture technology that uses radio-frequency waves to read a movable item to identify, categorize & track...

- RFID is fast, reliable, and does not require physical line of sight or contact between reader/scanner and the RFID tagged item.

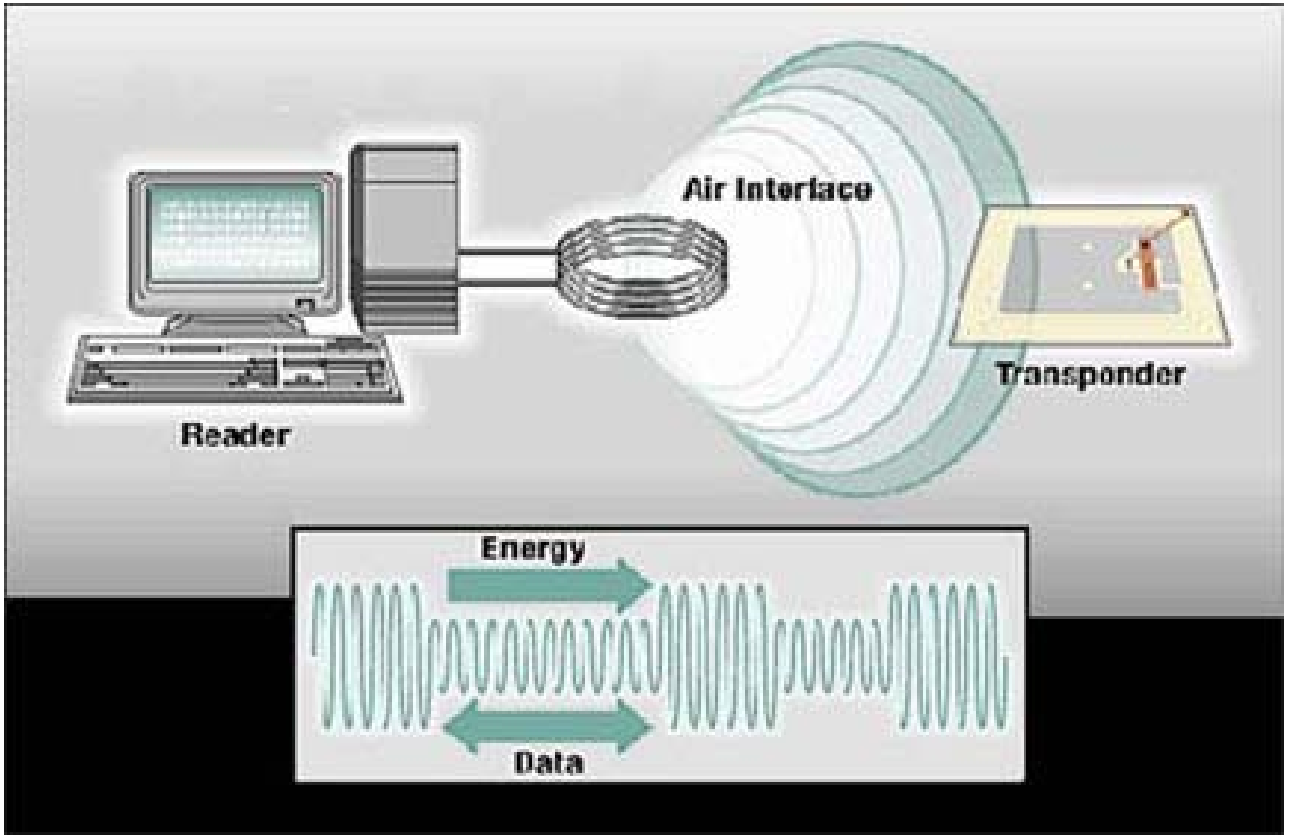
RFID vs. Bar Codes

- 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

"Advantages of RFID Versus Barcodes," http://www.technovelgy.com/ct/Technology-Article.asp?ArtNum=60 Viewed March 31, 2008
Hont, Susy d. "The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution," www.ti.com/rfid/docs/manuals/whtPapers/manuf_dist.pdf Viewed March 15, 2008

Introduction

- RFID System


Air Interface
Transponder
Reader
Energy
Data

- There are three parts to a RFID system:

  1. Antenna
     - Provides a means of communication and energy to communicate with RFID tag
     - RFID tag passes through field of the antenna and the RFID tag detects the activation signal from the antenna causing the RFID tag to transmit the information on the microchip to the transceiver.
       - Permanently affixed to a surface or handheld
  2. Transceiver
     - Has a decoder to interpret the data
  3. RFID Tag (Transporter)
     - Programmed with information

Principles

Overview of RFID technologies

Passive (powered from the field – range 3 to 10 m)

Active (powered from battery – range up to 75 m)

Semi-passive (charged by the field - range up to 75 m)

Type	Frequency	Range	Data	Penetration	Low cost
LF	125 kHz	+	+	++++	++
HF	13.56 MHz	++	++	+++	++++
UHF	860-960 MHz	+++	+++	++	++++
Micro-wave	2.49 GHz	++	++++	+	++

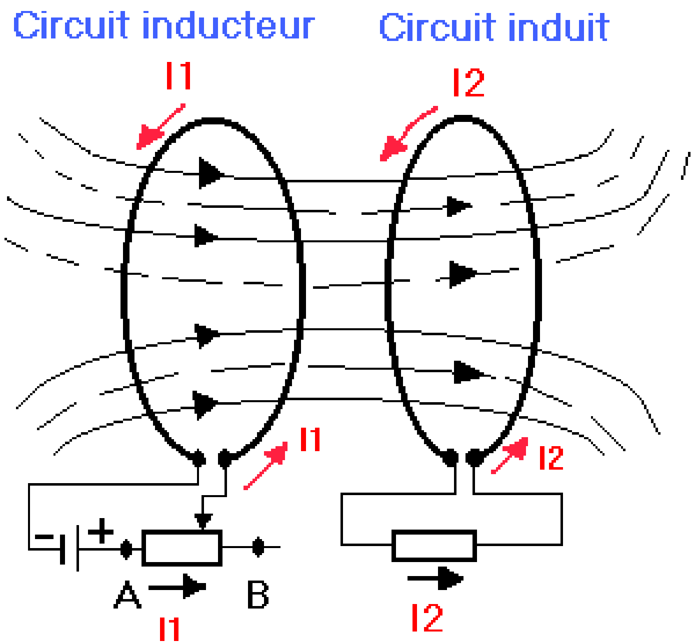
We notice a unit cost of 0.1 euros for the UHF technology
A unit cost of 0.01 euros is necessary for a large growth of RFID technology for tagging consumer goods

