RFID UHF pour l'identification et la traçabilité des objets

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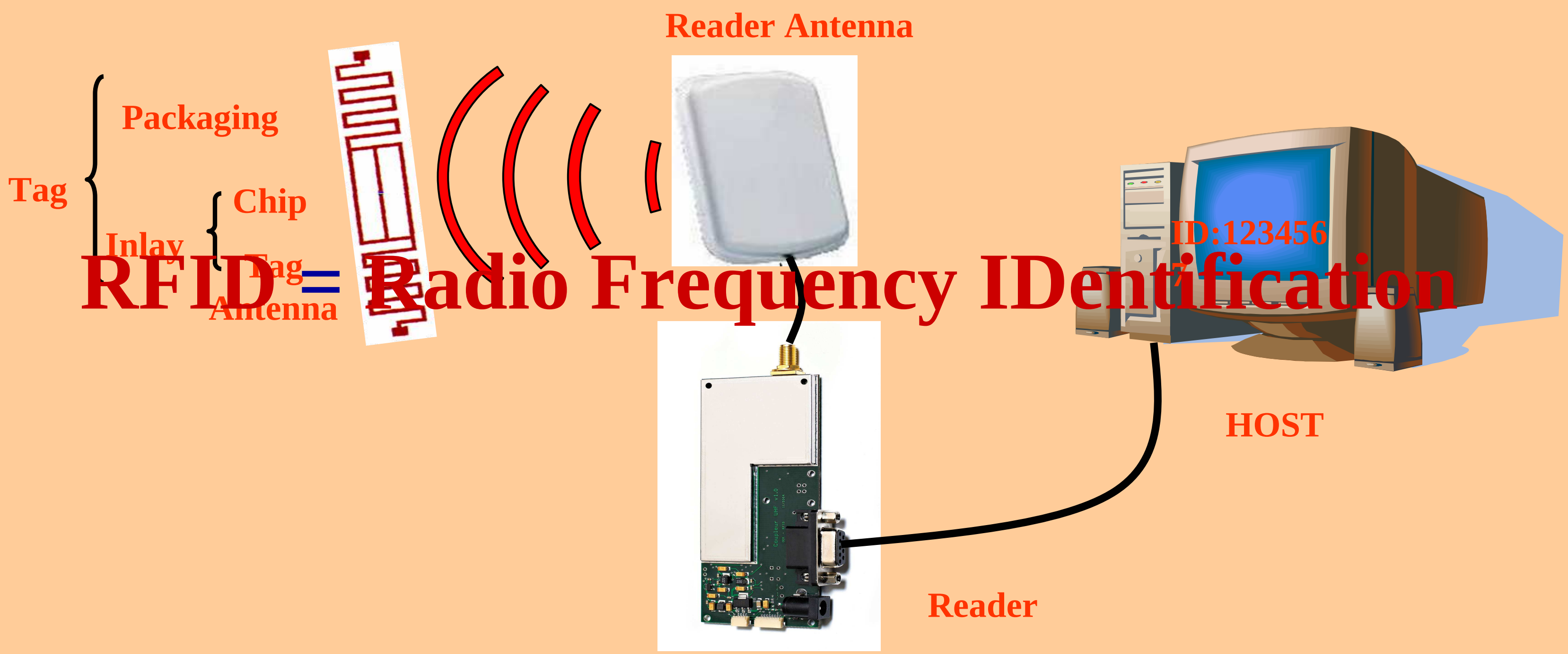
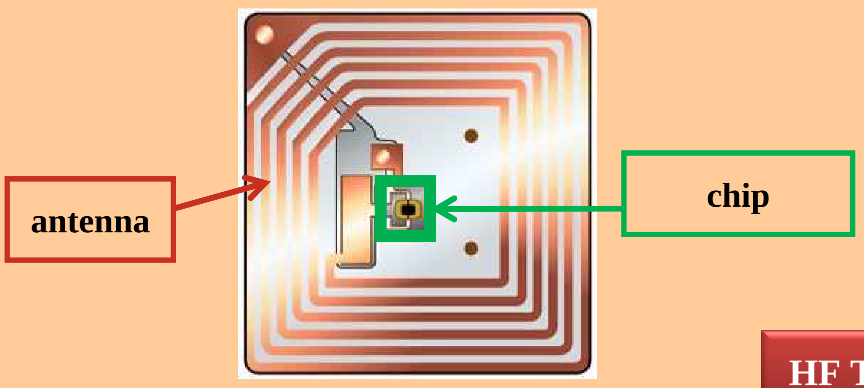
Agenda

- Generalities and Principles
- HF versus UHF
- UHF Spectrum regulations
- Back Scattering Modulation and Maximum Read Range
- UHF antennas (860-960 MHz)
- Propagation, absorption, detuning issues
- EPC Gen2 protocol
  - Integrated circuit – Memory
  - Coding and Modulation
  - Anticollision algorithms

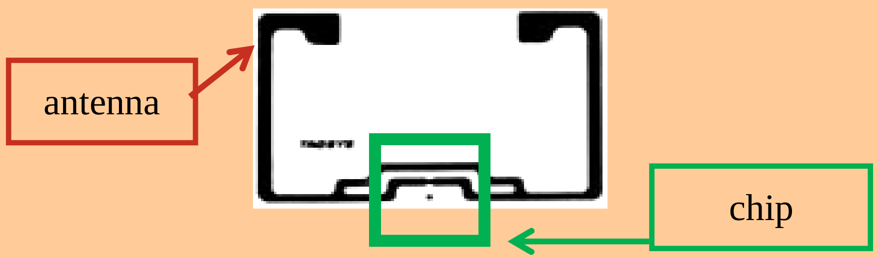
RFID Principles



RFID = Radio Frequency IDentification



HF Tag



UHF Tag

RFID Principles

- **Data** is stored in a **chip** connected to an antenna
- Uses radio frequency transmission in either, inductive **near field** or radiating **far field**.
- Ability to automatically identify **multiple objects without line of sight**.
- Tags can be **passive**, semi-passive or **active**, **with** or **without security**.

RFID Principles

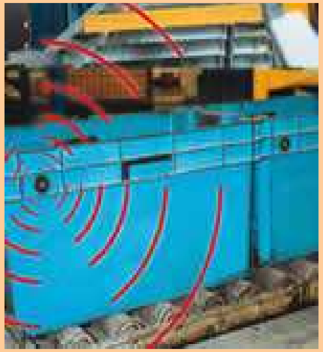
- Different Frequencies are used : **LF**, **HF**, **UHF**…..

- Could replace **the bar code !!!**
  - **Simultaneous** reading of a large number of tags
  - **Tag does not need to be within line of sight of the reader**
  - **Tag may be embedded in the tracked object**

- Used for **many applications** in a growing number of **markets world-wide**.

RFID Applications

Animal Identification



Industrial Identification

Textile Logistic

Baggage Logistic

Pharmaceutical Identification

- Real-time inventory and stock control
- Supply chain management
  (fashion, retail, pharmaceuticals)
- Libraries
- Rental
- Animal ID

Library

Les métiers de la RFID

Chip manufacturer /designer

Inlay manufacturer

Label manufacturer

LF/HF/UHF readers

Infrastructure, RFID stations

Supervision
Communication
Installation
Maintenance

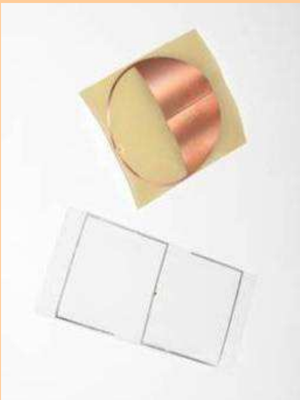
EM MICROELECTRONIC - MARIN SA

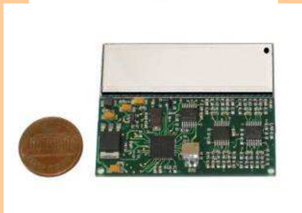
Impinj

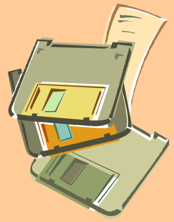
ST

PHILIPS

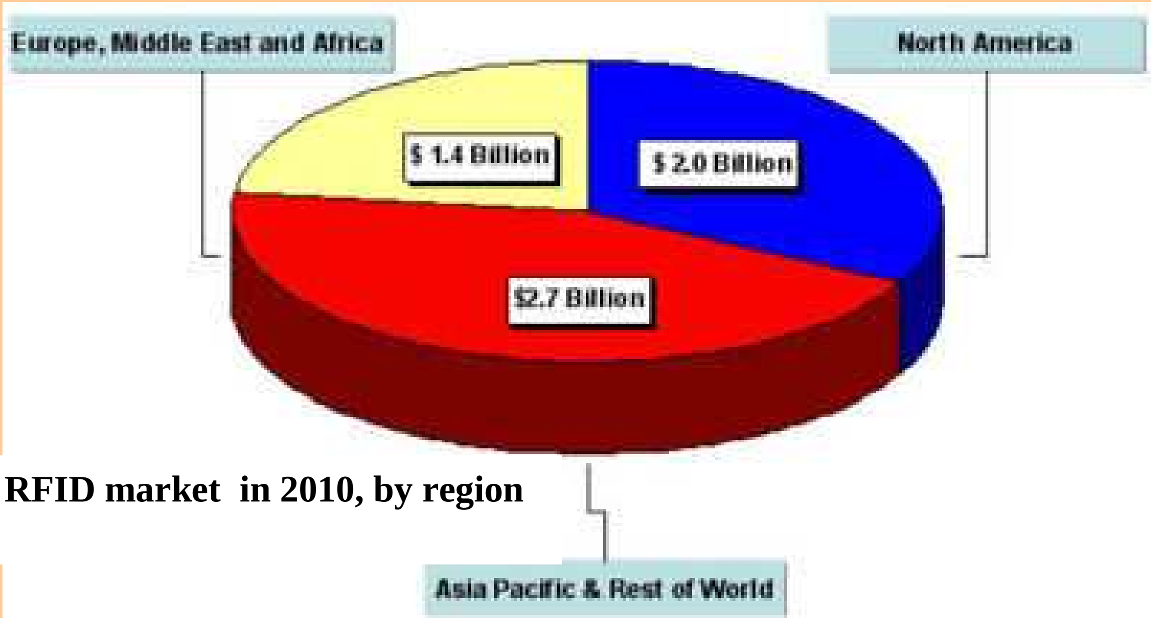
ATMEL





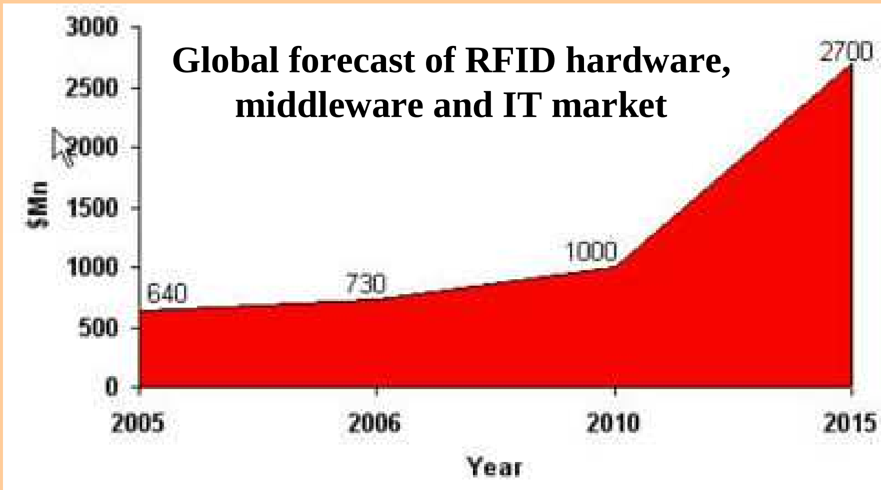


Market Potential



Estimated value share of RFID market in 2010, by region

Global forecast of RFID hardware, middleware and IT market

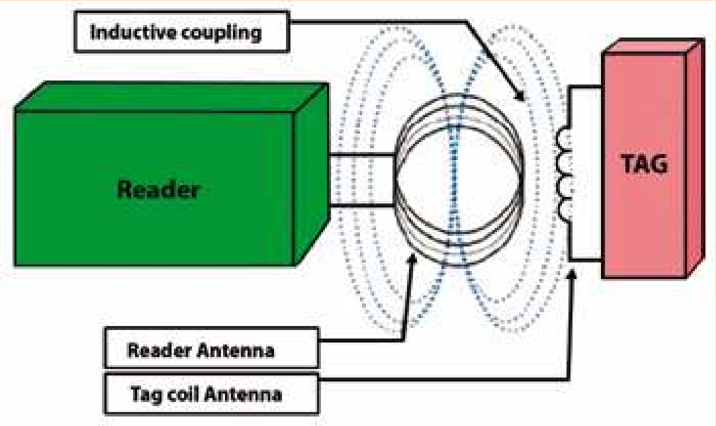


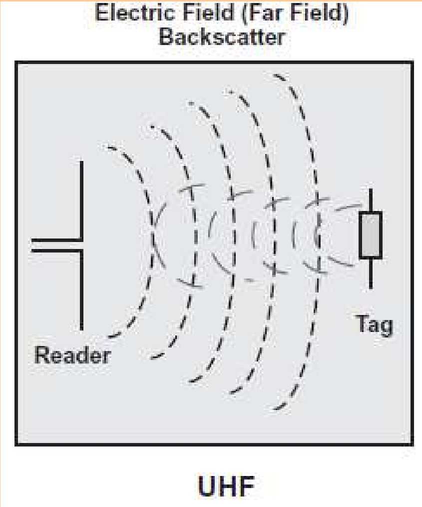
HF versus UHF

Inductive Coupling - Propagation coupling

Near field (HF)

