InnoSoc
Innovative ICT Solutions
for the Societal Challenges

Fundamentals and Applications of RFID technology

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History of RFID technology

Léon Theremin

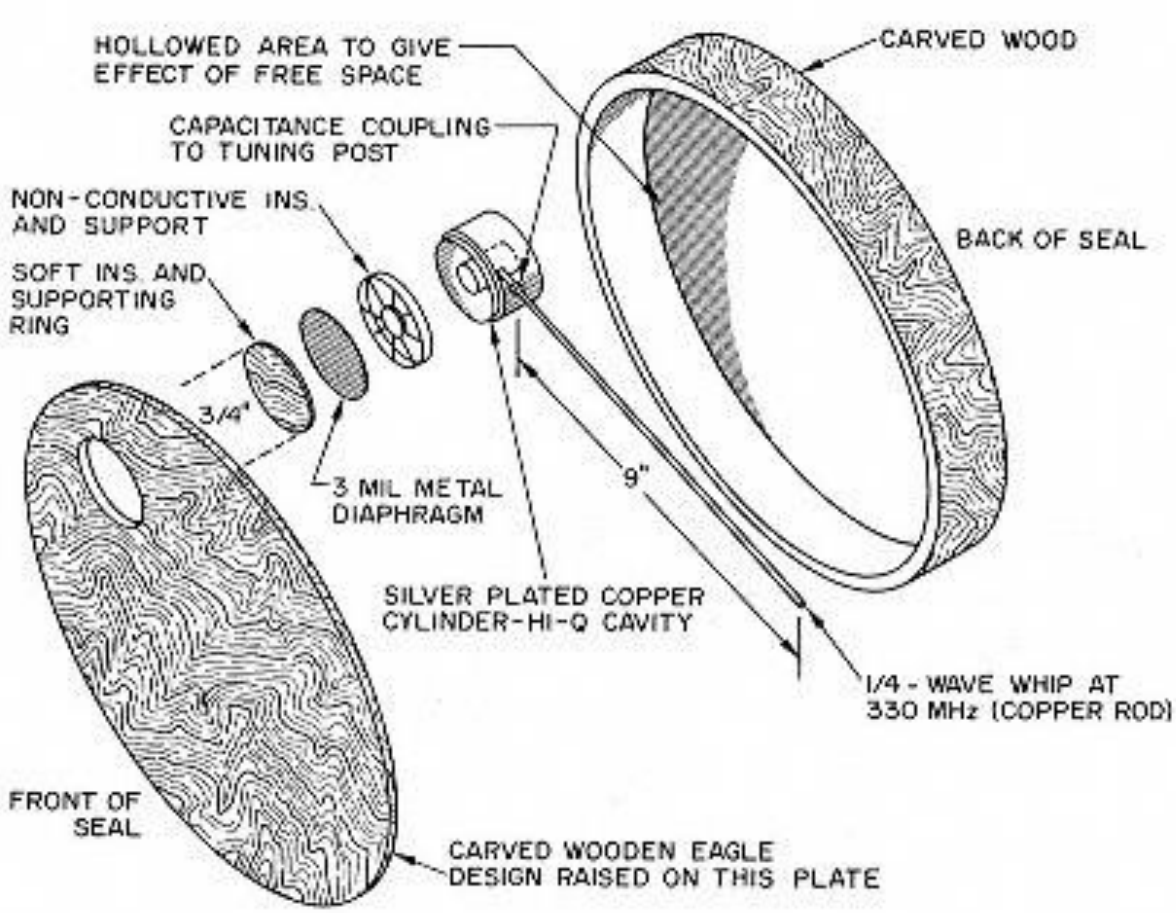
- Inventor
- Inductive coupled music instrument