Principles

Principles of a BF and a HF passive RFID tag

Transponder : wireless feeding

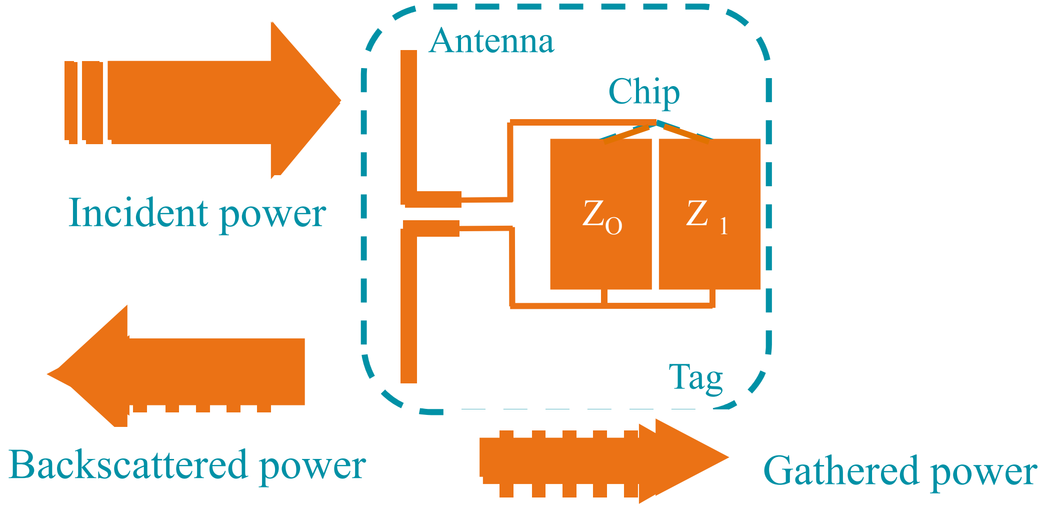
Electromagnetic Induction



Principles

Principles of an UHF passive RFID tag

$$P_{inc}$$



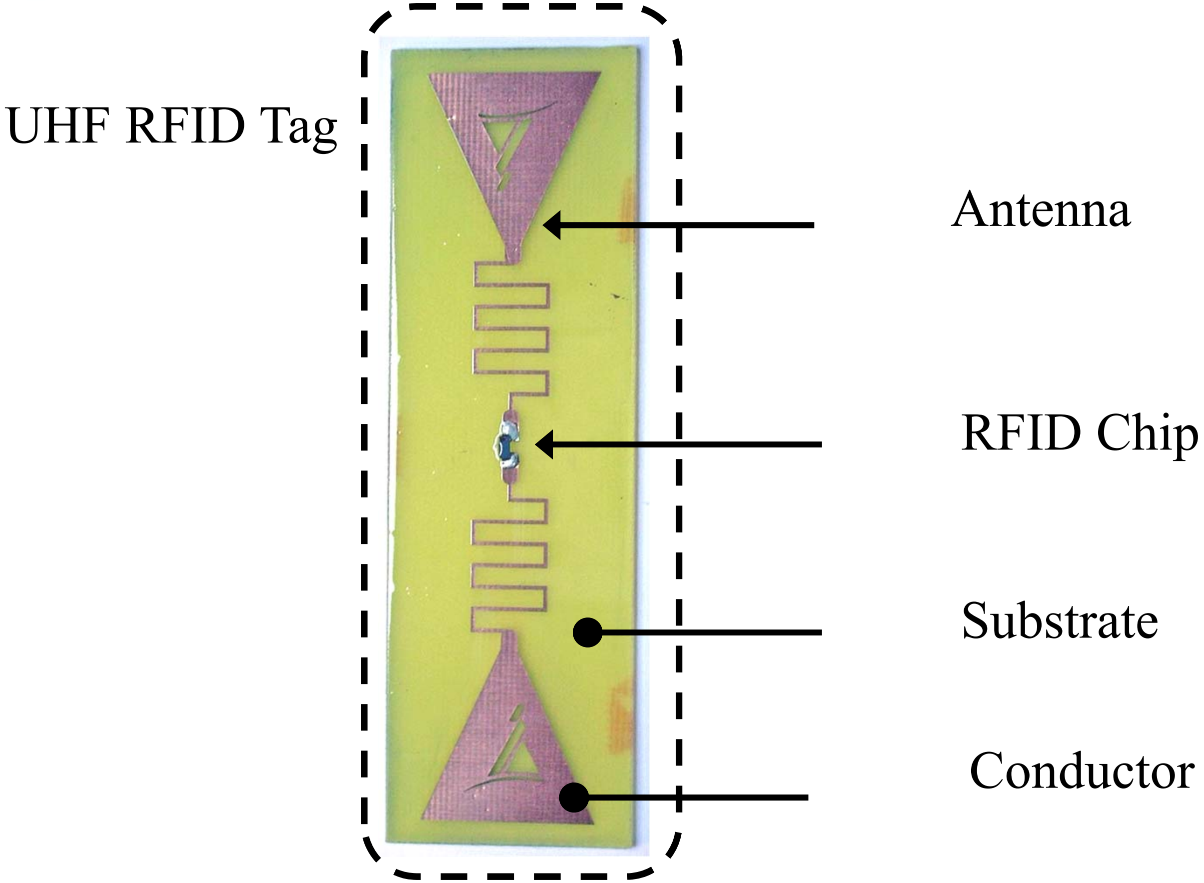
$$P_{bac} = P_{inc} As$$

$$P_{gat} = P_{inc} A_{eff}$$

➯ **A passive UHF RFID tag uses the backscattering modulation principles**

Principles

Composition of an UHF passive RFID tag

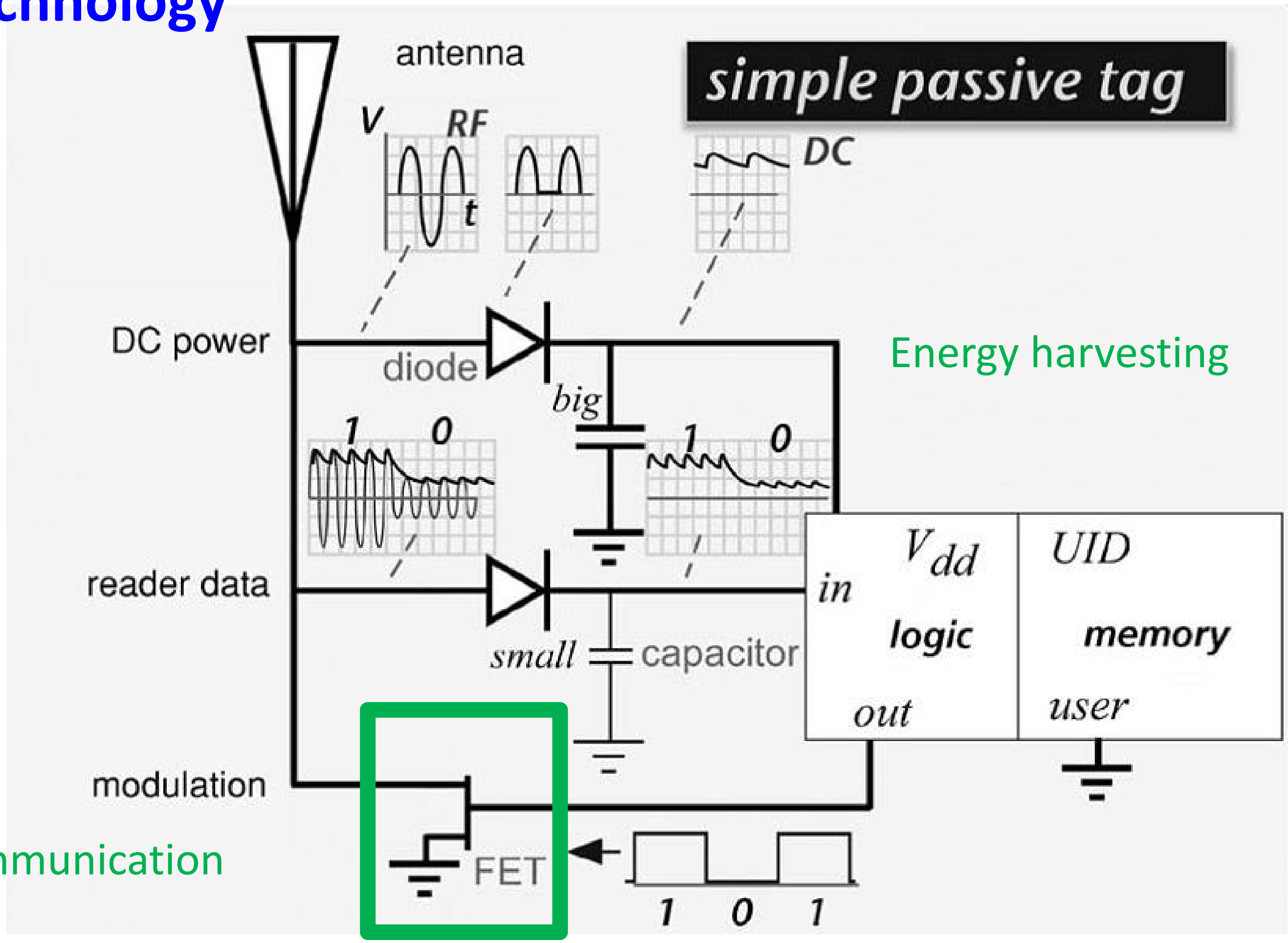


➯ **To design the antenna, the chip, substrate and conductor physical properties must be known**