Far field (UHF)





Inductive coupling
- Frequencies : LF (125 kHz) and HF (13,56 MHz)
- Impedance variation
- Loop antennas

Propagation Coupling
- Frequencies : UHF (900 MHz) and MW (2,45 GHz)
- Backscattered modulation
- Dipole antennas

UHF vs HF (1)

UHF

- Based on electromagnetic waves
  - Electric Field
  - Magnetic Field
  - Best Performances in "Far-Field" (FF)
- Long Range
  - E and H field in FF decrease with 1/r
- Performances in presence of dielectrics
  - bad

→ Dipole antenna

HF

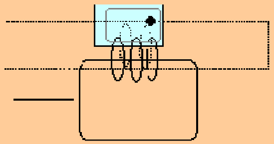
- Based on Magnetic Field
  - in "Near-Field" (NF)
- "Short" Range
  - H field in NF decrease with 1/r^3
- Performances in presence of high dielectrics
  - good

→ Loop antenna

UHF vs HF (2)

Low Frequency (LF): ~125 kHz
Inductive coupling
RW distances: 1m

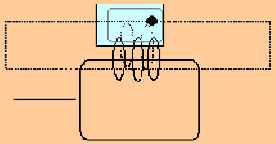
Data rate 10 kbits/s
Metal: low perturbations
Water: no perturbations



Inductive Coupling

High Frequency (HF): 13,56 MHz
Inductive coupling
RW distances: Max: 1m

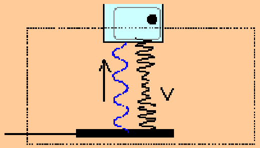
Data rate >=100 kbits/s
Metal: high perturbations
Water: no perturbations



Inductive Coupling

Ultra High Frequency (UHF): ~900 MHz
E-field coupling
RW distances: up to 10 m

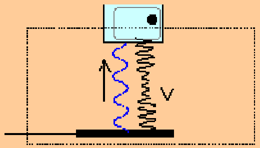
Data rate >= 256 kbits/s
Metal: high perturbations
Water: med. perturbations



Propagation Coupling

Micro Wave (MW): ~2,45 GHz
E-field coupling
RW distances: >10m

Data rate >= 256 kbits/s
Metal: high perturbations
Water: high perturbations

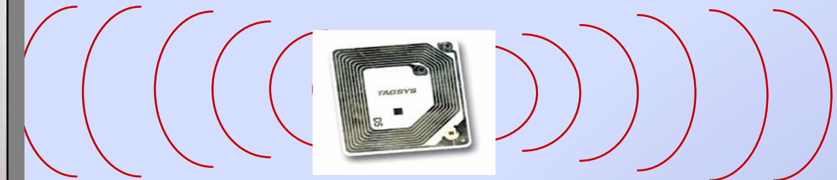


Propagation Coupling

Security

People

Short Range



Long Range

Objects

Identification
Authentication
Data Security

Identification

Smart cards, key fobs,….

Labels, Tags

Security

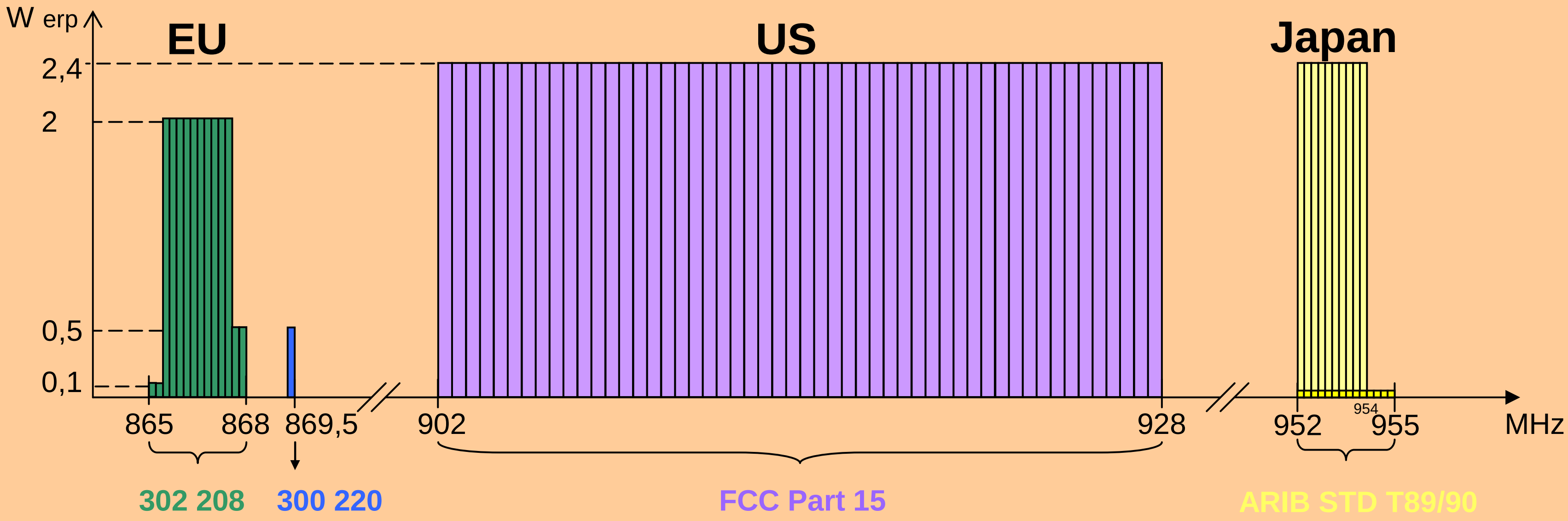
Limited Security

- Access Control
- Security
- Payment
- Passport/Visas
- Transport ticketing

- Laundry
- Library
- Supply Chain
- Logistics
- Luggage
- Apparel
- Traceability

UHF Spectrum regulations

UHF regulation overview



	302 208	FCC Part 15	ARIB STD-T89/T90
Channel bandwidth	**200 kHz**	**500 kHz**	**200 kHz**
Channel nb	**15**	**52**	**9 for (high power)** **14 for (low power)**
Synchronization	**LBT**	**Frequency Hopping**	**LBT**
Radiated power	**2 Werp**	**2,4 Werp**	**2,4 Werp (high power)** **12 mWerp (low power)**

- Listen Before Talk technique: Interrogators are only permitted where they employ frequency agile techniques
- Only 10 sub bands – likely to be many more readers than that in same radio ‘space’ ⇒ Real risk of system degradation and data loss if these sub-bands are not used responsibly.

ETSI EN 300 208 limitations

1. **Very low** l**isten threshold (-96 dBm)**
   ► in free space, a reader transmitting at 2W will be detected by another reader at a range of 78 km!
   ► sharing channel is thus almost impossible in a same area

2. **The Transmit spectrum mask defines spurious emissions at -36 dBm**
   ► this spurious level is not compatible with the listen level of -96 dBm
   ► readers in 2 adjacent channels must be spaced by 30 m

3. **The channel spacing is reduced to 200 kHz limiting the uplink data rate**

Conclusions

► performances with the current 302 208 regulation are very limited

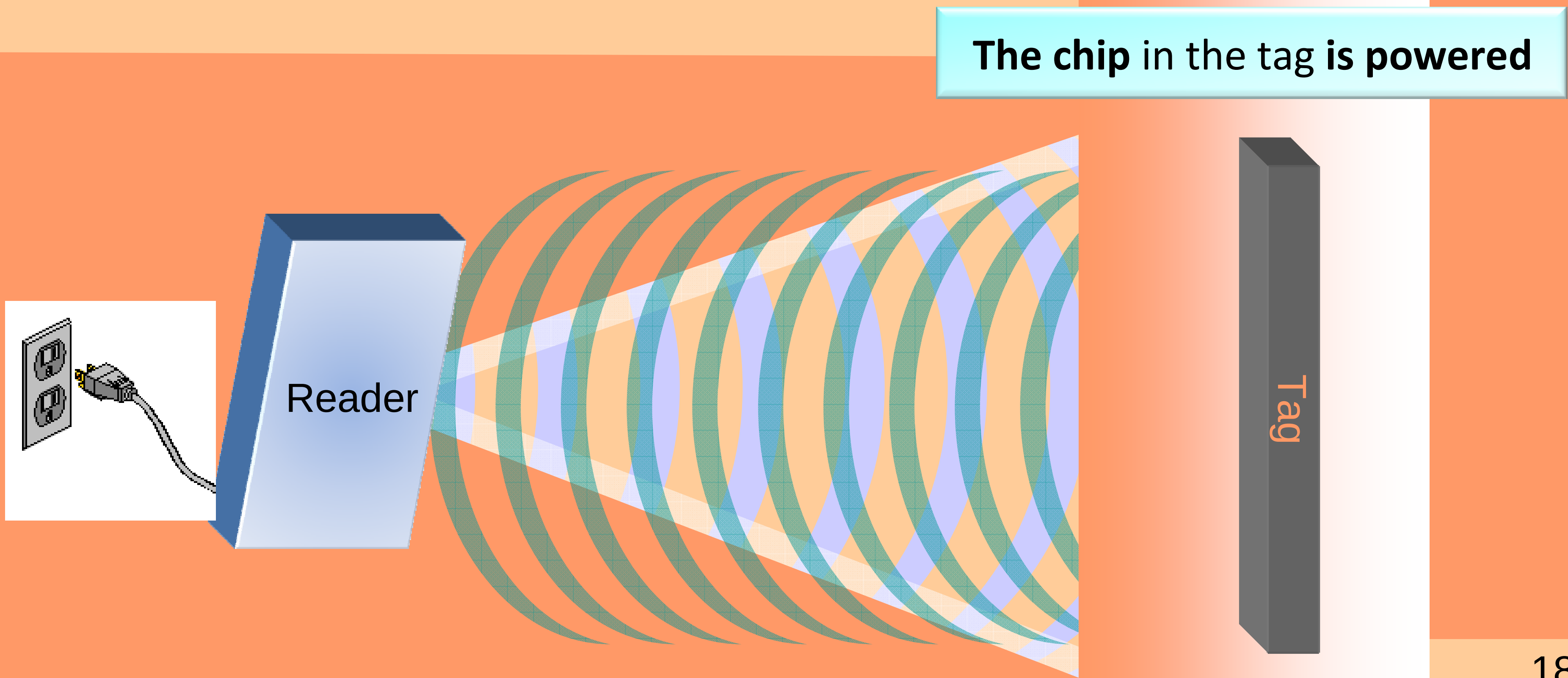
► a task group (TG34) is updating the regulations

- Limitation of 4 to 5 readers transmitting at the same time
- Time multiplexing by “global listen” or by “radio communication” between readers

Back Scattering Modulation and Maximum Read Range

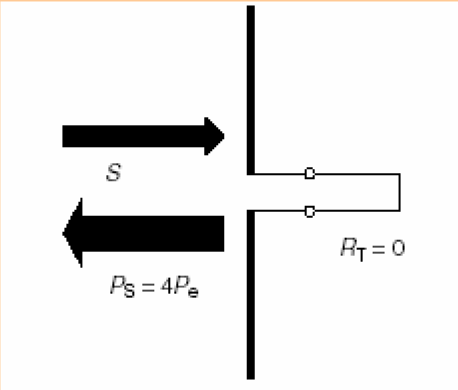
Reader/tag data exchange (UHF)

- The reader sends commands & energy to the tag via **pulse amplitude modulation.**
- The tag sends responses to the reader via **backscatter modulation.**

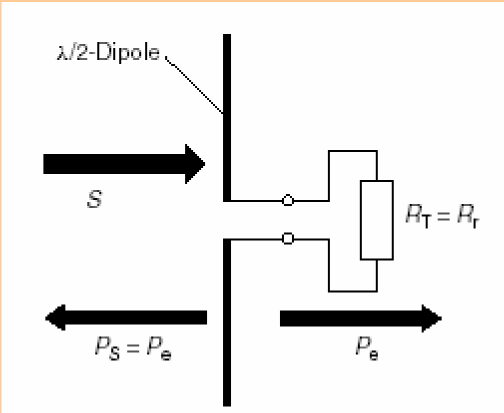


Backscattering concept (UHF)