Léon Theremin

- 1945 „The Thing”
- Gift to US from Soviets

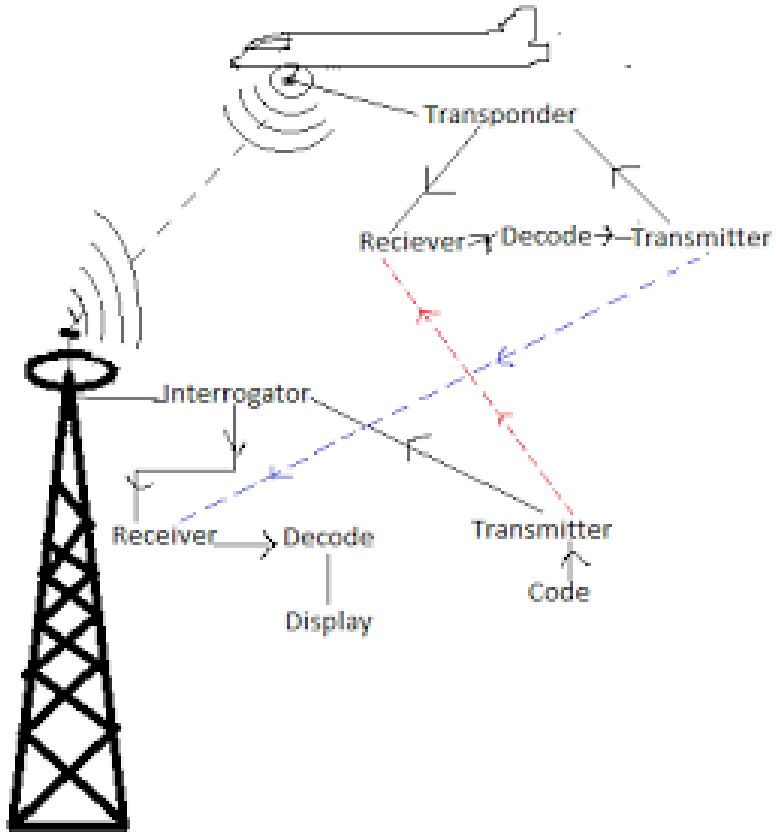
Passive espionage device

- Re-radiated power on 330 MHz
- Sound tuned the antenna
- Tuning modulated, re-radiated RF signal
- The received signal contained the sound information of the room



Aircraft detection

- Identification-Friend or Foe(IFF)
- Secondary surveillance radar (SSR)



RFID History

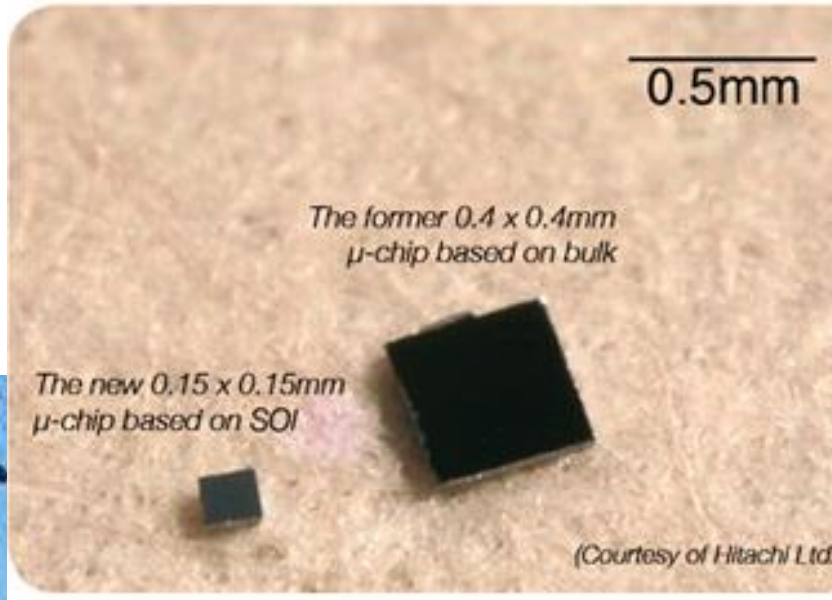
- Mario W. Cardullo claims to have received the first U.S. patent for an active RFID tag with rewritable memory on January 23, 1973.
- 1970s, Los Alamos National Laboratory start to develop a system for tracking nuclear materials.
- 1980, Alamos scientists who worked on the project left to form a company to develop automated toll payment systems.
- 125 kHz -> 13,56 MHz, greater range
- In 90', the technology was too expensive to grow