Tags

Classification of RFID technologies

Passive technology

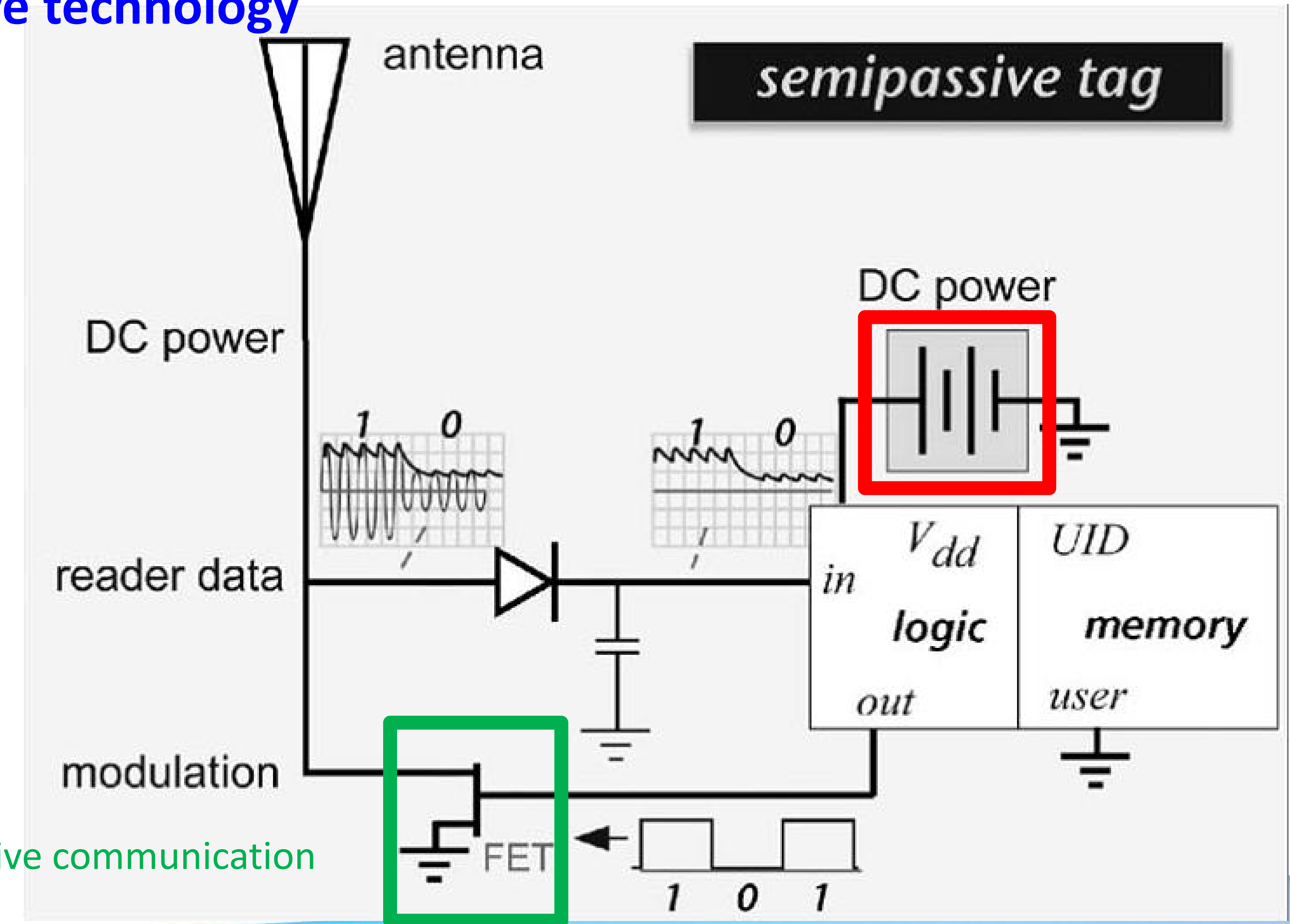


Energy harvesting

Passive communication

Classification of RFID technologies

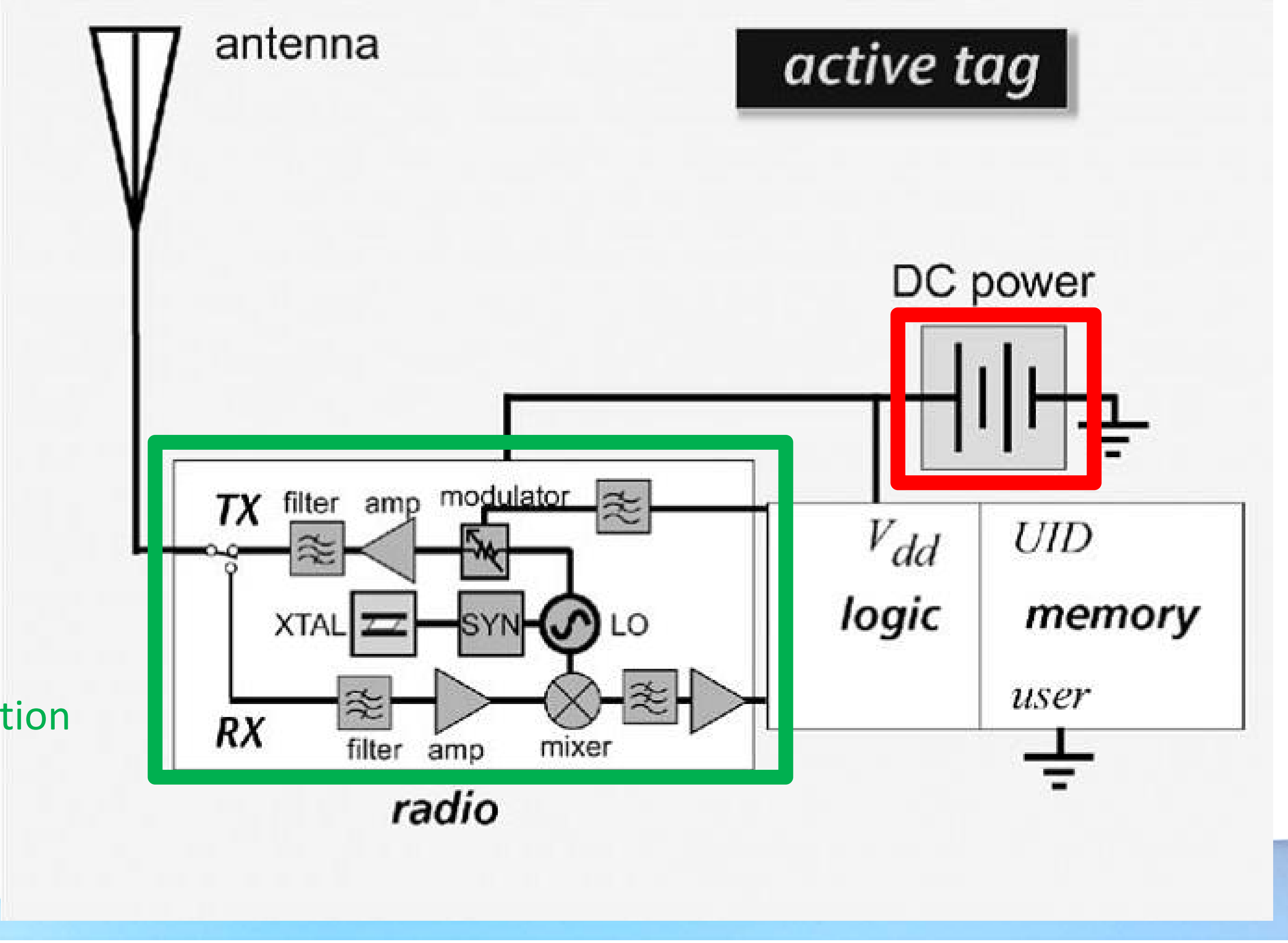
Semi Passive technology



Passive communication

Classification of RFID technologies

Active technology



Active communication

Focus on passive far field technologies

Technology	Equation	Limitation	Typical range
Passive	Friis (reader → tag)	Threshold power of the tag IC	Up to 10 meters
Semi-passive	Radar	Sensitivity of the reader	Up to 20-25 meters
Active	Friis (reader → tag and tag → reader)	Sensitivity of tags and reader	Up to 100 meters and above

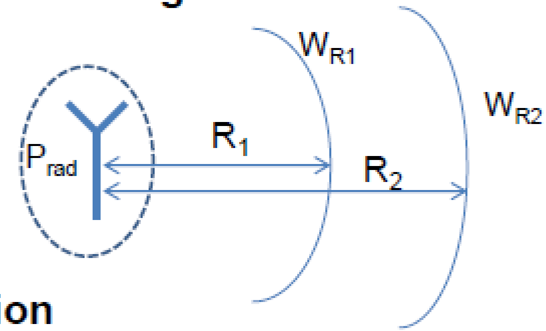
- The black magic behind passive RFID

Focus on passive far field technologies

Power density

$$W = \frac{D \cdot P_{rad}}{4\pi R^2} \quad \text{in W/m}^2$$

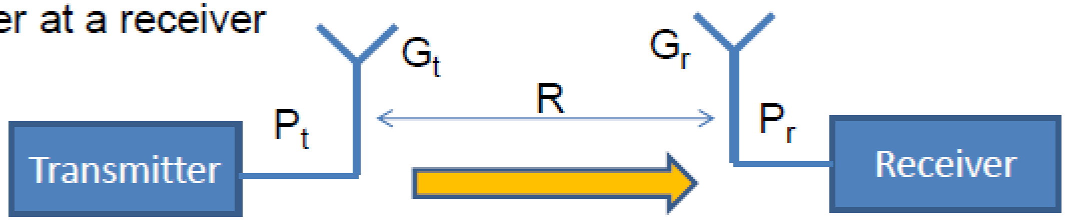
$$W = \frac{|E|^2}{\eta} = \eta \cdot |H|^2$$



$W_{R2} < W_{R1}$
$R_2 > R_1$

Friis transmission equation

The Friis transmission equation can be used in far-field region to predict the power at a receiver