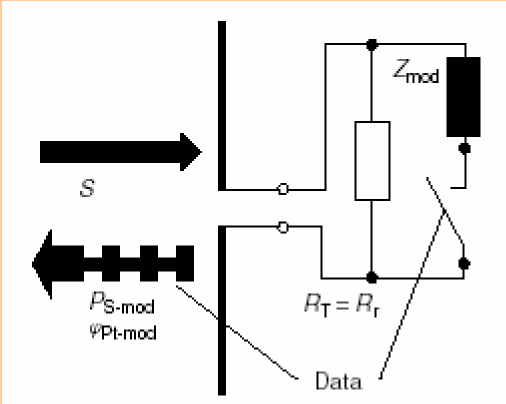
The tag changes its impedance by switching on and off a resistor (or a capacitor). This impedance variation will change the tag reflections seen by the reader antenna, ,i.e., the tag RCS=Radar Cross Section



Maximum reflection



Partial absorption



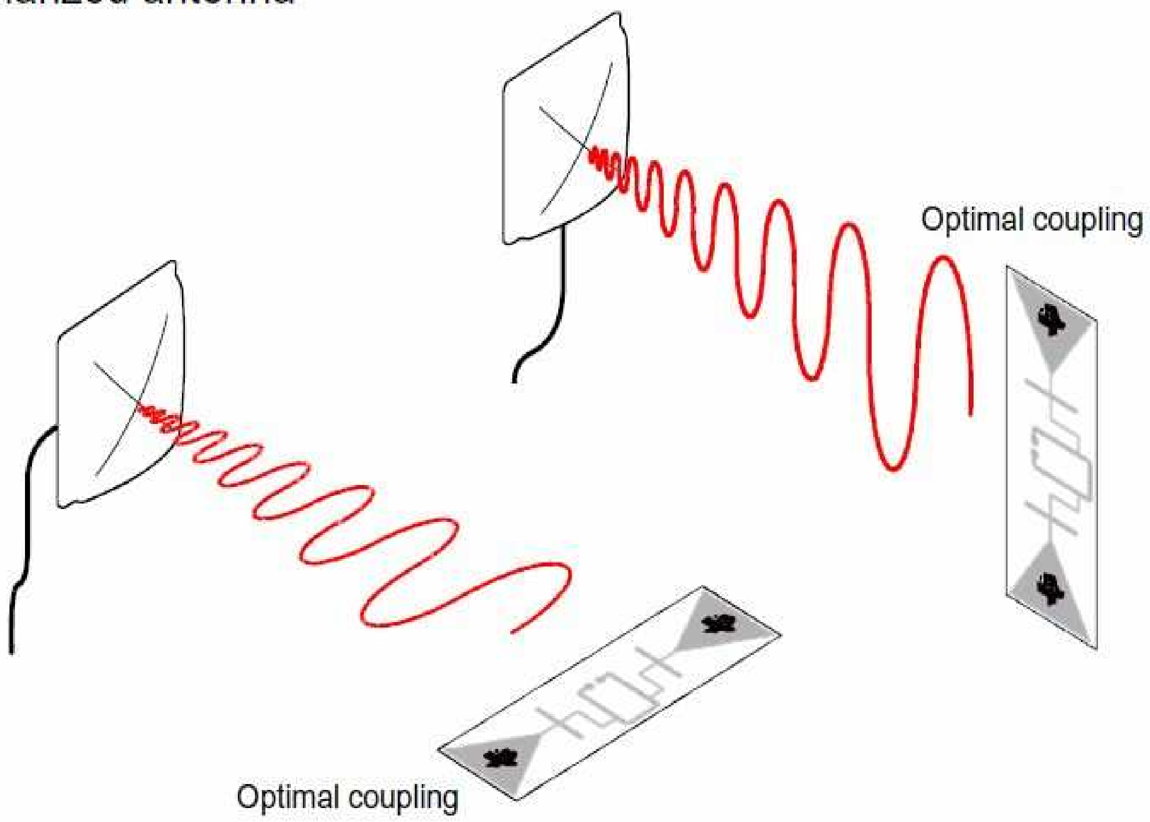
Backscattered Modulation

$$\Delta RCS = \frac{\lambda^2}{4 \cdot \pi} \cdot G_{Tag}{}^2 (|\Gamma_{mod}|^2 - |\Gamma_{unmod}|^2)$$

Reader with linear polarized antenna

With linear polarized antennas:

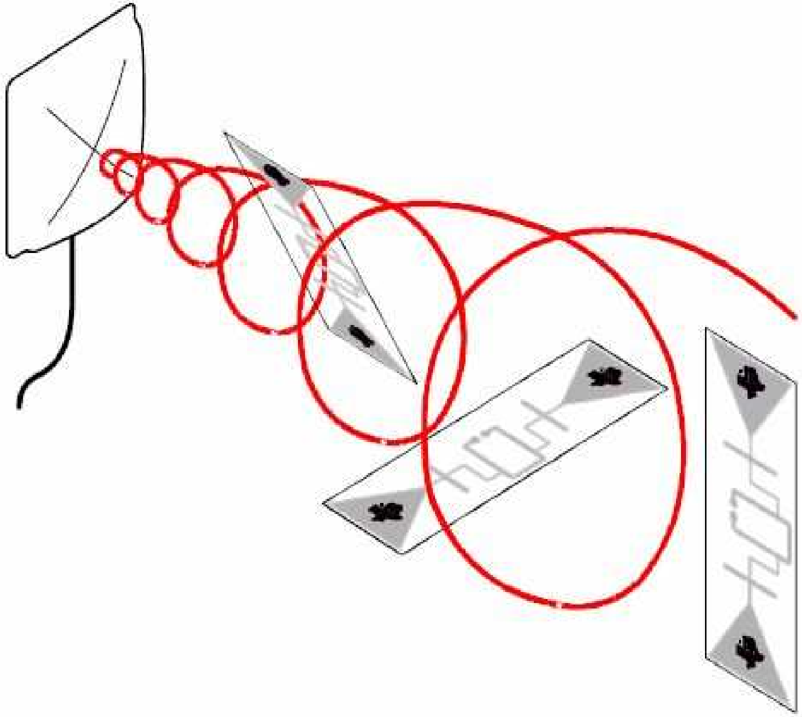
- A tag's performance depends on its orientation with respect to a linear polarized antenna



Reader with circular polarized antenna

With circular polarized antennas, tag orientation is less critical.

- The helical nature of the field from a circular polarized antenna allows it to read tags in more than one orientation.

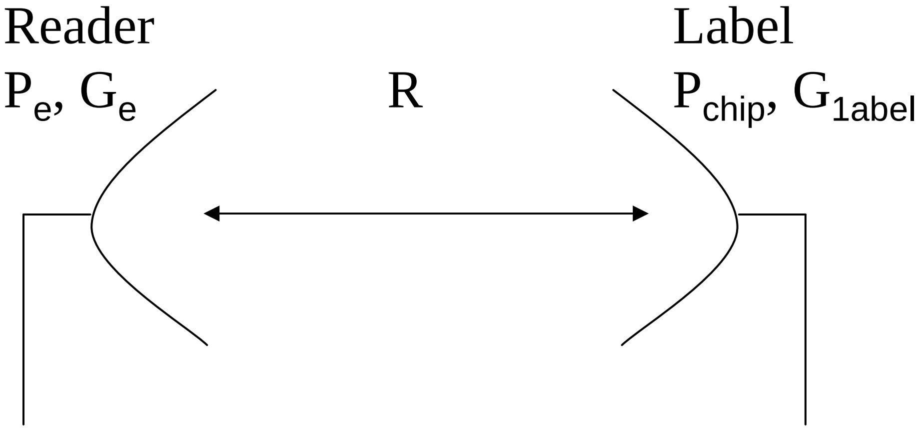


- The down side of circular polarized antennas is that their output is less than linear antennas (approximately 1/3 down).

FRIIS Formula applied to RFID

- Transferred power from a reader antenna to the chip

$$P_{Chip} = P_{EIRP} \cdot \frac{\lambda^2}{(4 \cdot \pi \cdot R)^2} \cdot G_{Label}$$



Peirp = Pe * Ge (dBi)

Read Range of an UHF/GHz Chip

- Example III (UHF)
- under EN 302 208 European regulation:

  P_{ERP} = 2 W equals P_{EIRP} = 3.28W; G_{Label} =1.64
  f = 869MHz; P_{CHIP} = 35µW
  $\vartheta_{Matching}$ = 0.8 ; $\vartheta_{Polarisation}$ = 1 ; $\vartheta_{Antenna}$ = 0.5

$$R_{max} = \sqrt{\frac{3.28W \cdot 1.64 \cdot 0.35m^2}{(4 \cdot \pi)^2 \cdot 35 \cdot 10^{-6} W} \cdot 0.8 \cdot 1 \cdot 0.5} = 6.90m$$

Active vs passive

Passive tag

RF Chip powering + backscattering

Up to 10 m !

Semi-passive=
Battery assisted

Battery for chip powering only, RF transmission from tag to reader is backscattering

Up to 50 m !

Active tag

Battery for chip powering & RF Transmission

Emits its own signal.

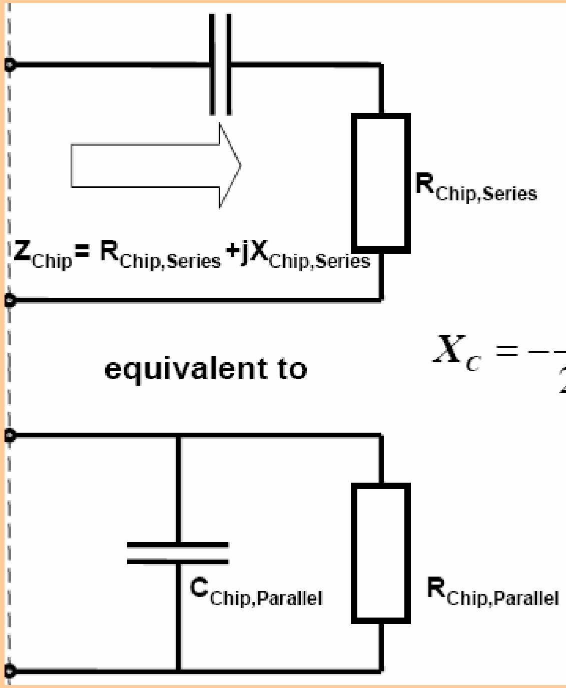
Up to 200 m!

Price ↗ with reading distance

24

UHF antennas (860-960 MHz)

Chip equivalent circuit



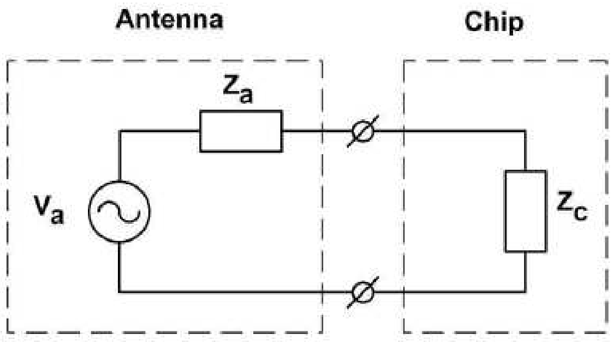
$$Z_C = R + jX_C$$

$$X_C = -\frac{1}{2 * \pi * f * C} = -\frac{1}{\omega * C}$$ ......capacitive reactance

Example of UHF RFID chip: Monza 4 Impinj

		Single-port connection
Chip Load Model		1650 Ω || 1.21 pF
Conjugate Match Impedance	866 MHz	13 + j151 Ω
	915 MHz	11 + j143 Ω
	956 MHz	10 + j137 Ω
Read Sensitivity		-17.4 dBm
Write Sensitivity		-14.6 dBm