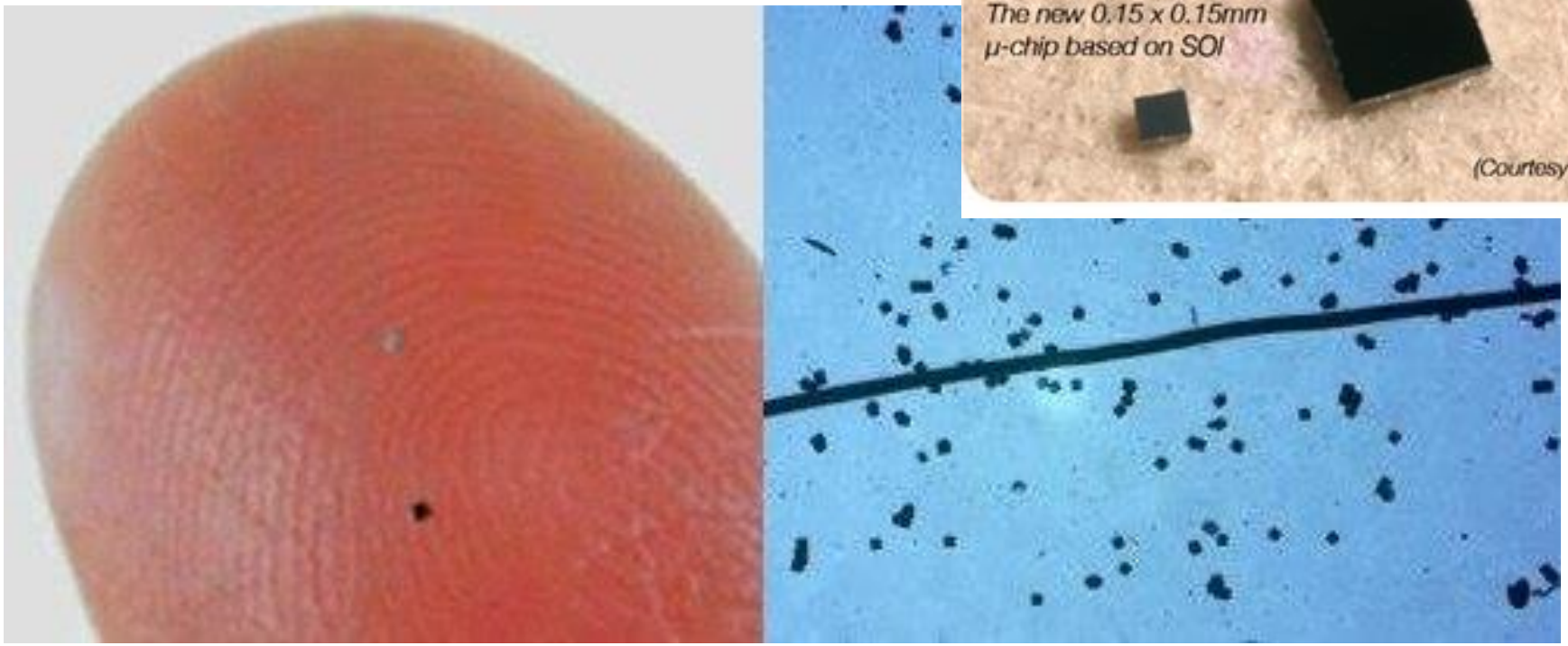
RFID History

- Some of the biggest – Tesco, Wal-Mart, and the U.S. Department of Defense – have said they plan to use EPC technology to track goods in their supply chain.
- EPCglobal ratified a second-generation standard in December 2004
- This Gen 2 become adopted – with other EPC RFID technology – in the whole world.

Privacy concerns

- Hitachi made a hair wide RFID with the „µ chip”