Linear form

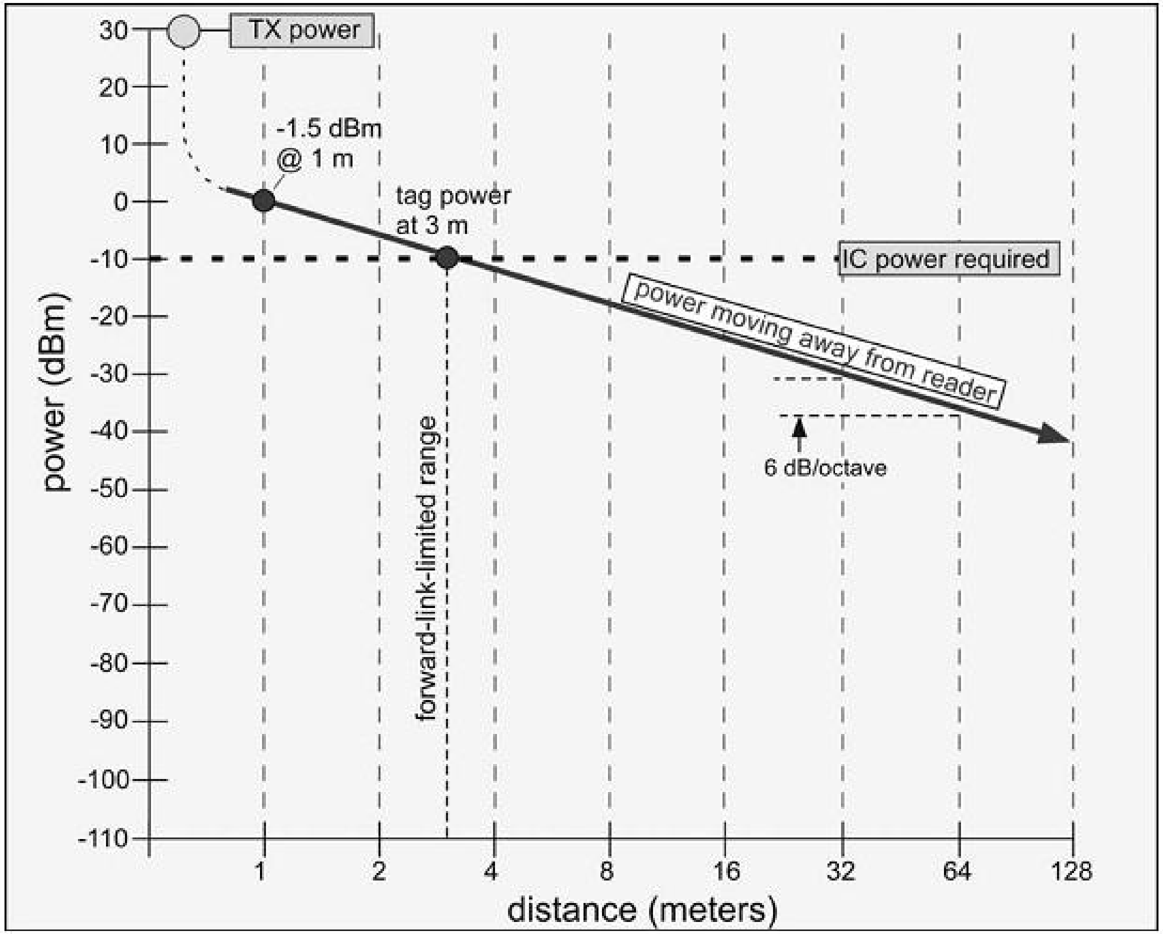
$$\boxed{\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2}$$

Log. form

$$\boxed{P_r = P_t + G_t + G_r + 20log_{10}\left(\frac{\lambda}{4\pi R}\right)}$$

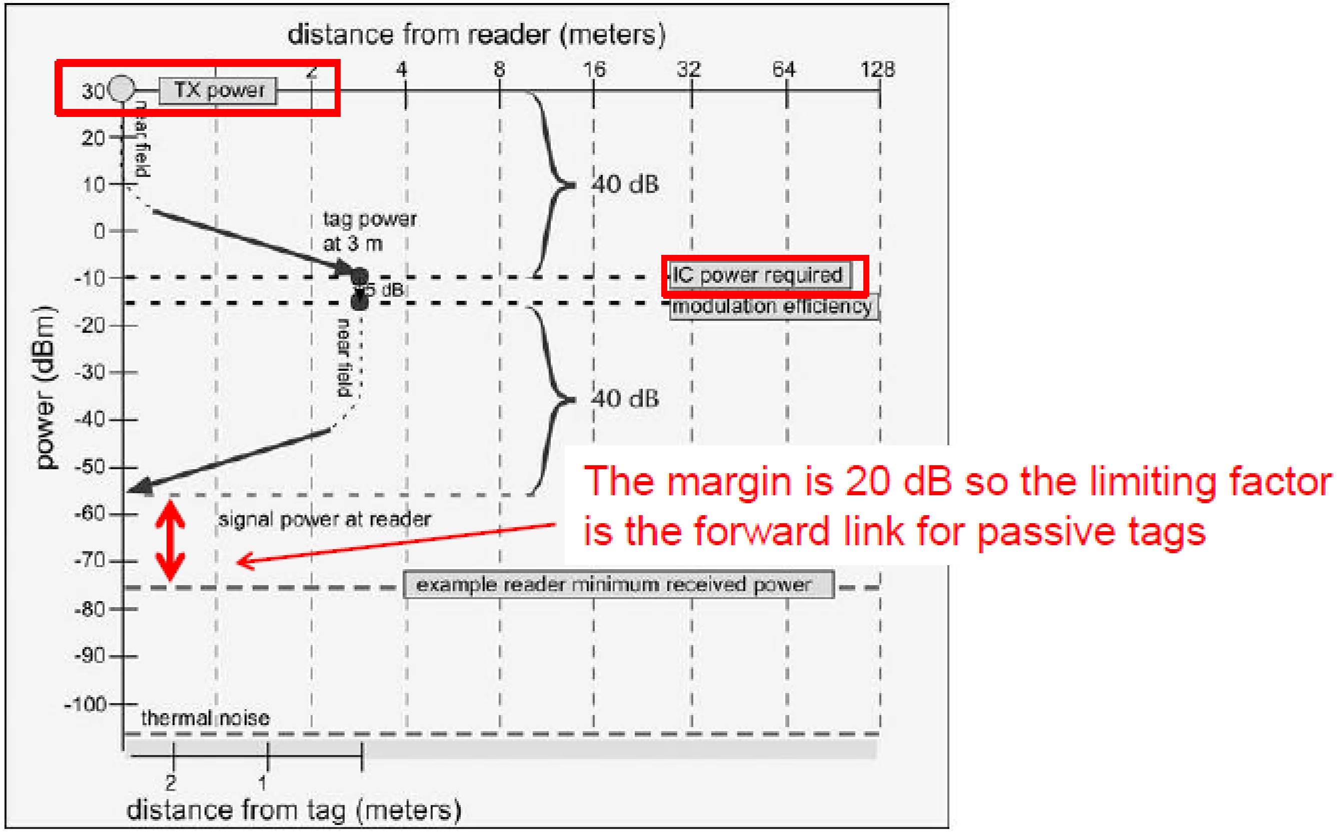
Focus on passive far field technologies

- Finding the read range based on the **forward link** (passive tags)



Focus on passive far field technologies

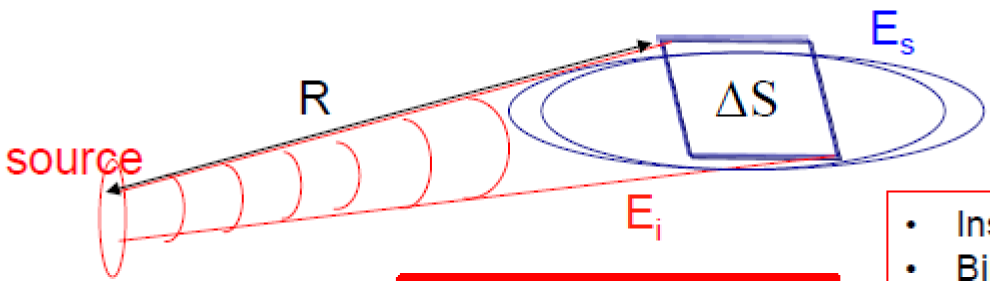
- Finding the read range based on **the forward and reverse link** (passive tags)



- The black magic behind passive RFID

Focus on passive far field technologies

- Definition of radar cross section (RCS)



RCS reflecting the power density captured by ΔS in m^2

RCS calculation

$$\boxed{\sigma = \lim_{R\to\infty}\left[4\pi R^2 \frac{|E_s|^2}{|E_i|^2}\right]}$$