Impedance matching

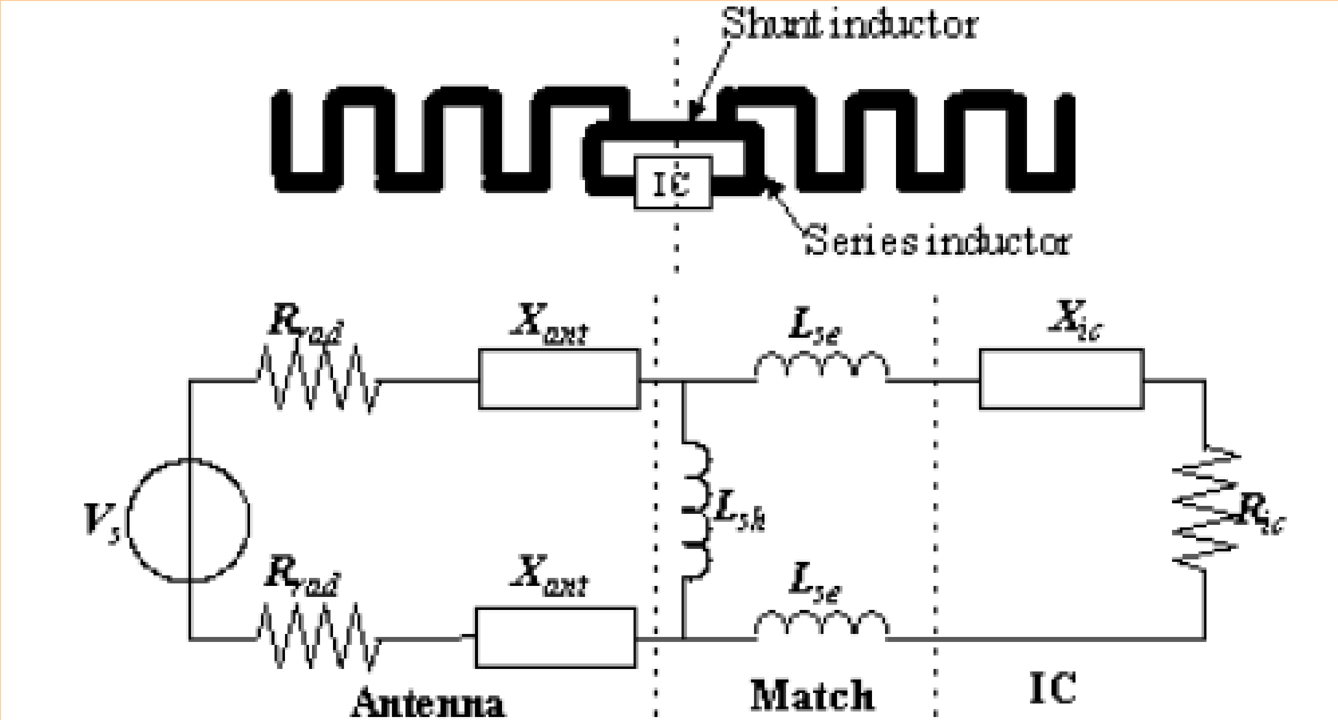


$$\Gamma = \frac{Z_a - Z_c^*}{Z_a + Z_c}$$

- ➢ Know impedance behavior of the Antenna
- ➢ Know impedance behavior of the Chip
- ➢ **Match it!**

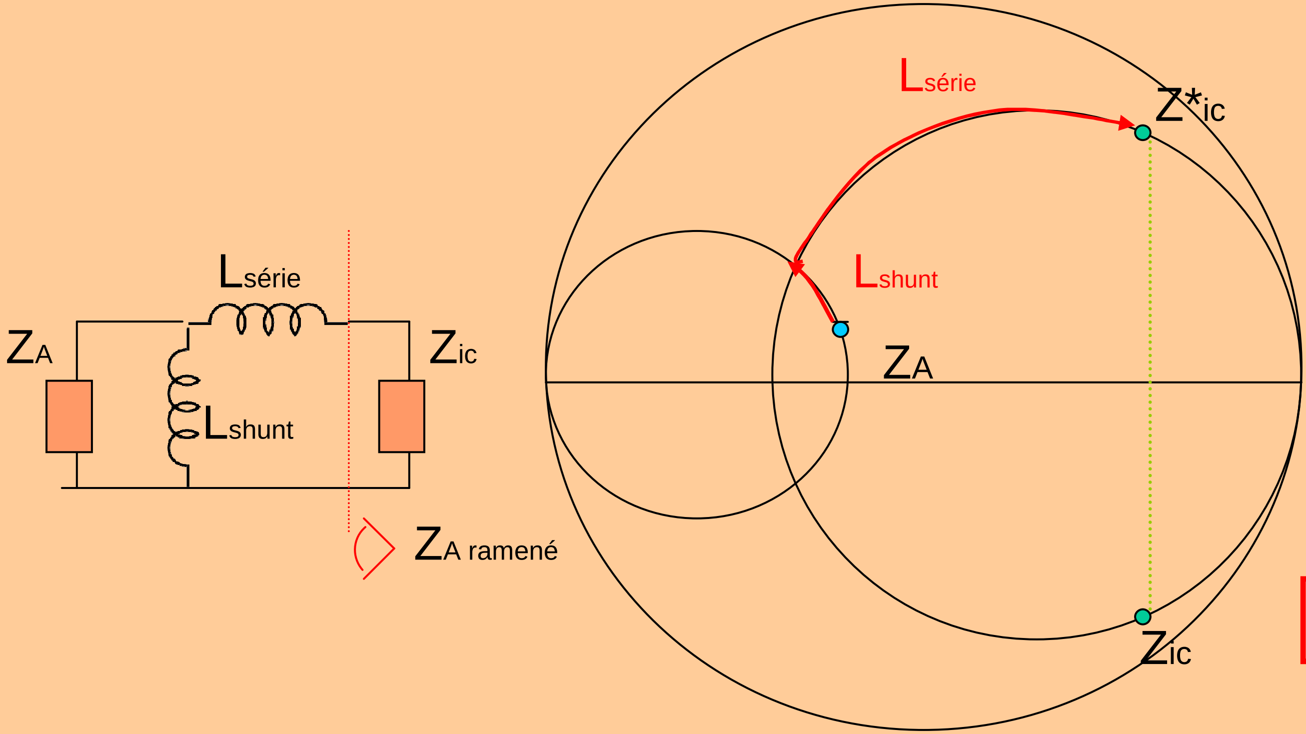
- The chip inp… ≈ 22- j 195 … e(Z_{chip})) ≈9
- To ensure maximum power transfer from the antenna to the reader, the required output impedance should be ≈ 22 + j 195 Ω for 915Mhz.
- This means a inductive (coil-like properties) antenna impedance

Connexion directe de la puce à l'antenne



Adaptation de l'impédance IC à l'impédance antenne via un transformateur d'impédance associant inductance série et inductance parallèle

Principe de l'adaptation



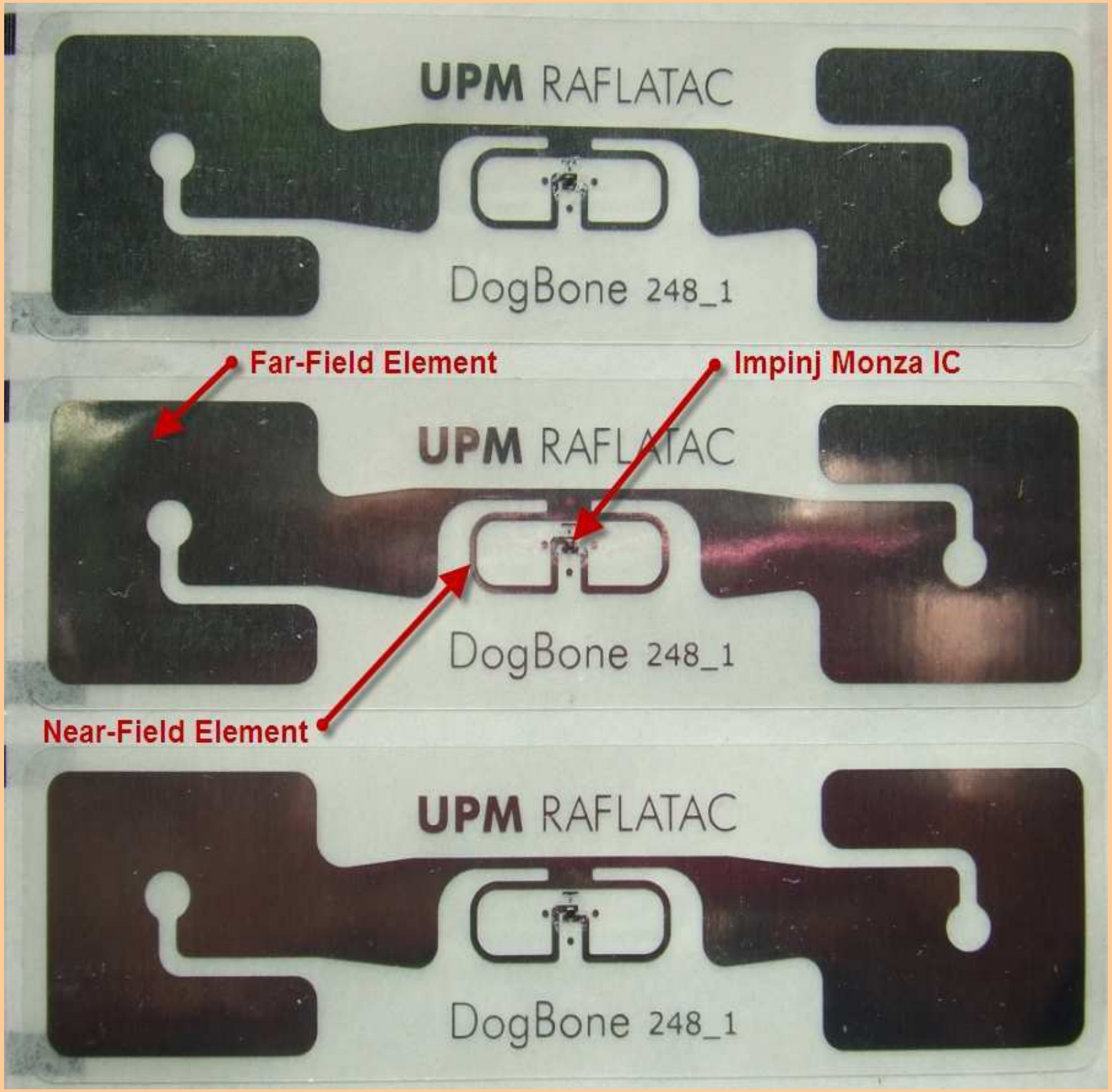
On veut: $Z_{A\ ramené} = Z^*_{ic}$

• Z_A = résonance série du dipole (quelques dizaines d'ohms et réactance faible)

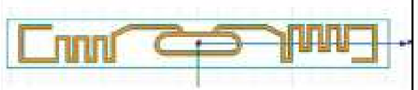
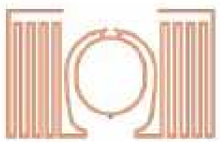
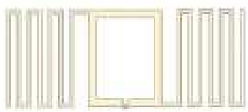
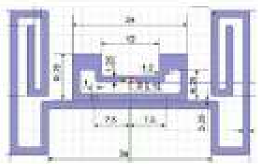
$\Rightarrow$ A priori à l'INTERIEUR du cercle Re(Zic)=constante car valeur faible

$\Rightarrow$ validité du transformateur d'impédance proposé.

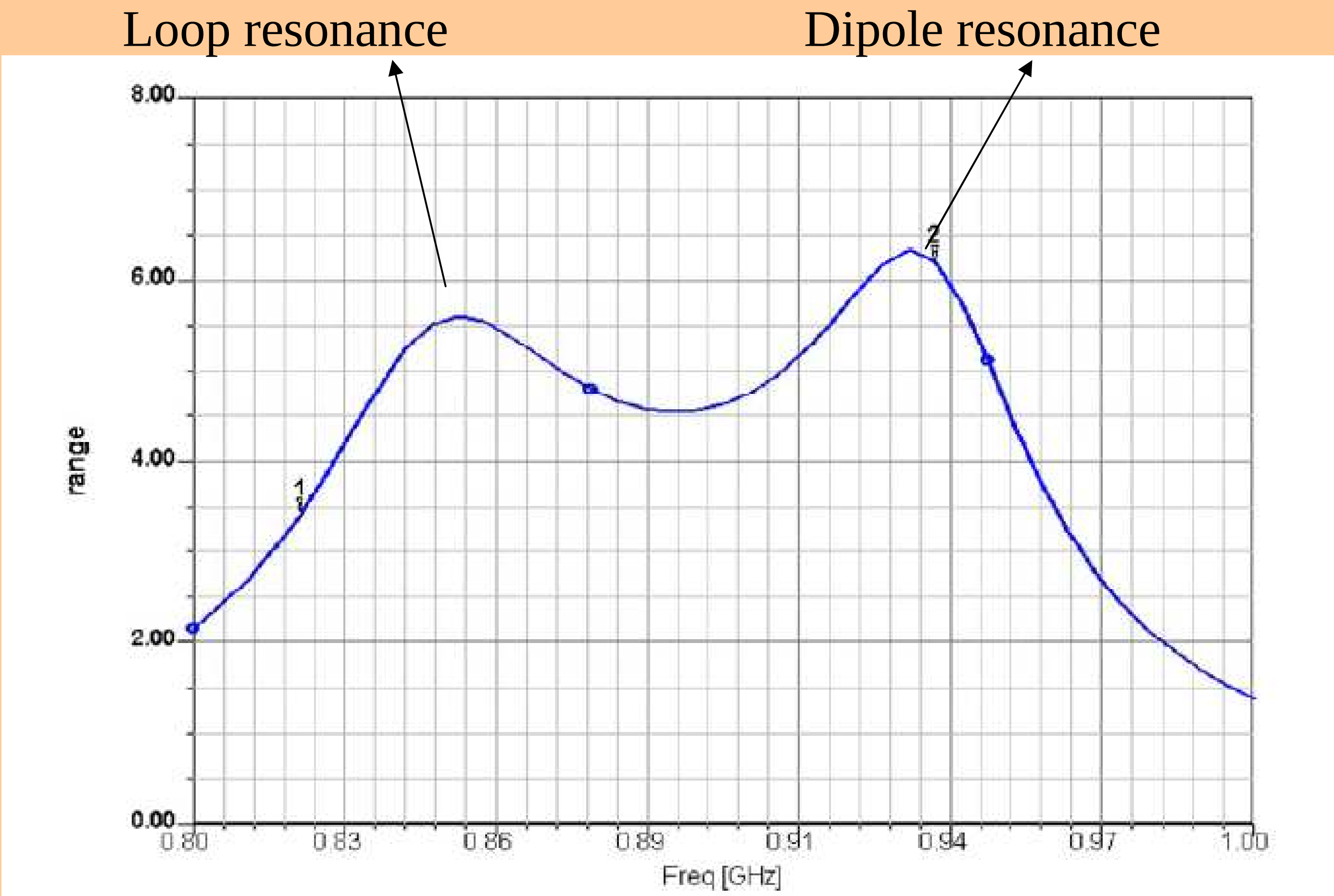
Near-field and far-field elements



Examples de tags UHF à connexion directe

Antenna Design	Layout	Description
Range: Far Field **Name: FF98-4**		Dimension: 98mm x 10mm Works best up to Epsilon r = 4
Range: Far Field **Name: FF95-8**		Dimension: 95mm x 10mm Works best up to Epsilon r = 8
Range: General Purpose **Name: GP33**		Dimension: 33mm x 24mm
Range: Mid Range **Name: MR34**		Dimension: 34mm x 15mm
Application: Fashion / airport baggage tagging **Name: OmniDir50**		Dimension: 50mm x 30mm