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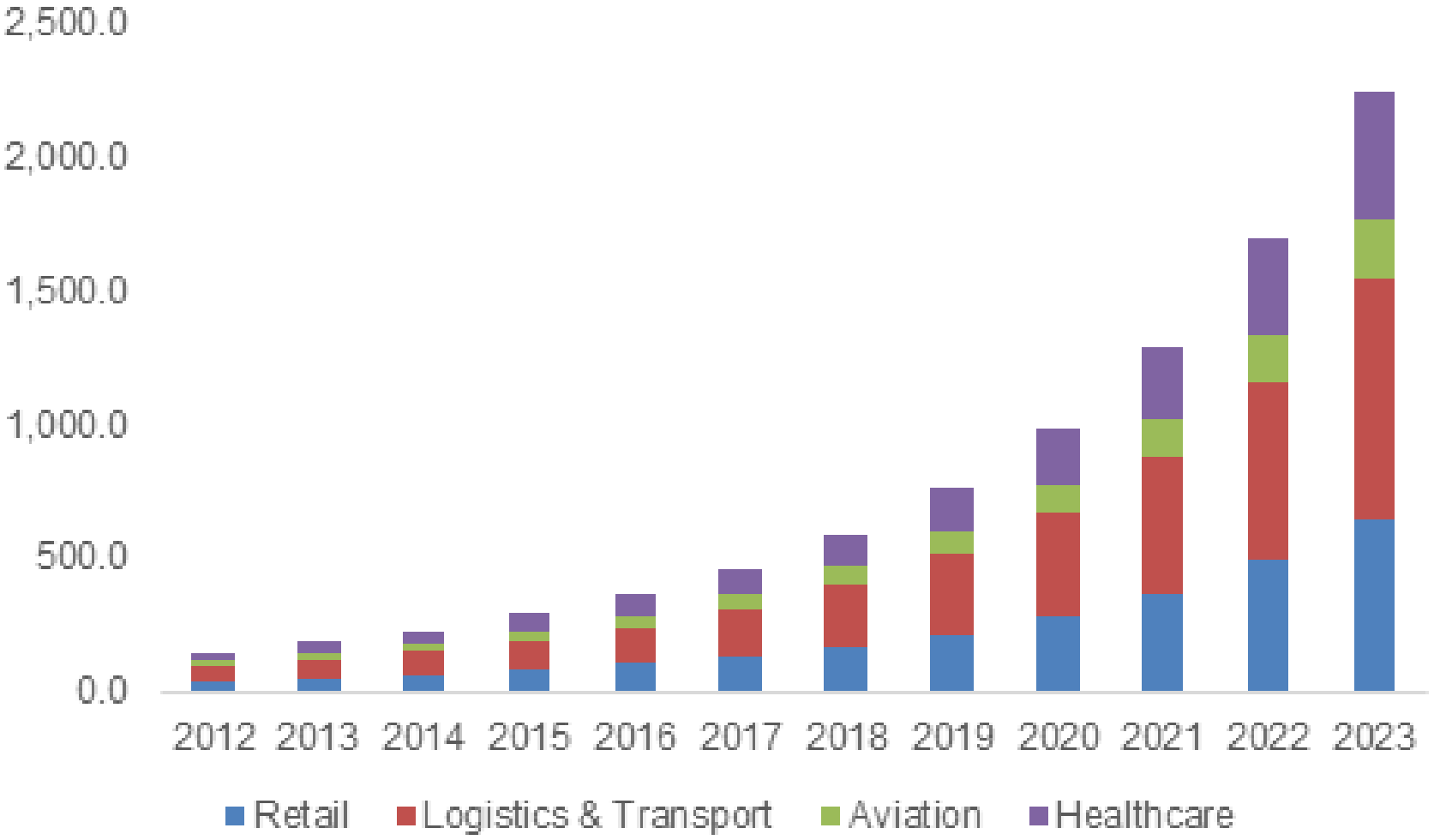
RFID market share

Market penetration



Some Manufacturers

ALIEN

CONFIDEX
Capturing IDeas

MOTOROLA

The applier who lighted a spark

- Cutting half the loading time of trucks
- Very foreseeing