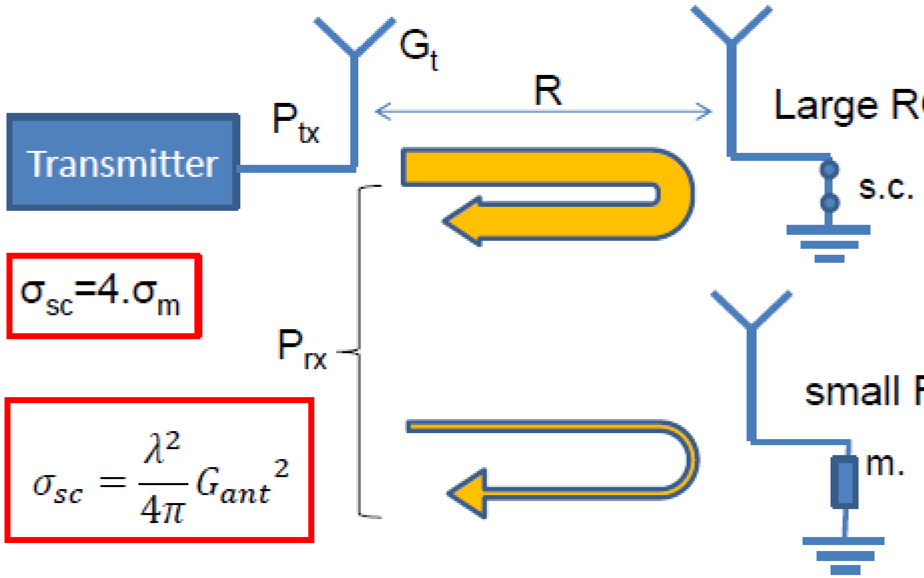
- Insect: 0,00001 m^2
- Bird: 0,01 m^2
- RFID tag 0,01-0,1 m^2
- Stealth aircraft: <0,1 m^2
- Surface-to-air-missile: ≈0,1 m^2
- Human: 1 m^2
- small combat aircraft: 1–3 m^2
- large combat aircraft: 5–6 m^2
- Cargo aircraft: up to 100 m^2
- Large ship (212 m length): 10.000–80.000 m^2

- RCS is computed in EM simulators.
- RCS is independent from observation distance R in far field approximation.

- The black magic behind passive RFID

Focus on passive far field technologies

- Definition of radar equation



$$\boxed{\sigma_{sc} = 4.\sigma_m}$$

$$\boxed{\sigma_{sc} = \frac{\lambda^2}{4\pi} G_{ant}^{\ 2}}$$

$$\boxed{\Delta P_{rx} = P_{tx} \frac{G_{tx} G_{rx} \lambda^2}{(4\pi)^3 R^4} \Delta\sigma}$$

$$P_{rx}^{\ sc} = P_{tx} \frac{G_{tx} G_{rx} \lambda^2}{(4\pi)^3 R^4} \sigma^{sc}$$

$$P_{rx}^{\ m} = P_{tx} \frac{G_{tx} G_{rx} \lambda^2}{(4\pi)^3 R^4} \sigma^{m}$$

The incident power is reflected back with a level defined by the RCS of the radar target

Exercise:

An RFID reader operating in the European band from 865,4 to 867,6 (2W ERP) and in the USA band from 902 to 928MHz (4W EIRP) is installed to detect two types of passive RFID tags having different ICs.

- The first IC type is an NXP UCODE HSL featuring a power threshold of -14.5dBm.
- The second IC is an NXP UCODE Gi2L with a power threshold of -18dBm. Tag antennas are λ/2 dipoles and feature a gain of 1.64. The antennas are aligned for maximum radiation and are polarization-matched.

With the help of the Friis equation applied on the forward link, find the theoretical read range in free space for the two ICs in the USA and the European frequency band.

Focus on passive far field technologies Back to the basics

- Friis equation -> read range calculation of passive tags

Bande de fréquence (MHz)	Région	Puissance	NXP UCODE HSL [1.7] Ptag=-14.5dBm @ 860MHz et -9.2dBm @ 2.45GHz	NXP UCODE Gi2L [1.7] Ptag=-18dBm
869.4-869.65	Europe	0.5W ERP	5.38m	8m
865.5-867.6	Europe	2W ERP	10.75m	16m
902-928	USA	4W EIRP	11.28m	16.9m
2400-2483.5	Europe	0.5W EIRP	0.8m	/
2400-2483.5	Europe/USA	4 W EIRP	2.27m	/

Focus on passive far field technologies Back to the basics

- Friis equation -> read range calculation of semi passive tags

Exercise:

An RFID reader operating in the European band from 865,4 to 867,6 (2W ERP) and in the USA band from 902 to 928MHz (4W EIRP) is installed to detect a semi-passive RFID tag.

Tag antenna is $\lambda/2$ dipoles and feature a gain of 1.64. The antennas are aligned for maximum radiation and are polarization-matched. Power sensitivity of the reader receiver is set to -74dBm. Gain of the receiving antenna of the reader is 1.64.

With the help of the radar equation, find the theoretical read range in free space in the USA and the European frequency band.

Focus on passive far field technologies Back to the basics

- Friis equation -> read range calculation of semi passive tags

Bande de fréquence (MHz)	Région	Puissance	ΔSER dipôle $\lambda/2$: $0.642.\ \lambda^2$
869.4-869.65	Europe	0.5W ERP	10m
865.5-867.6	Europe	2W ERP	19.7m
902-928	USA	4W EIRP	19.8m
2400-2483.5	Europe	0.5W EIRP	4.3m
2400-2483.5	Europe/USA	4 W EIRP	7.3m

Focus on passive far field technologies Back to the basics

- Friis equation -> Wireless harversting to switch on a LED

Exercise:

An UHF RFID reader sends a power of 4W EIRP at 915MHz. With the help of the Friis equation, find until which distance is it possible to switch on a red LED (1.6V, 2mA):

a)connected to a dipole antenna (2.2dBi)

b)connected to a dish antenna (30dBi) Is the antenna can be connected directly to the LED according to the received voltage ? The antennas are aligned for maximum radiation and are polarization-matched.

Design of RFID tag antennas (12 slides)