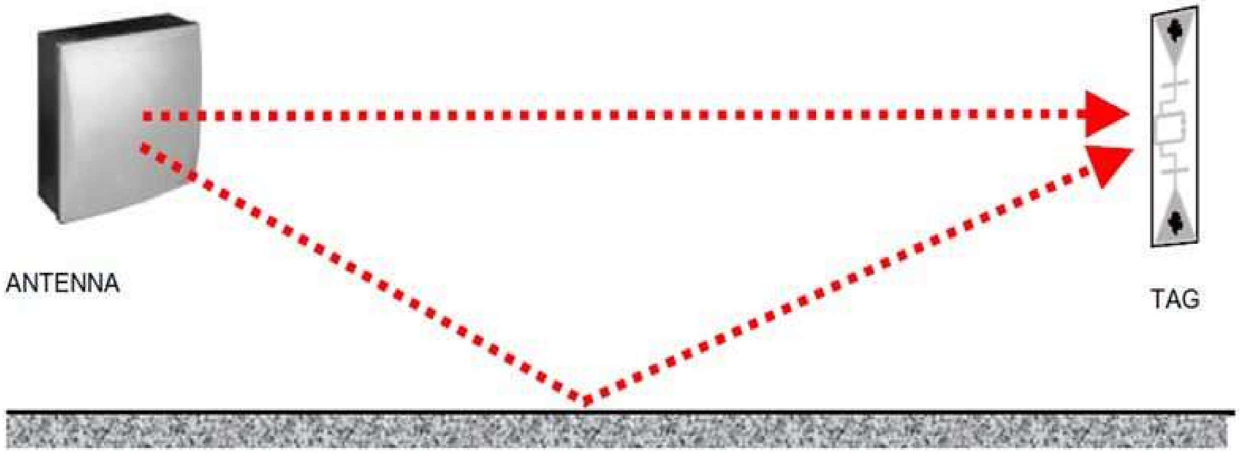
Read range (in meters)

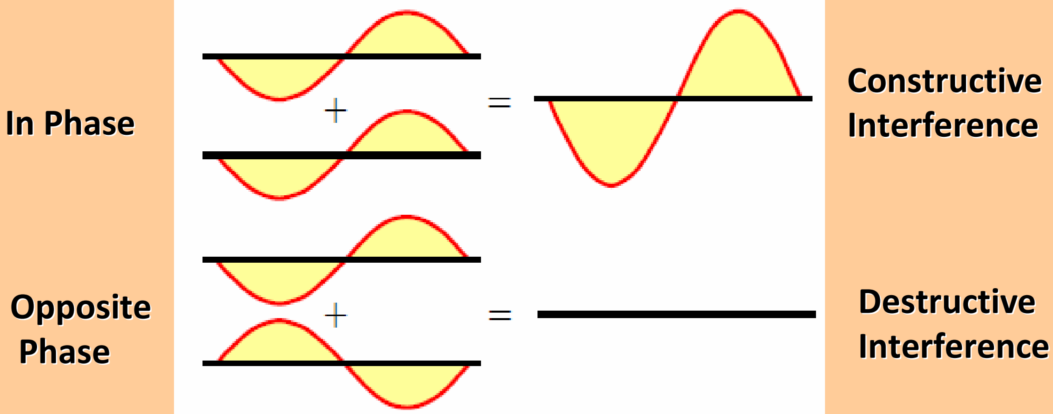


Propagation, absorption, detuning issues

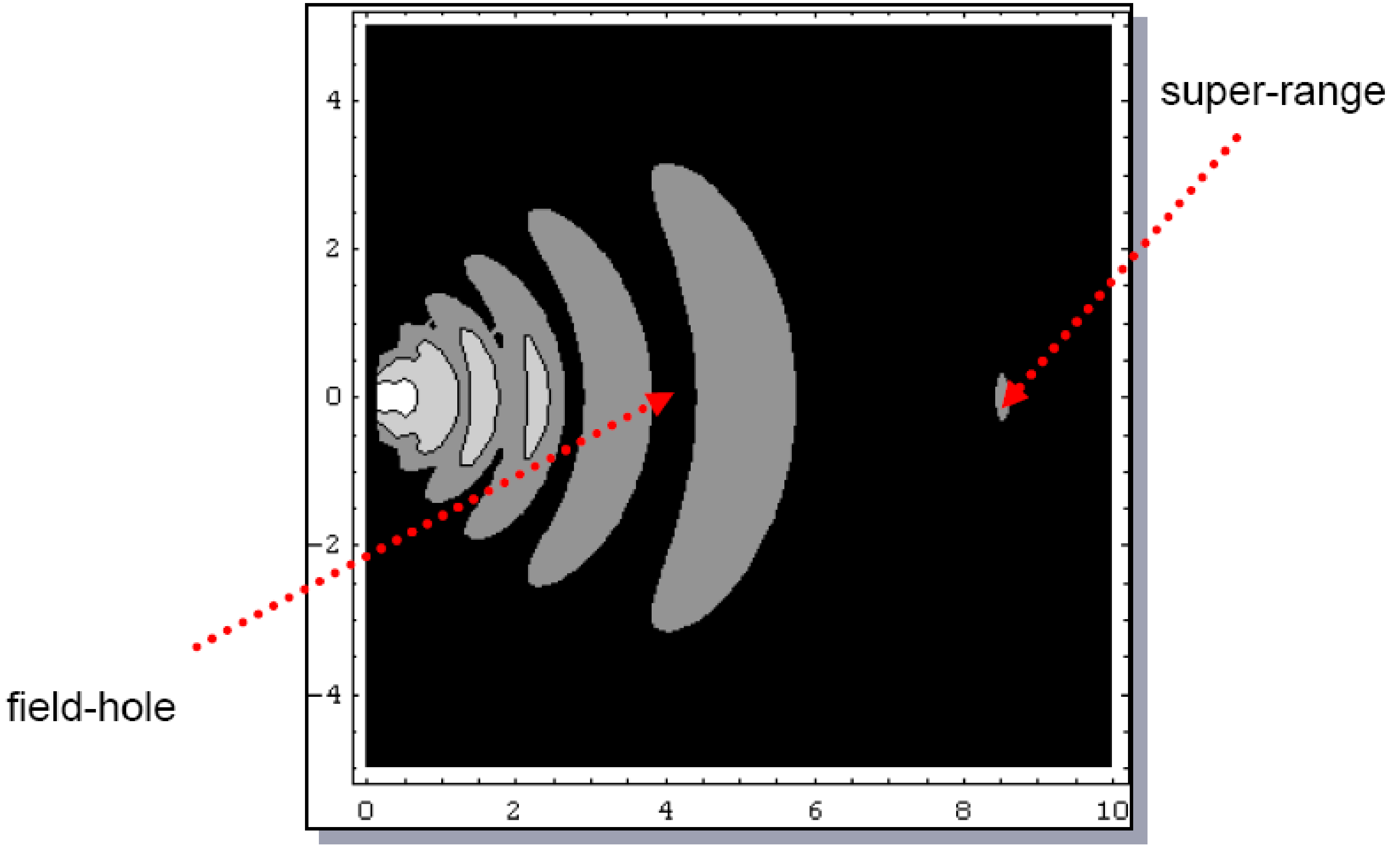
Multipath effects (1)

1 At UHF frequencies multi-path RF waves, caused by reflections from the floor and other obstructions, may combine constructively or destructively.

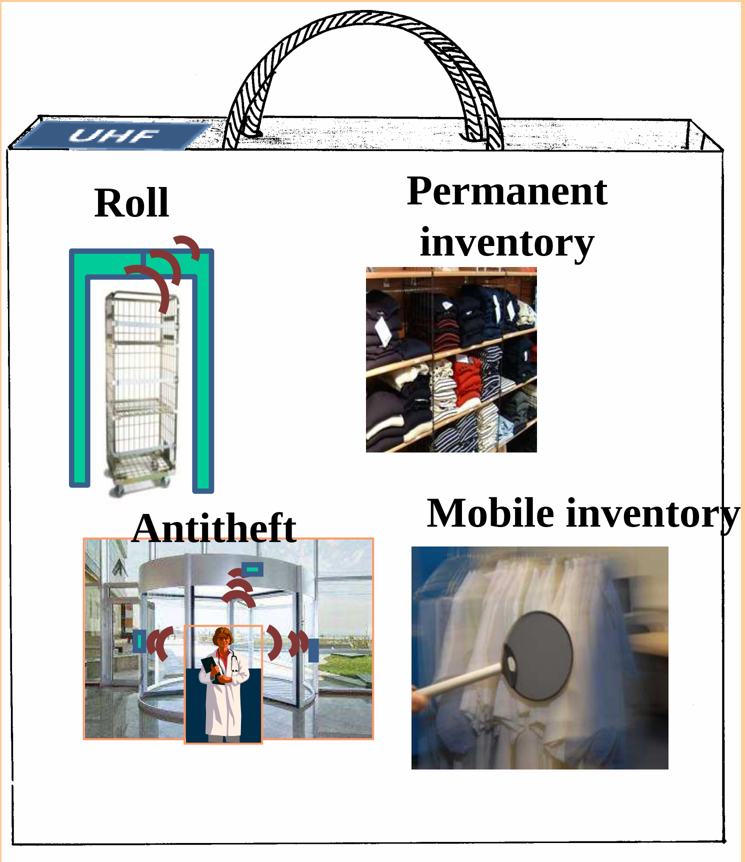




Multipath effects (2)



Dynamic reading



Tags detected

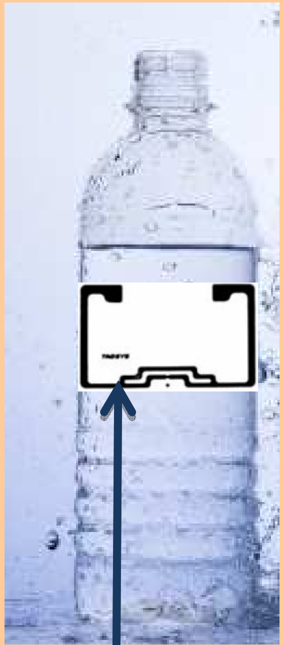
100 %

90 %

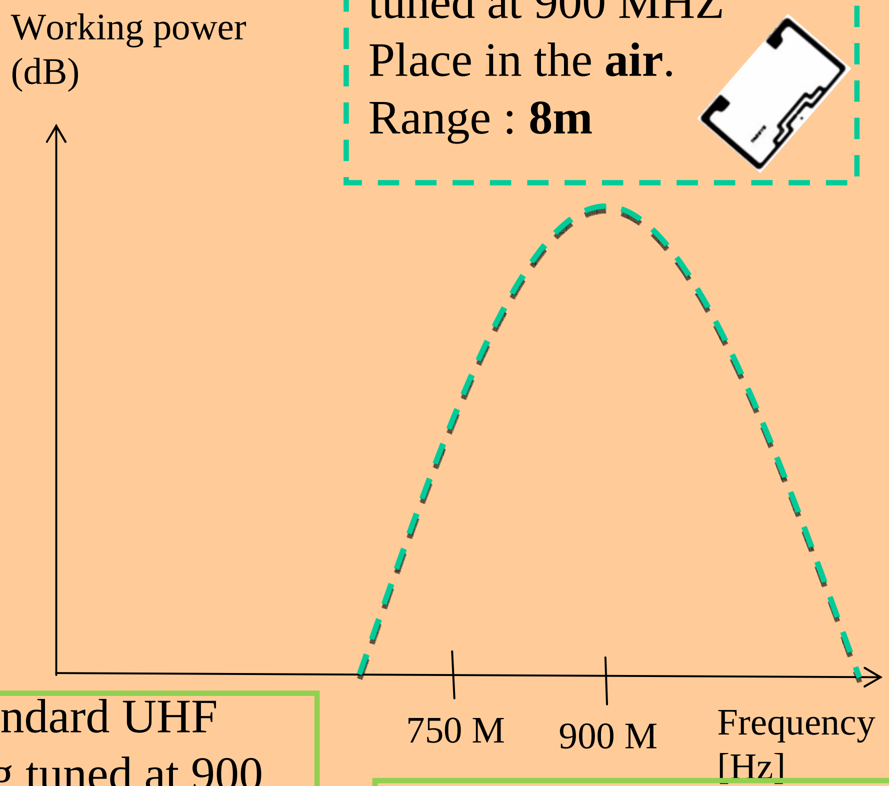
0 %

Environmental constraint

UHF



The tag is NOT read!!