- Infrastructure was not good, there were no standards for the RFID tech -> EPCGlobal
- Improved inventory accuracy by 13%

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Introduction to RFID technology

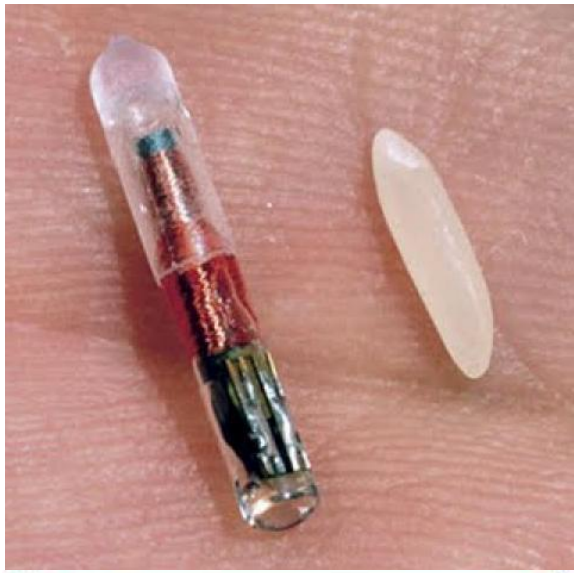
What is RFID?

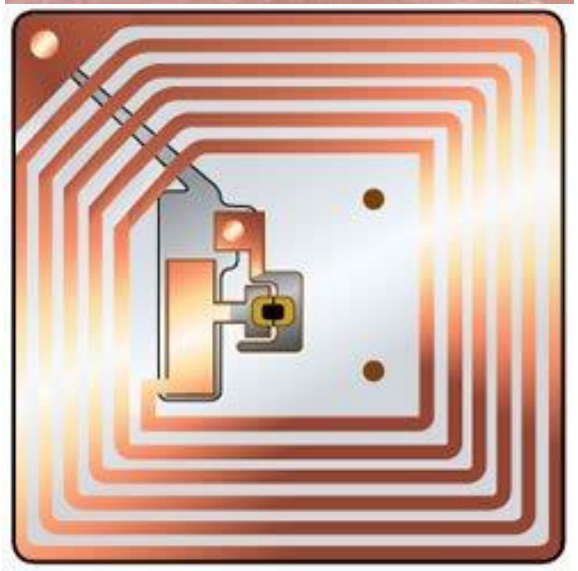
What is RFID?