Context

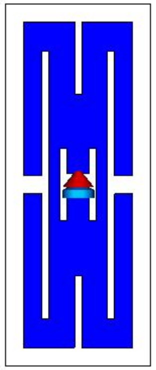
Strategy

Characterization and modeling of RFID Chips

Design antennas

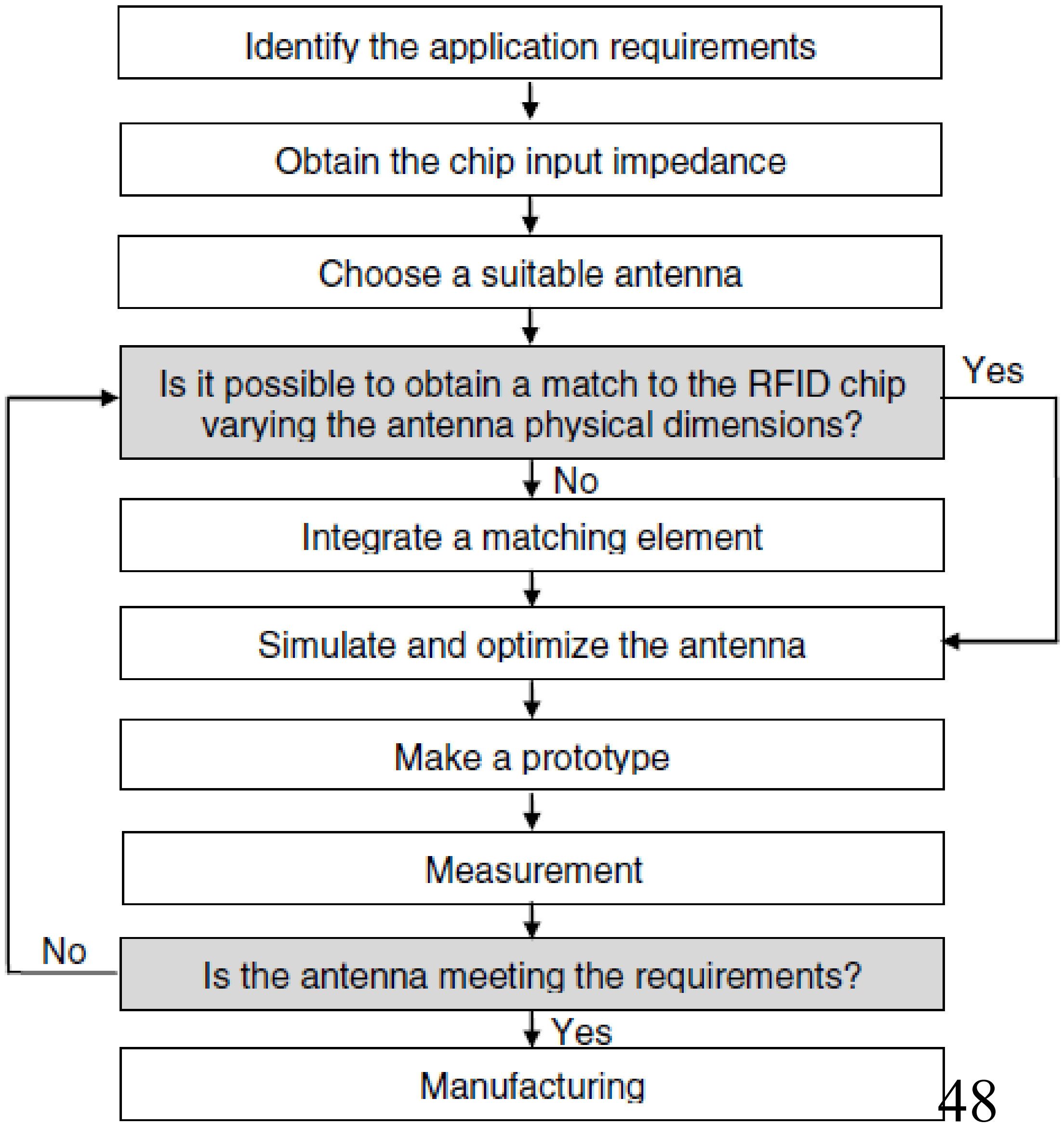
Matching

Why is it necessary the tag mounted on mellic surface?

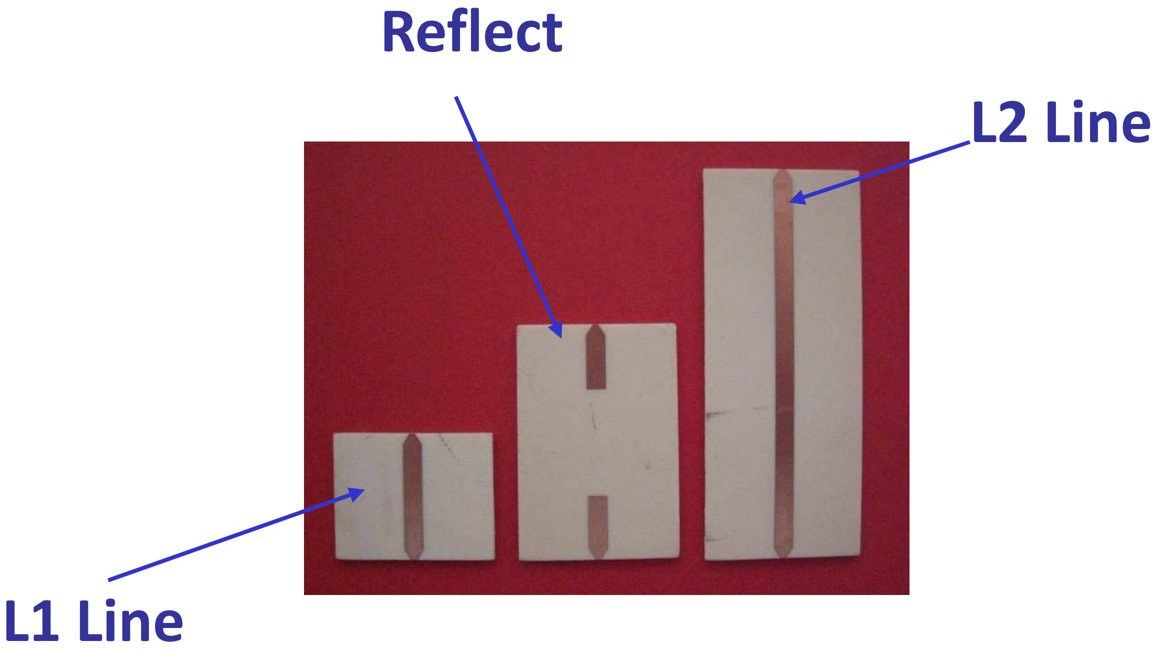


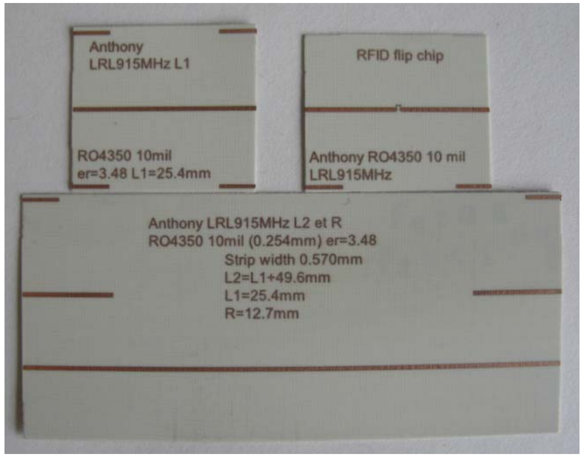
Tag UHF mounted on metallic surface

Strategy


Identify the application requirements
Obtain the chip input impedance
Choose a suitable antenna
Is it possible to obtain a match to the RFID chip varying the antenna physical dimensions?
Yes
No
Integrate a matching element
Simulate and optimize the antenna
Make a prototype
Measurement
Is the antenna meeting the requirements?
No
Yes
Manufacturing

Measurement technique
LRL calibration for the characterization of the chip





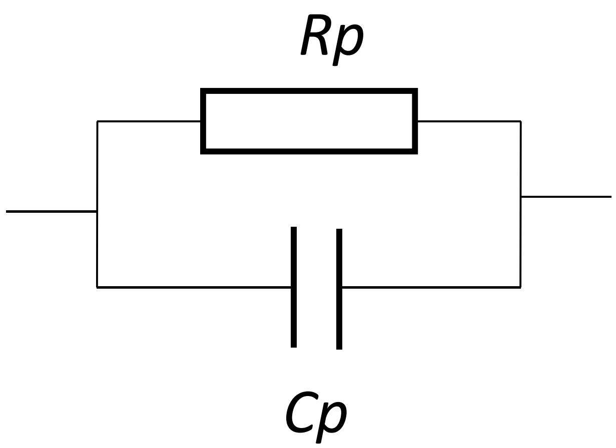
Microstrip LRL calibration
kit and Chip board

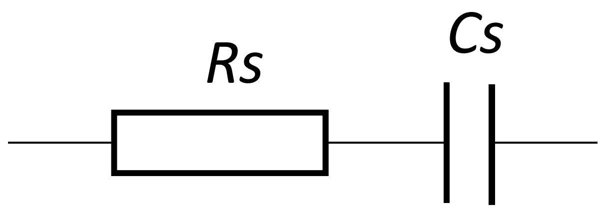
Chip impedance model (1/2)

- varied when the input power is varied

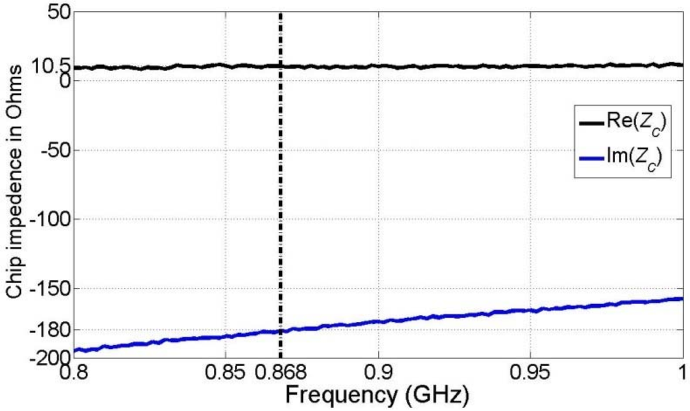
→ must be measured at low power

- modeled either by a parallel or series equivalent circuit

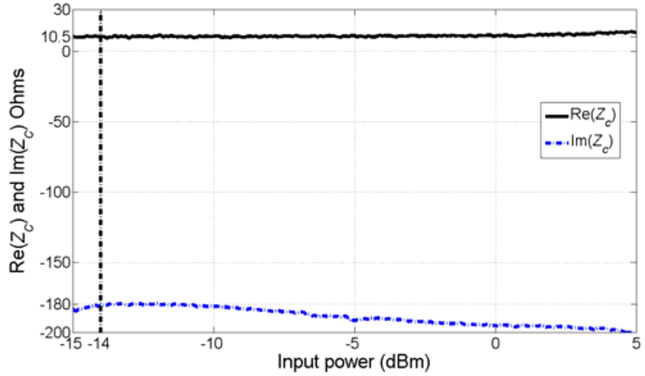




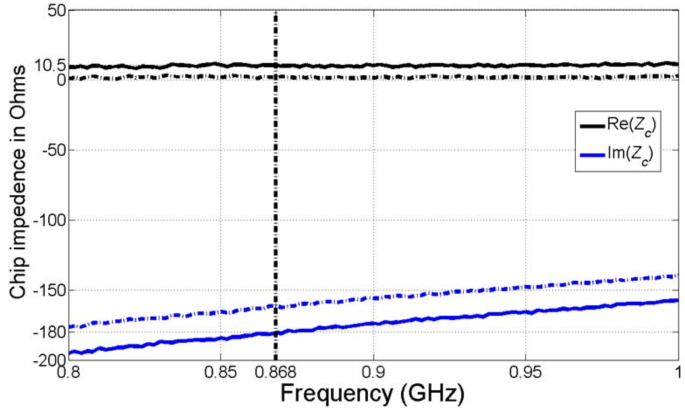
Chip impedance model (2/2)