Standard UHF Tag tuned at 900 MHZ
Place in the **air**.
Range : **8m**

Standard UHF Tag tuned at 900 MHZ
placed in **water**.
Range : **≈0 m**

Attenuation ≈ -40 dB
Detuning :
[900→750]MHZ

HF

Detection of the tag

38

UHF RFID Inlay: Material Detuning Effect

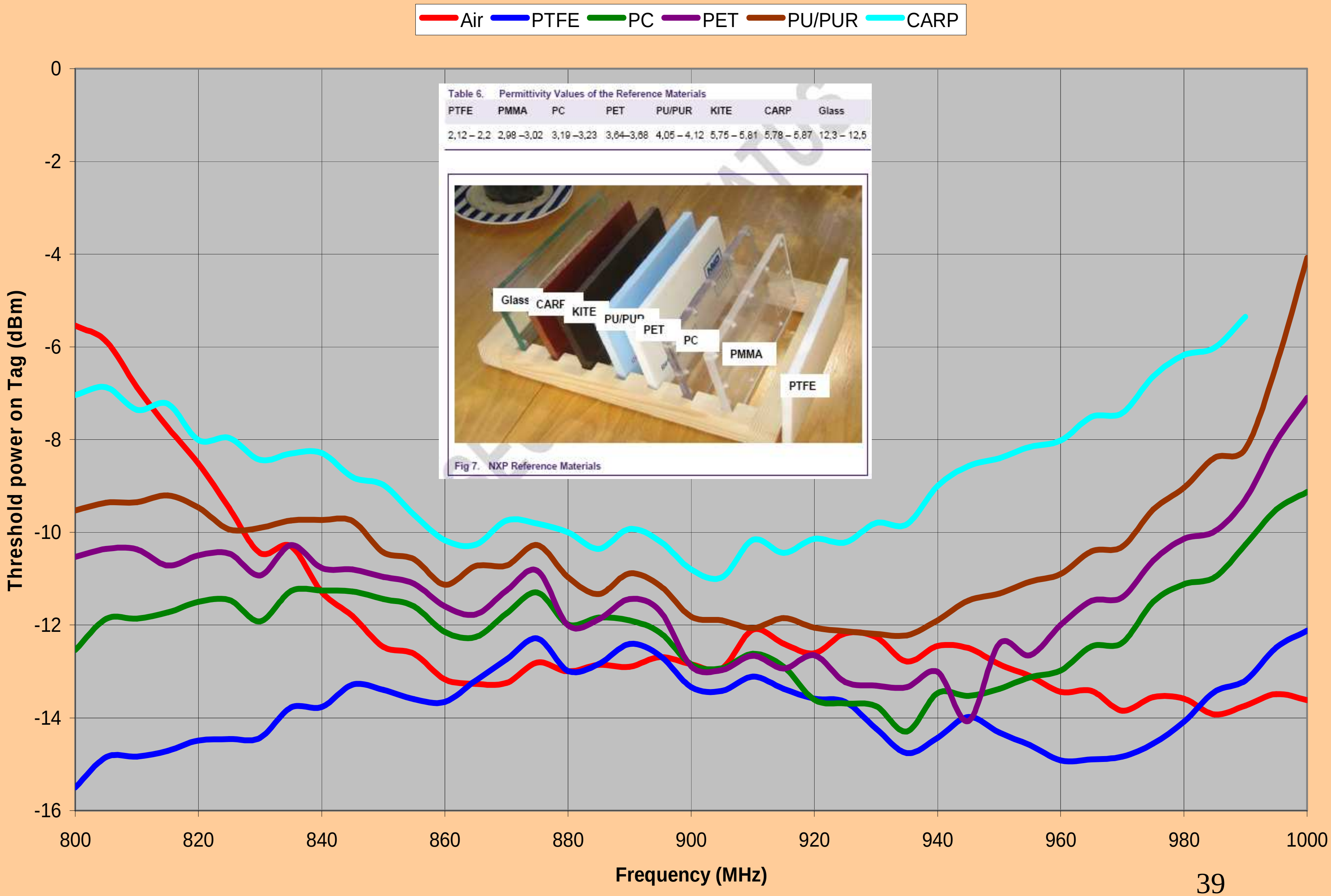


Table 6. Permittivity Values of the Reference Materials

PTFE	PMMA	PC	PET	PU/PUR	KITE	CARP	Glass
2,12 – 2,2	2,98 –3,02	3,19 –3,23	3,64–3,68	4,05 – 4,12	5,75 – 5,81	5,78 – 5,87	12,3 – 12,5

Fig 7. NXP Reference Materials

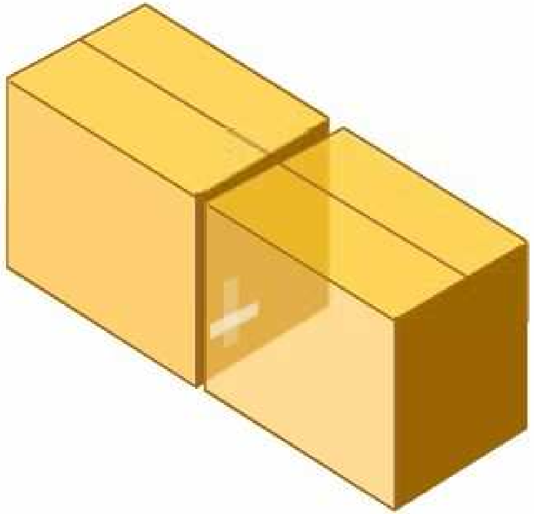
Label position

It may not be possible to read labels on cartons in the center of a pallet.

- It depends on a number of factors:
  - Output power of the reader antennas
  - The distance from the antennas
  - The material in the cartons

- If at all possible, position the labels on the outside of the pallet load.

- One situation that **must** be avoided is overlapping labels
  - Labels that overlap are the same as placing each label close to metal. They de-tune each other and performance is lost.



EPC Gen2 protocol

UHF RFID Standard: EPC Gen2

- **EPC Global**

● *Not-for-profit organization entrusted by industry to establish and support the Electronic Product Code (ePC).*

● *Develop a global standard for immediate, automatic, and accurate identification of any single item in the supply chain of any company, in any industry, anywhere in the world. The tag is only a token to access distributed and replicated data bases.*

● *EPC Global Generation 2 (new global protocol available since december 2004)*

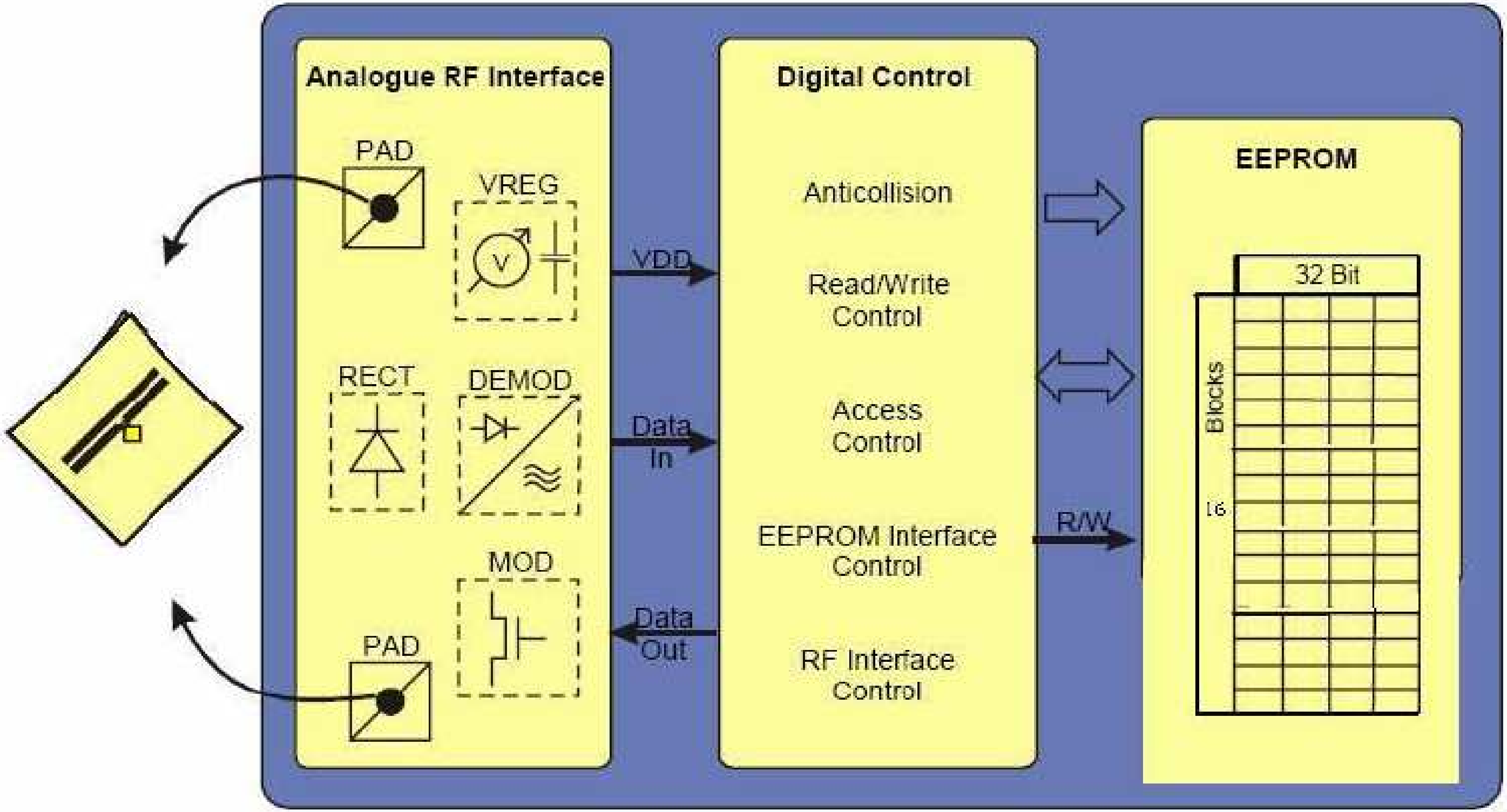
- **ISO 18 000 – Part 6 (International Standard Organization)**

Information technology - Radio frequency identification (RFID) for item management Type C (same as EPC Global Gen2, RTF protocol)

EPC Gen2 protocol

Integrated circuit - Memory

Gen2 Block Diagram



+ data encoder
+ clock extractor

Memory types and Gen2 operations

Read Only (RO)

Data (ID) are burned into the tag at factory ⇒ can never be changed

Write Once Read Many (WORM)

Data generally written into tag at point of application ⇒ when encoded, cannot be reprogrammed

Read Write (RW)

Data may be written, erased and rewritten into memory in field

Operation	Function
Inventory	Singulate tags and receive their EPCs
Read	Read tag memory
Write	Write tag memory
Lock	Permalock, lock, or unlock tag memory
Kill	Render a tag permanently inoperative

Memory zones

Not everything below is implemented usually:

UID/EPC MEMORY
EAS/AFI/WRITE ACCESS
KILL/READ/WRITE PASSWORDS
USER MEMORY BLOCK 1
USER MEMORY BLOCK 2
....
USER MEMORY BLOCK N

- **UID = Unique ID**
  Unique ID, usually read only similar to the MAC address of a network card.
- **EPC memory = Electronic Product Code**
  Writable 96 bits EPC code similar to barcode
- **EAS = Electronic Article Surveillance**
  Security bit implemented on some chips
- **AFI = Application Family Identifier**
  Byte used to categorize the tag by application
- **Write access**
  Byte used to store the ACL (Access Control List) of the user memory
- **Passwords to kill the tag or read/write**
  Different 32 bits passwords used by the tag. If unused, bits are zero
- **User memory**
  Structure and size depends on the chip - up to a few kb