- Radio Frequency Identification RF-id
- Query-response technology
  - Matthew 7:7 - Ask, and it shall be given you; seek, and ye shall find; knock, and it shall be opened unto you:

What is RFID?

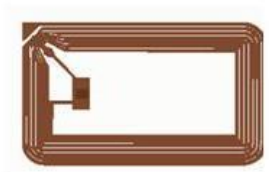
- Radio Frequency Identification RF-id
- Two main types by appearance novaday
  - Encapsulated chips
    - Into living tissue, or damageproof case
  - Thin film tags
    - Easy to store and manufacture

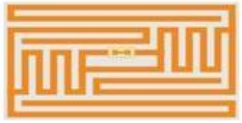


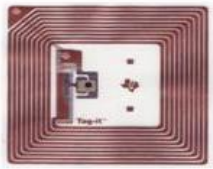


Tag types

- Label
  - Stick
  - Vignette
  - Disposable
  - Inexpensive
- Hard tags
  - Durable
  - Permanent
  - Reusable
  - Rewritable


Paper Tag


EPC Tag


Inlay Tag


Button Tag


Metal Tag


Glue Tag


Key Tag


Glass Tube Tag


Ear Tag

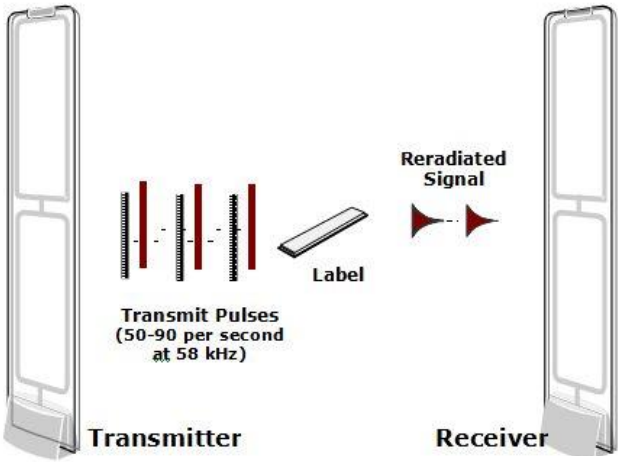

Ceramic Tag


Disc Tag


Pocket Tag

Reader types

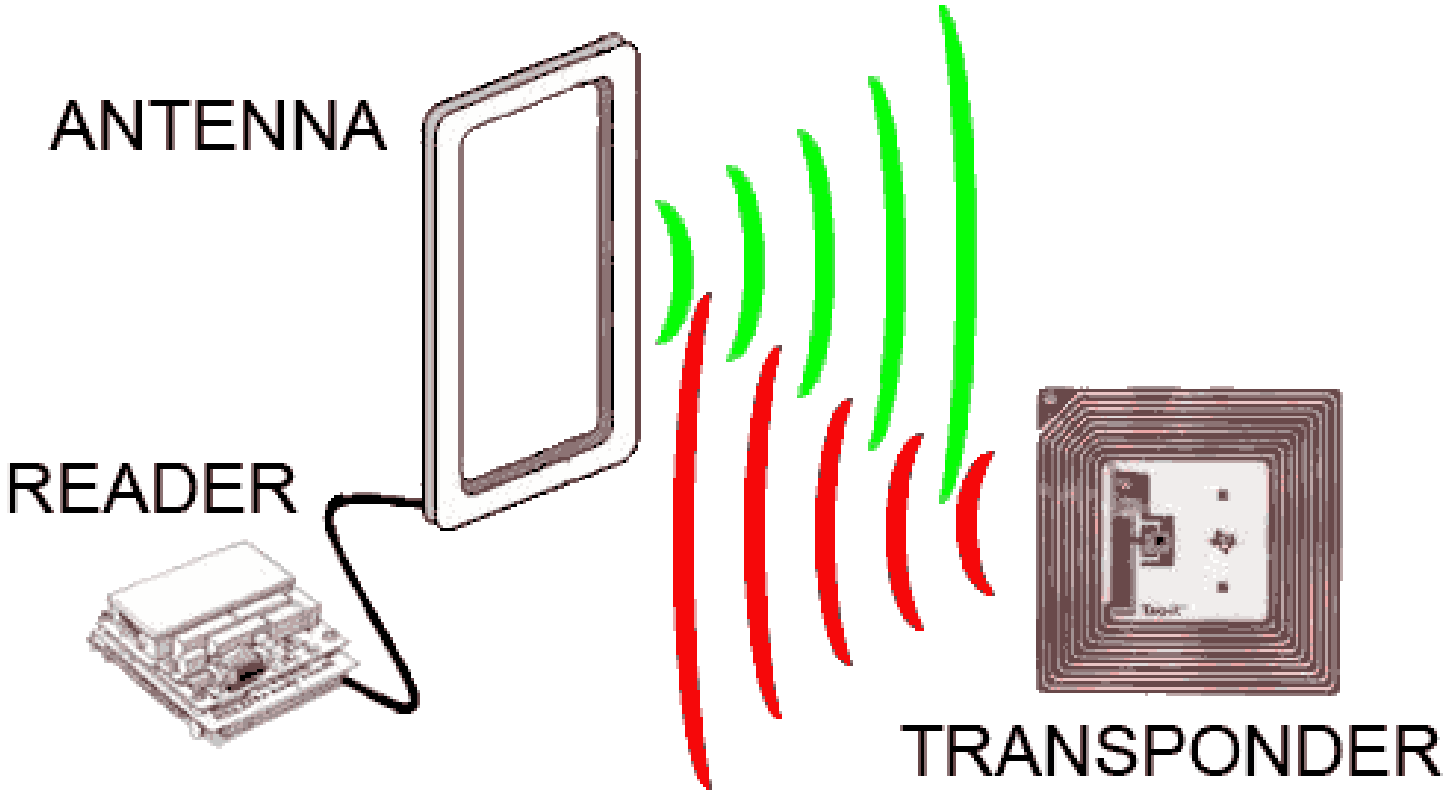
- Fixed
  - Tag is mobile
  - Battery recommended