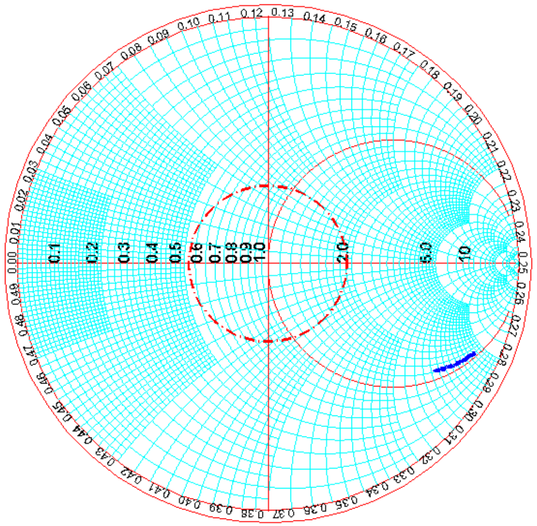
Impedance of RFID XRAG2 chip



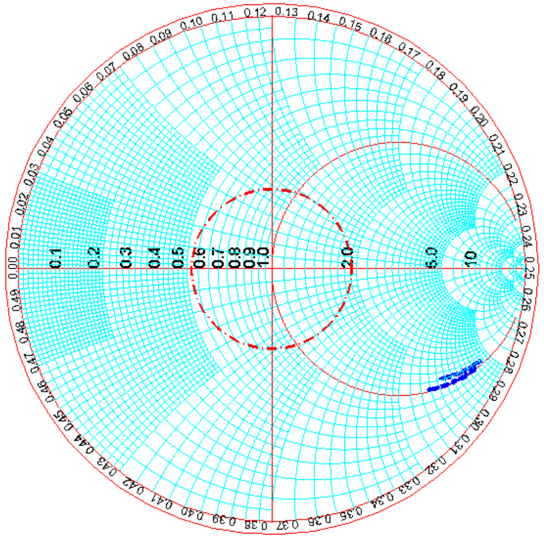
Measured XRAG2 chip impedance versus input power at a frequency of 868 MHz