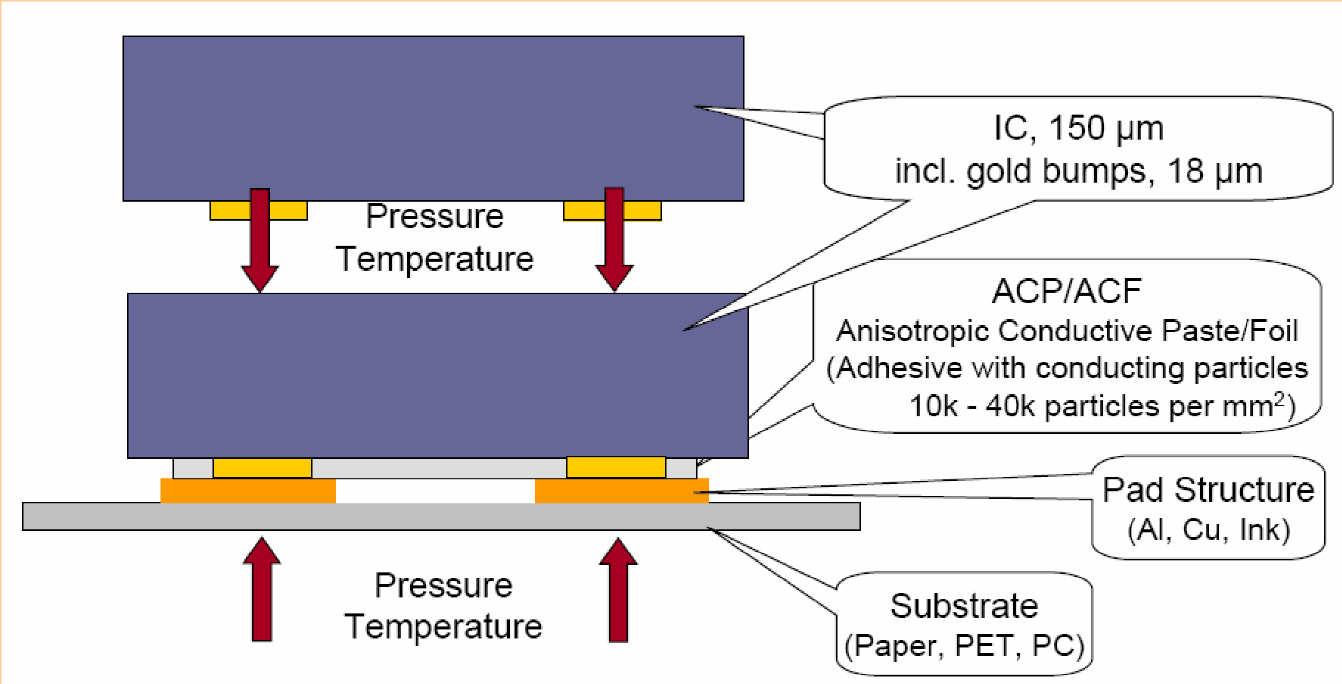
Delivery types

Bumped Wafer on Film Frame Carrier
UCODE HSL, UCODE EPC 1.19, UCODE EPC G2

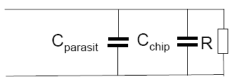
Standard Package TSSOP8
UCODE HSL, UCODE EPC G2

I•Connect Flip Chip Package
UCODE EPC G2

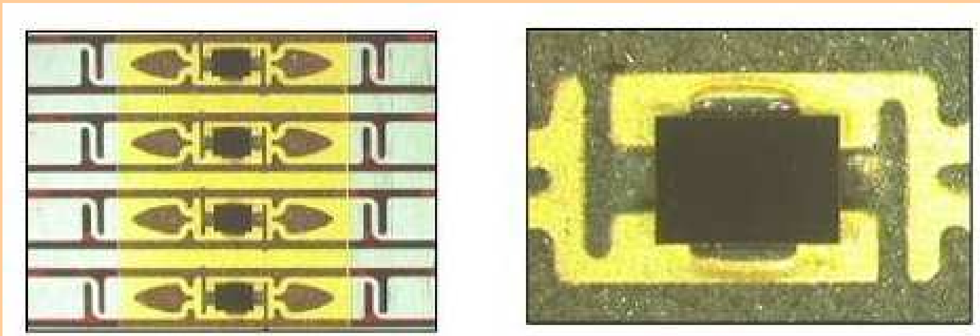
Flip Chip Assembly



Assembling process adds parasitic Capacitances



$$C_{tot} = C_{parasit} + C_{chip}$$



EPC Gen2 protocol
Coding and Modulation

Reader-to-Tag communications

Modulation

ASK: can be detected with a simple envelope detector

- Double-sideband amplitude shift keying (DSB-ASK)
  - Simple, but not spectrally efficient
- Single-sideband amplitude shift keying (SSB-ASK),
  - More complex (requires a IQ modulator)
  - More spectrally efficient
- Phase-reversed amplitude shift keying (PR-ASK)
  - Reduces the width of the spectrum

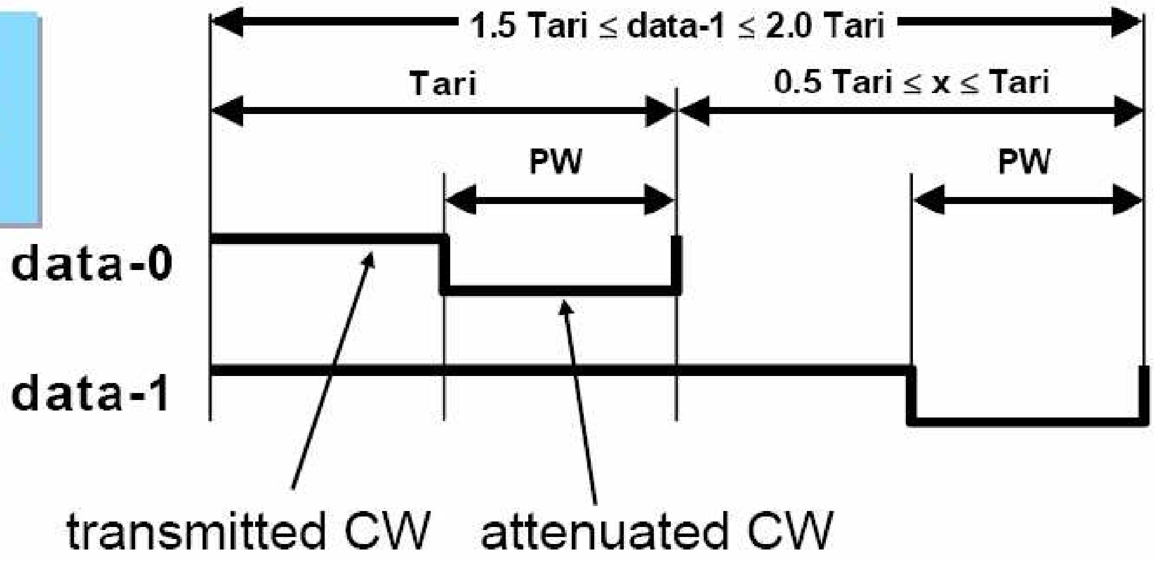
Data Coding

Pulse interval encoding (PIE)

- Ensures a constant RF energy from the reader to power the tag chip.

Reader-to-Tag: PIE encoding

Tari = reference time interval (duration of a data-0)



Data rates according with local radio regulations.

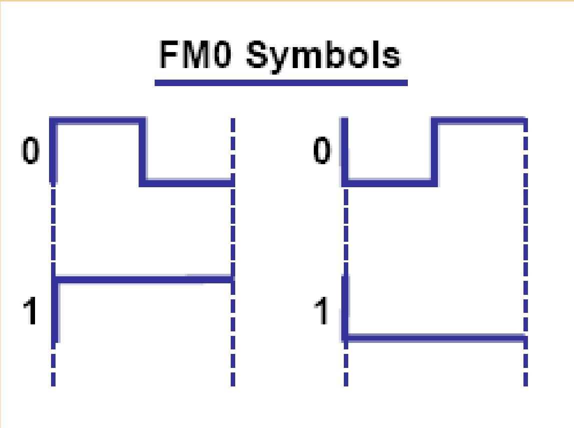
6.25µs = 160kbps

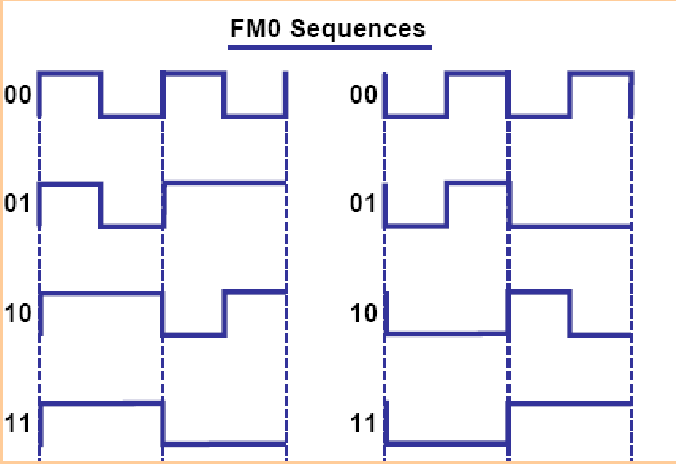
12.5µs = 80kbps

25µs = 40kbps

Tari Value	Tari-Value Tolerance	Spectrum
6.25 µs	+/– 1%	DSB-ASK, SSB-ASK, or PR-ASK
12.5 µs	+/– 1%	
25 µs	+/– 1%	

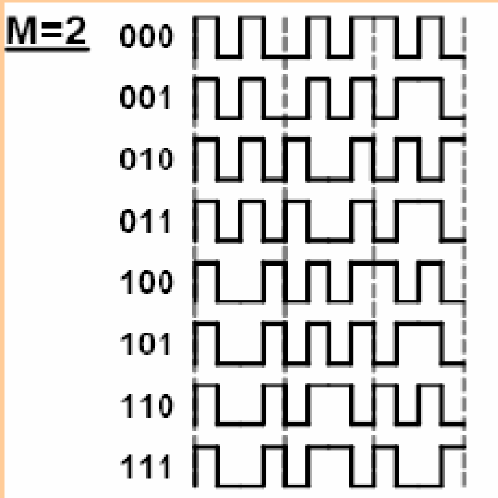
Tag-to-Reader: FM0 or Miller





FM0 inverts the baseband phase at every symbol Boundary

A data-0 has an additional mid-symbol phase inversion.

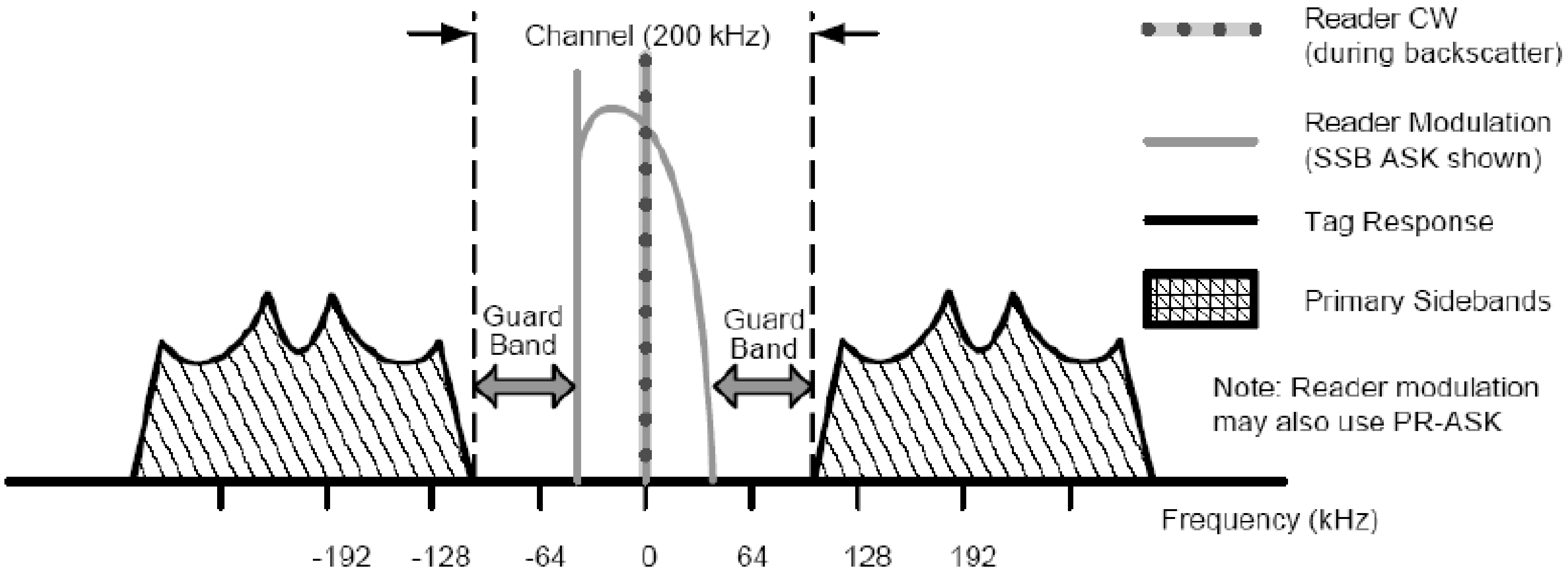


Baseband Miller inverts its phase between two data 0s in sequence, or in the middle of a data-1 symbol.