- Handheld
  - Reader is mobile
  - Battery needed

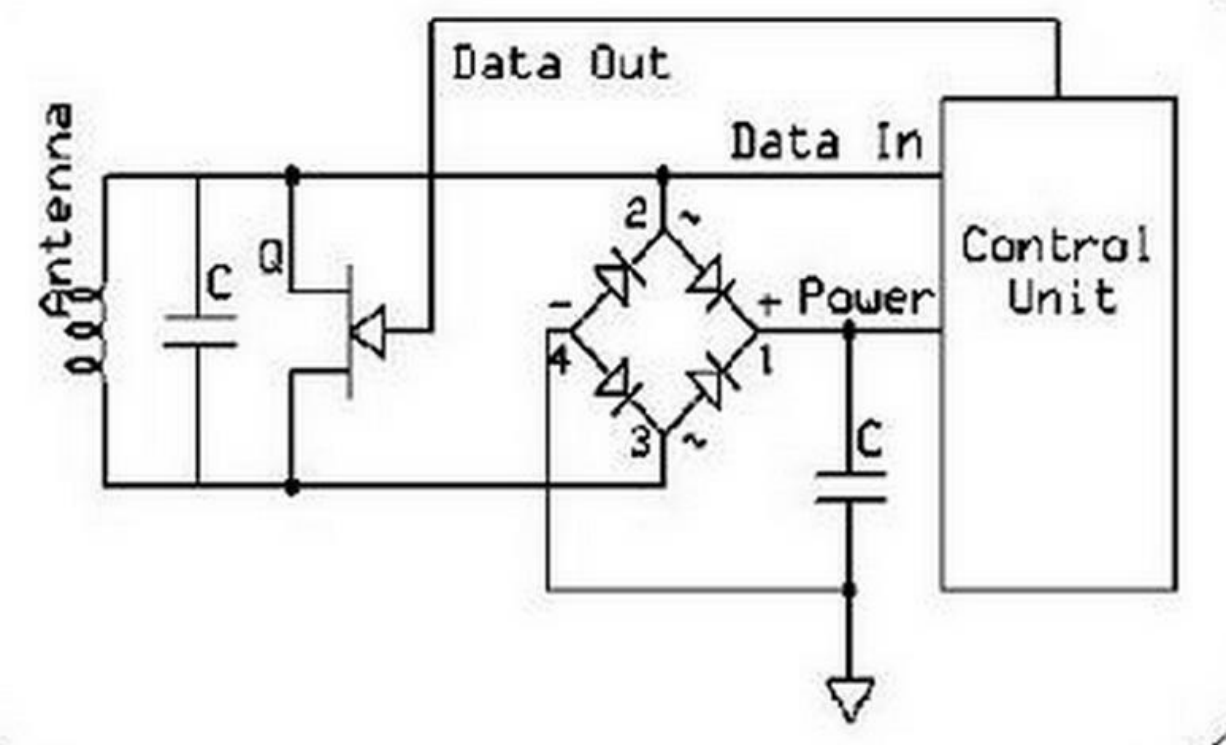
Query - response

- Radio Frequency Identification



Power accumulating

- Tag antenna receives the reader's (interrogator) emitted RF power
- Capacitor charges, reaches turn on voltage
- Control unit wakes, starts to switching Q transistor



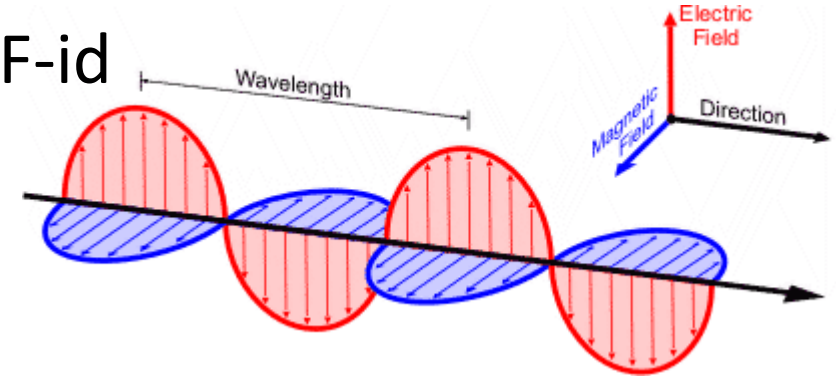
Active and semi-active

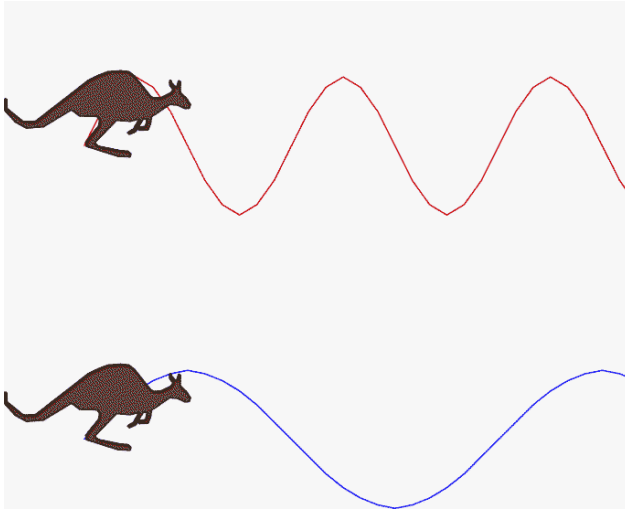
- Semi active needs inner power supply, a battery, to keep data in memory, or reading a sensor on the tag frequently.
  - Hovewer, it doesn't have powered transmitter
- Active tag only needs a query data from a reader or interrogator, its power is neglected, tag have its own for answering back
  - Long range

RFID

- Radio Frequency Identification RF-id
- Radio Frequency?
  - Electromagnetic wave can travel through the vacuum
  - Created by a periodic change of electric charge
  - 300 MHz -> 1 m