Comparison between the measured chip input impedance with and without globe top



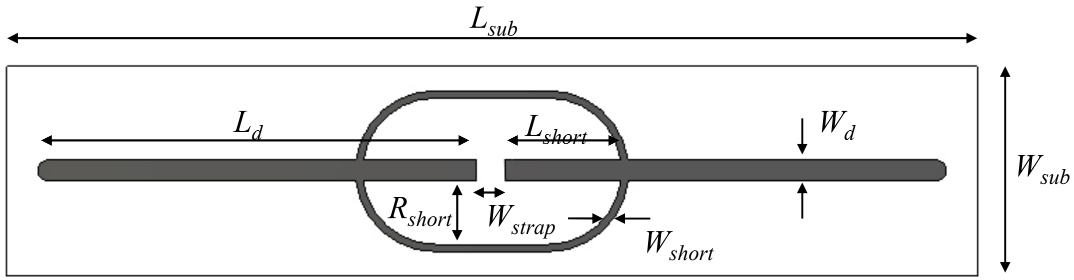
Measured XRAG2 chip Smith Chart

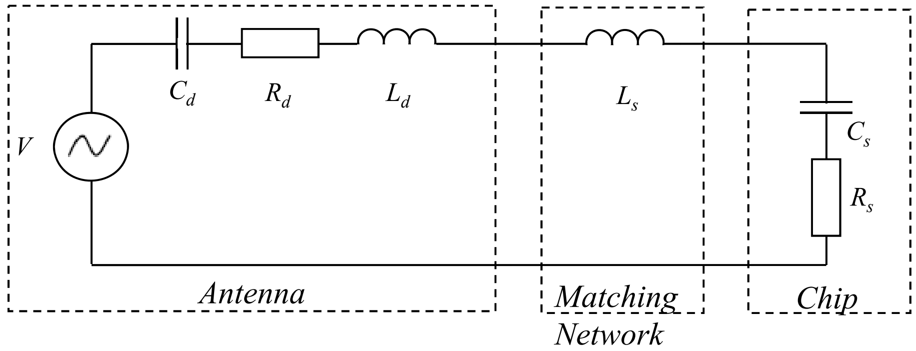


Measured XRAG2 chip Smith Chart
with and without globe top

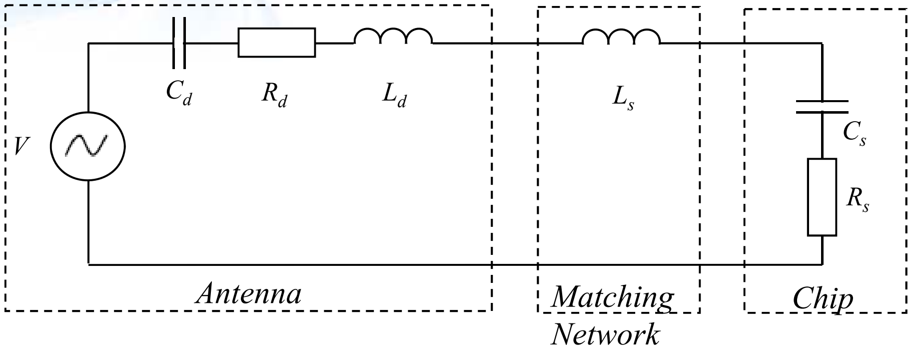
Matching network

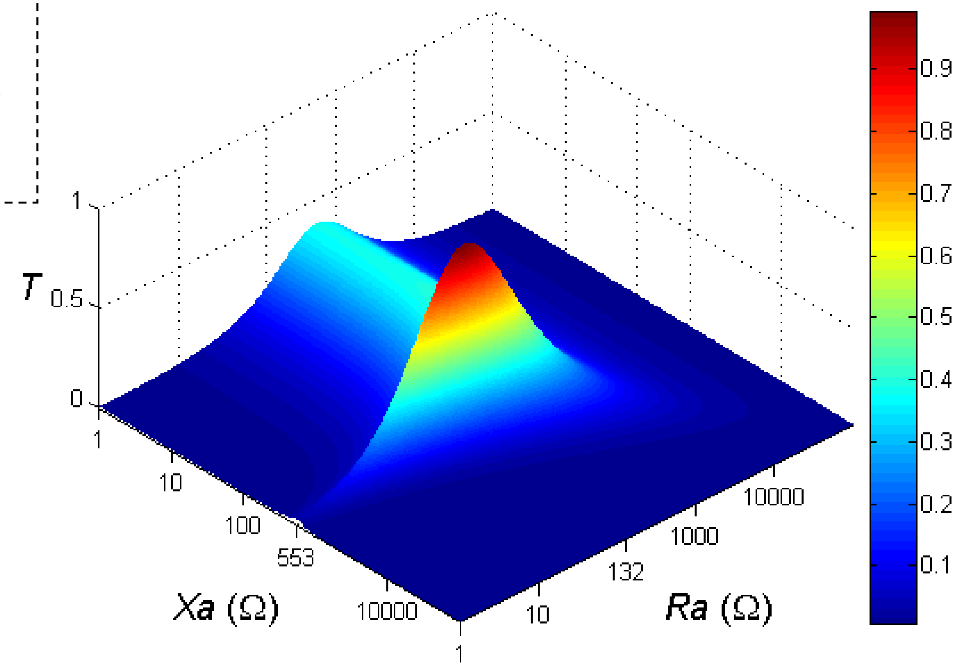
Matching condition $Za = Z_p^*$





Matching Network

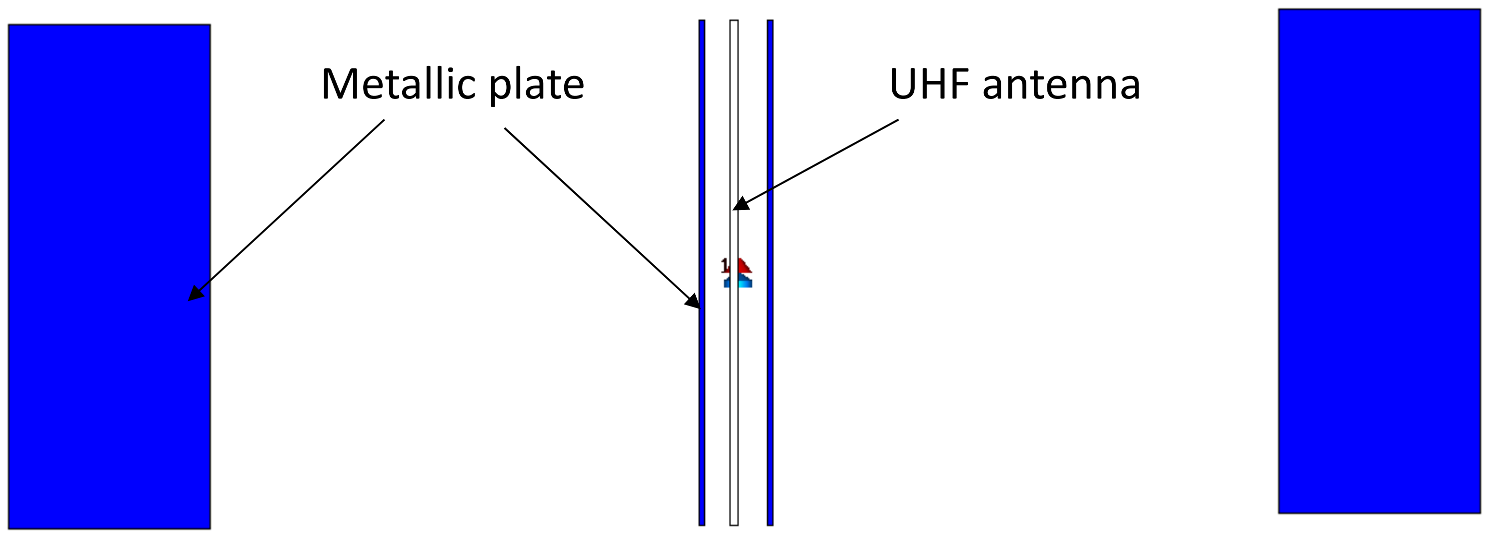




Transmission coefficient *T* as a function of the antenna impedance *Za* = *Ra* + j*Xa* for *Zc* = 132 - *j*553

Antenna design (1/2)

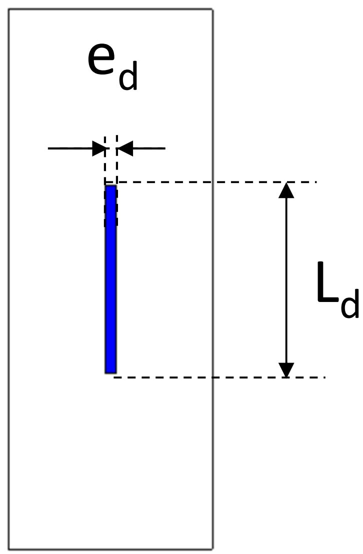
Composed by two metallic plates and an UHF antenna on a RO4003 substrate



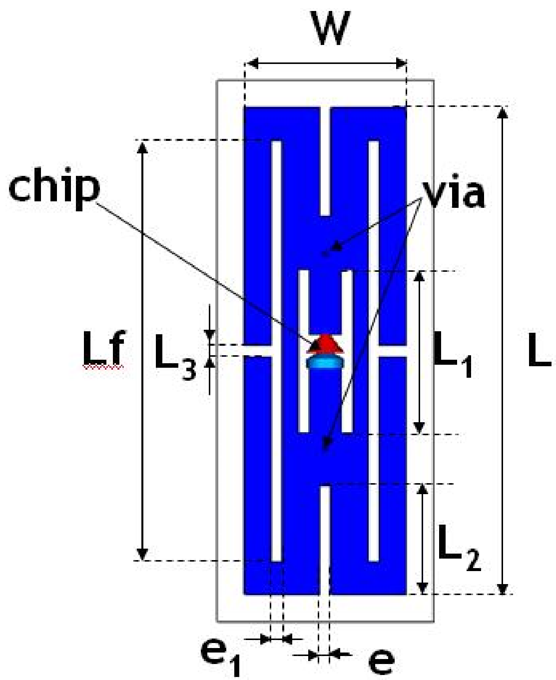
antenna (back view) antenna (left view) antenna (front view)

Antenna design (1/2)

UHF antenna on a RO4003 substrate

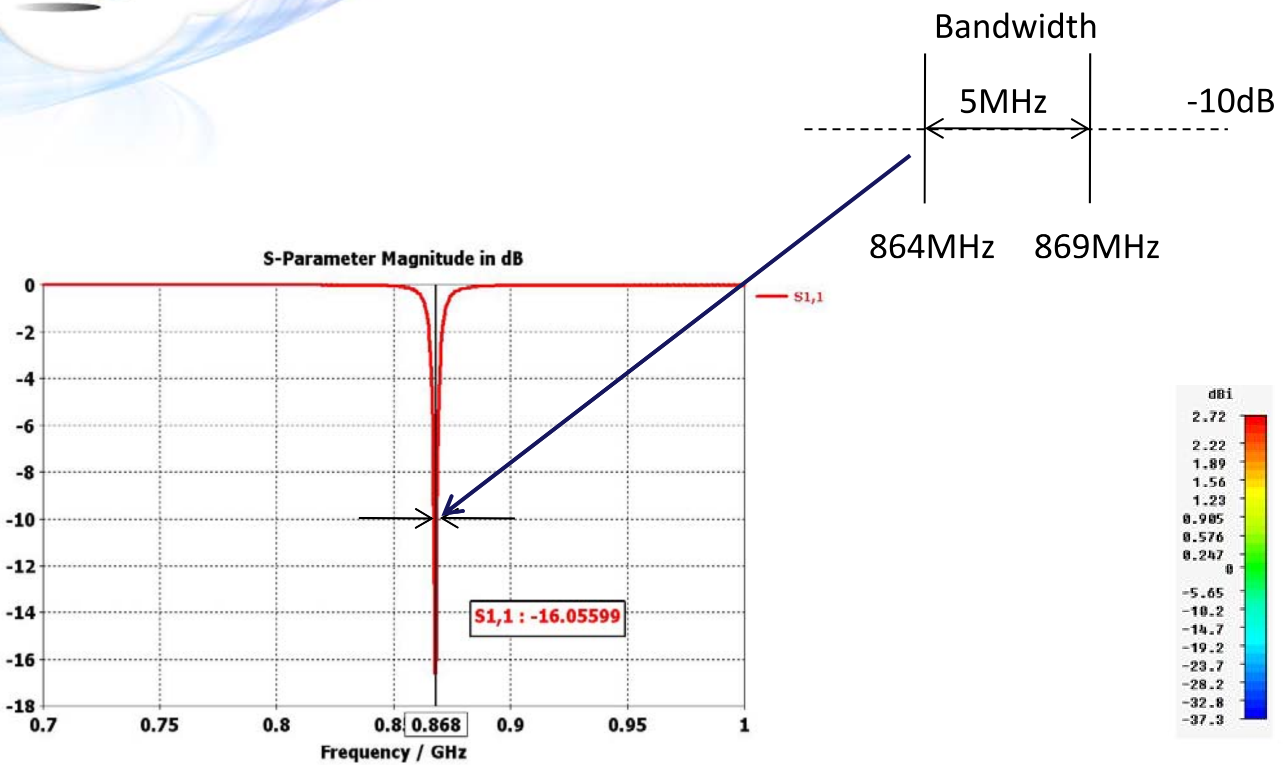


back view

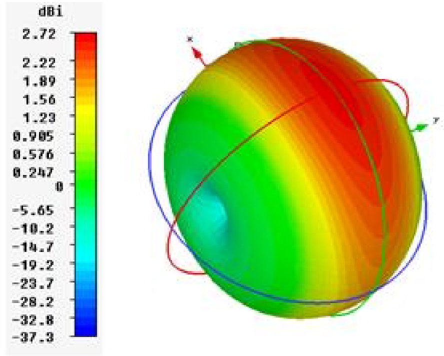


front view

Antenna design (2/2)



Reflection coefficient



3D radiation pattern of directivity

Conclusion and perspectives (1/2)

- Strategy design of Tag UHF
- Measurement of the chip RFID
- Design of tag antenna
- Network matching

Conclusion and perspectives (2/2)

Future works :

- Make and measure RCS parameter of this tag
- Put this tag on the bumper for using largely in many applications for vehicle identification and localization
- Expensive → Used for luxurious objects.
- Also used in identifying and localizing the metallic surface objects.