Subcarrier spectral allocation

Region	Link	Rates / Format
Europe	Forward	Tari=25μs SSB-ASK
	Backscatter	53.3 kbps at 213.3 kHz subcarrier

B: Subcarrier Spectral Allocation (CEPT: Multiple Channels)



Read rate - Bit rate

	EU	US
Read rate	600 tags/sec	Read rate: 1600 tags/sec
T→R Bit rate	**from 16 kbits/sec** (dense reader) **to 160 kbits/sec** (Maximum throughtput)	from **64 kbits/sec** (dense reader) to **640 kbits/sec** (Maximum throughtput
R→T Bit rate	from **40 kbits/sec** (Nominal) to **80 kbits/sec** (Maximum throughtput)	from **40 kbits/sec** (Nominal) to **128 kbits/sec** (Maximum throughtput)

Environment	**Communication speed**
Noisy	Need to talk slowly and carefully
Europe	
Many readers	
Quiet	Can talk fast
North America	
Few readers	

- Gen2 sometimes needs fast tag reads (Pallets moving through a dock door)
- Gen2 sometimes needs slow tag reads (Noisy environments)
- Solution: Variable read rates

EPC Gen2 protocol

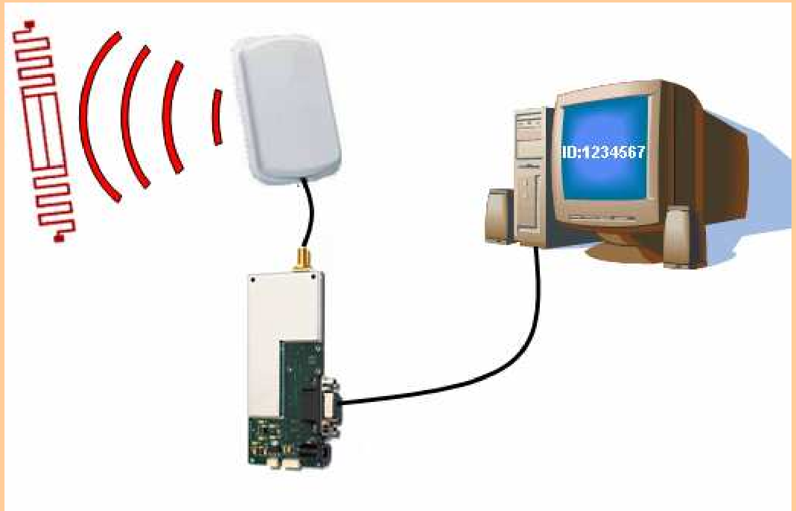
Anticollision algorithms

Protocol: *Reader Talk First vs Tag Talk First*

RTF

1. Tag power up
2. Wait for the reader cmd
3. Receive the reader cmd
4. Response to the reader

TTF

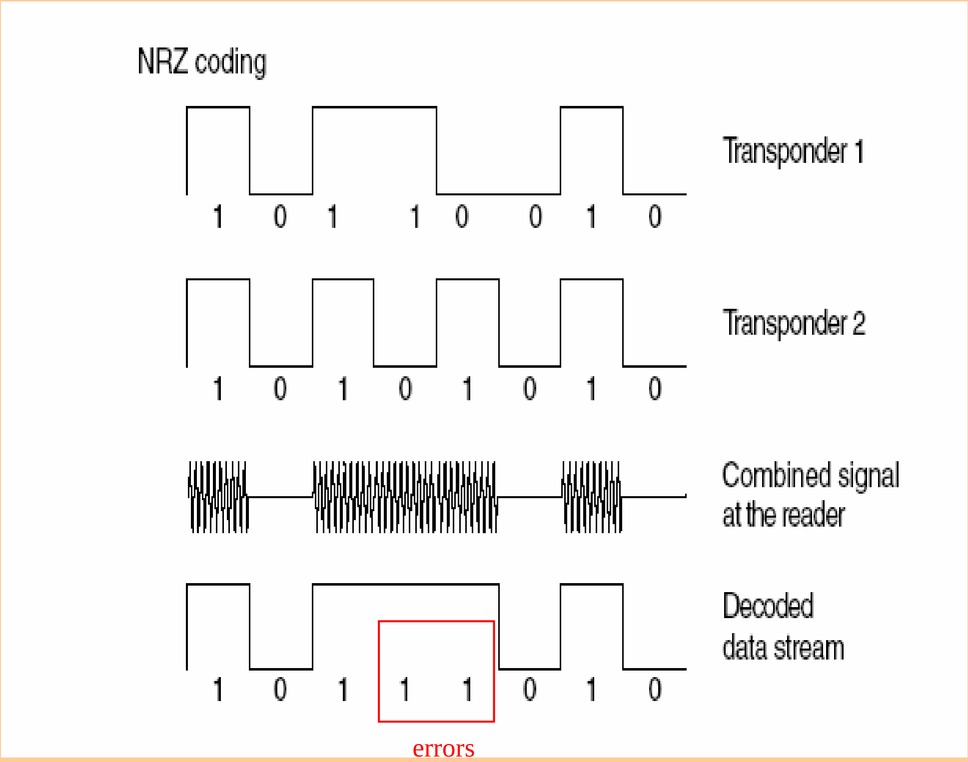


1. Tag power up
2. Send ID and data

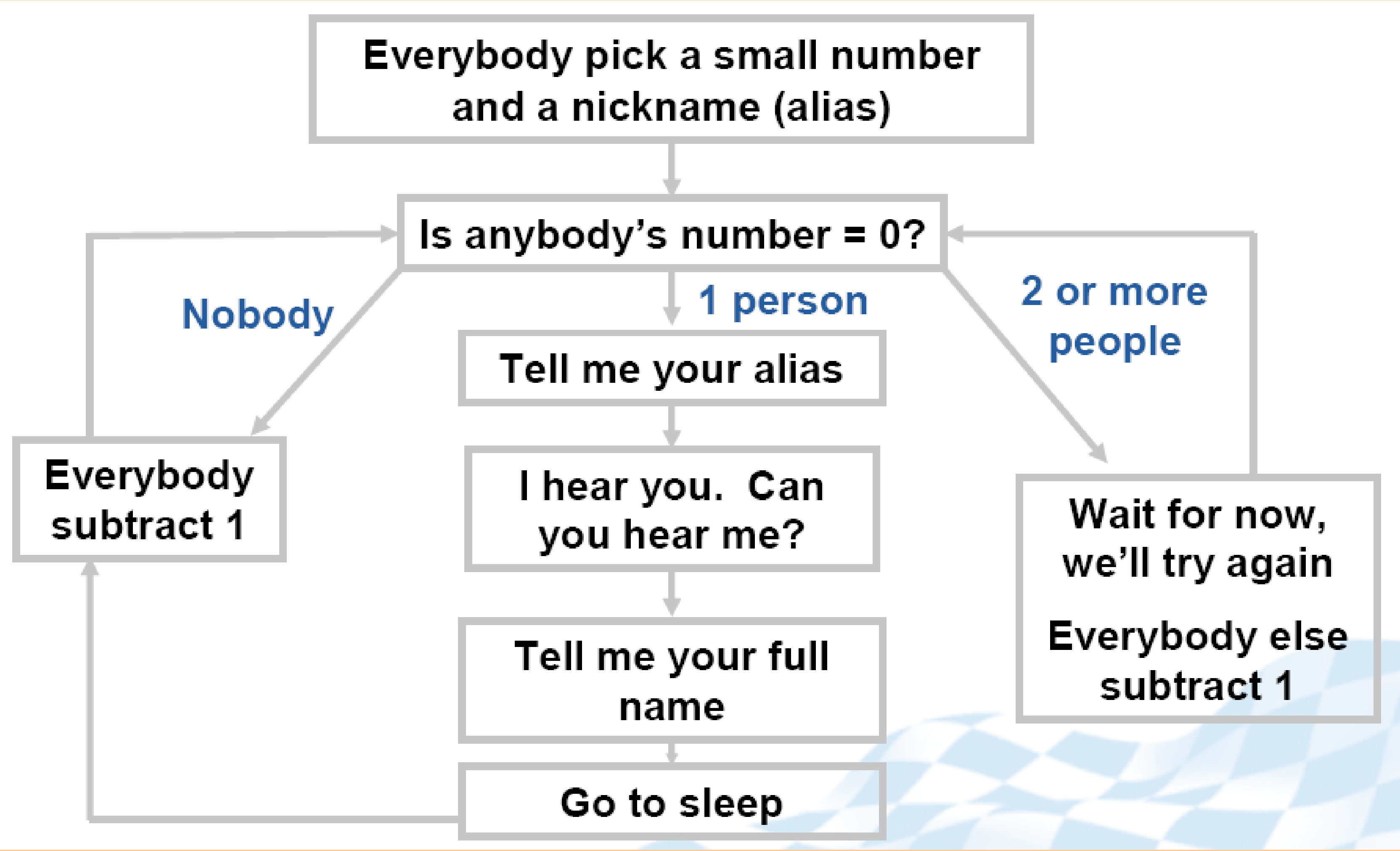
Collisions and Anticollision Algorithm

Origine of the collision:
A collision occurs when two or more transponders send theirs datas at the same time.

Anticollision algorithm in EPC Gen2 protocol:
Slotted Aloha-based probabilistic algorithm



Simplified Aloha algorithm



Slotted Aloha-based probabilistic algorithm

- **Reader issues a *Query* command with a parameter *Q***
  - Starting the inventory round
- **Tags load a *Q*-bit random value into their slot counter**
  - If a tag loads a zero it replies immediately, backscattering an RN16
- **Reader acknowledges the tag by sending an *ACK* containing this same RN16**
- **Acknowledged tag backscatters its PC, EPC, CRC-16**
- **Reader issues a *QueryRep* command**
  - Tag toggles the state of its **inventoried** flag and leaves the round
  - All other tags decrement their slot counters
  - If any tag decrements to zero, it replies with an RN16

Reader Signaling

Tag Signaling

Symbol	Description
P	Preamble (R=>T or T=>R)
FS	Frame-Sync
RN16	16-bit Random Number

RN16 (16 bits random number) ≠ Q-bit random value (length $L = 2^Q - 1$)

Collisions and Q adjustment

- Slot number of each tag is independently chosen

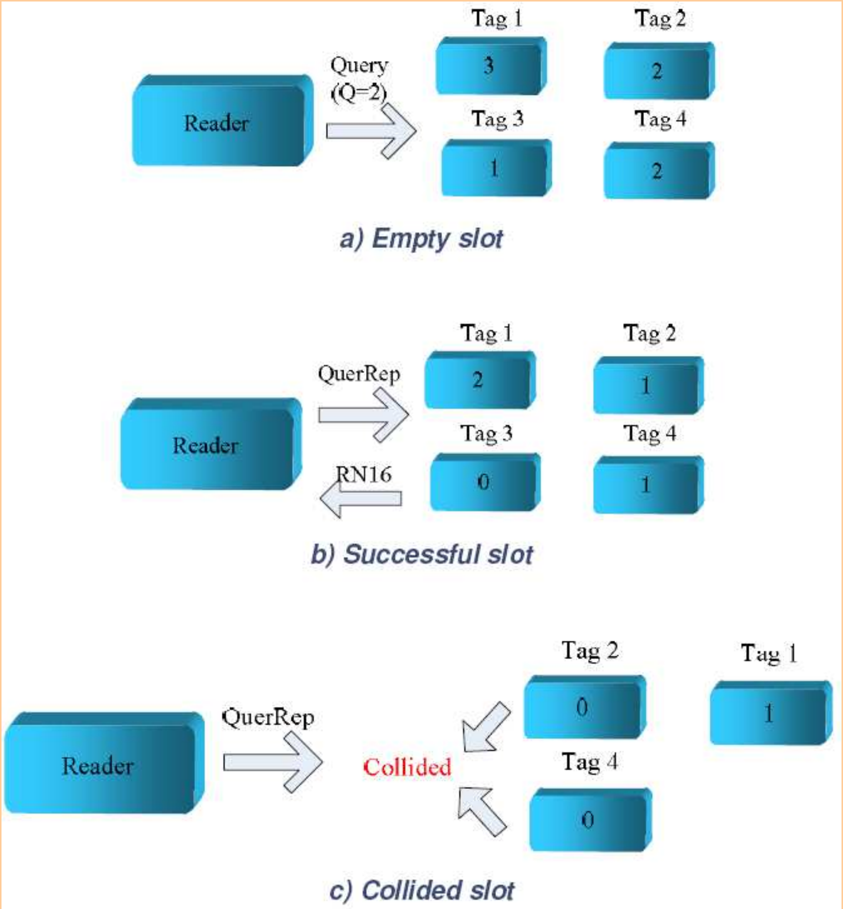
⇒ collisions happen

- If $2^Q - 1$ = number of tags in the read area

⇒ minimize collision rate

⇒ maximum system efficiency

- **The application can optionally set the starting point**
  - Application can optimize inventory, based on a priori knowledge of the population size, by setting the starting Q value
- **Real-time Q adjustment is handled by the reader**
  - At any given time instant, peak inventory efficiency requires:
    - Allocated slots ≈ Number of remaining (uncounted) tags
  - Real-time visibility into the physical layer metrics is critical
    - Number of single, collided, and empty slots



Typical read rate