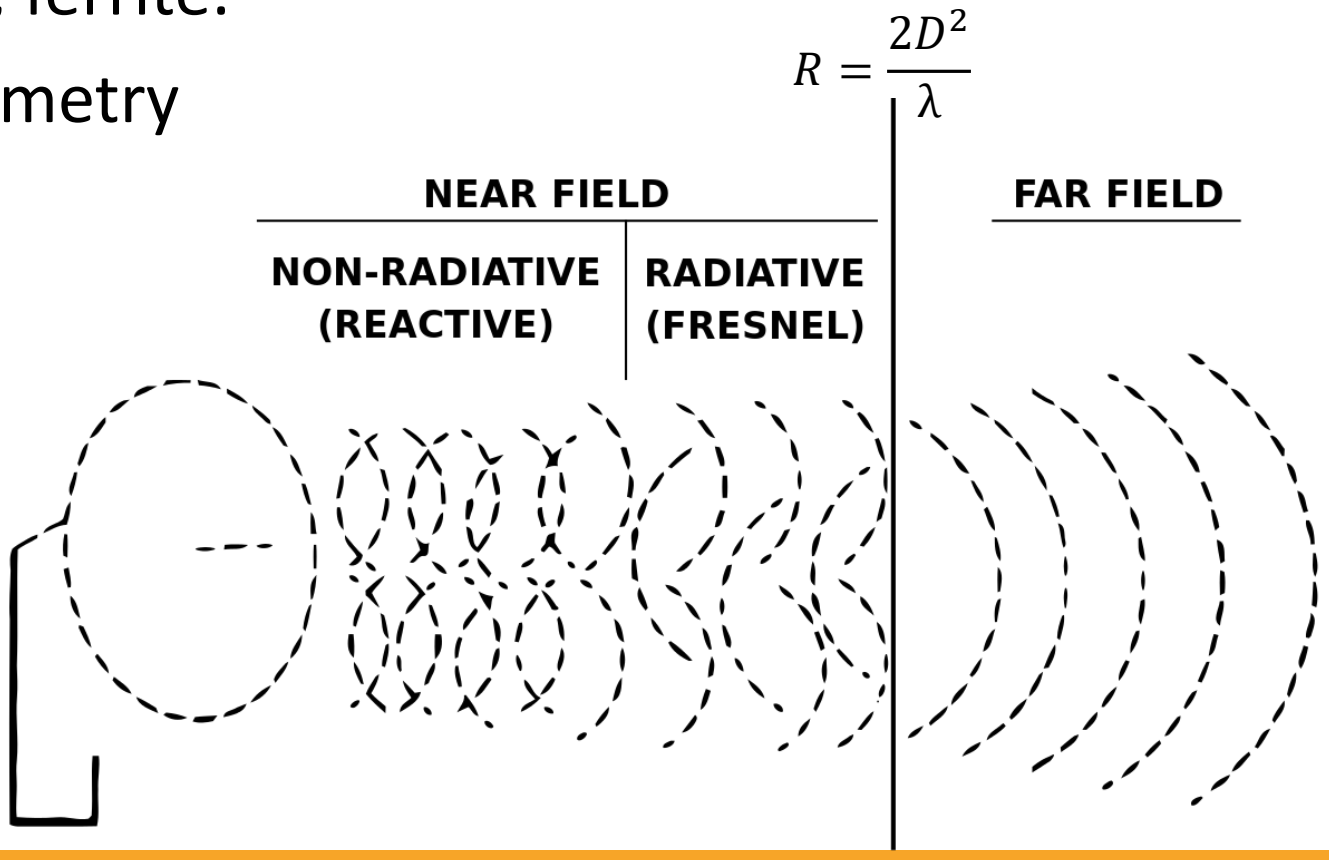
$$L[m] = \frac{300\ [MHz]}{f\ [MHz]}$$





Near field – Far field

- Coupling made if something is close to the antenna, especially metal, ferrite.
- D = antenna geometry
- λ = wavelenght
- R= crossline



- Middle of Hungary: Solt
- 540 kHz
- 2 MW
- AM

303.6 m

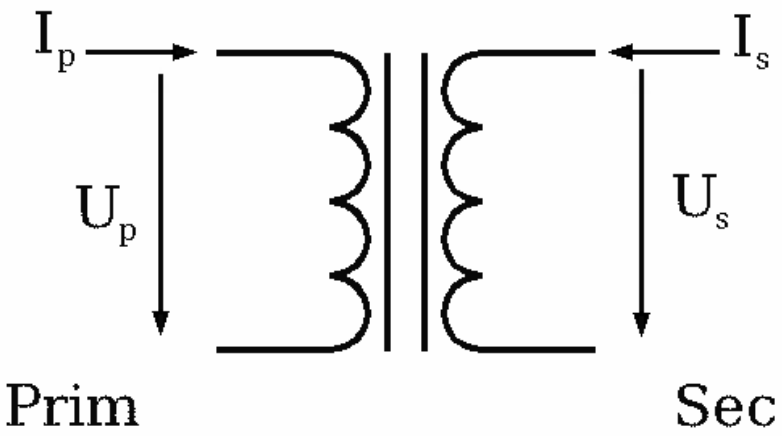
http://www.panoramio.com/photo/78595585#

https://en.wikipedia.org/wiki/Transmitter_Solt

RFID on 125 kHz? How?

$$\frac{300\ [MHz]}{0.125[MHz]} = 2400[m]$$

- We **dont** want to „receive” the power in the **far field**! We are taking advantage of **near field.**
- **Inductive coupled** = transformer theory
- So its not quite an antenna system, its a primary and secondary coil.
- On low frequencies:
  125 kHz – 13,56 MHz
- Ferrite antennas, loops

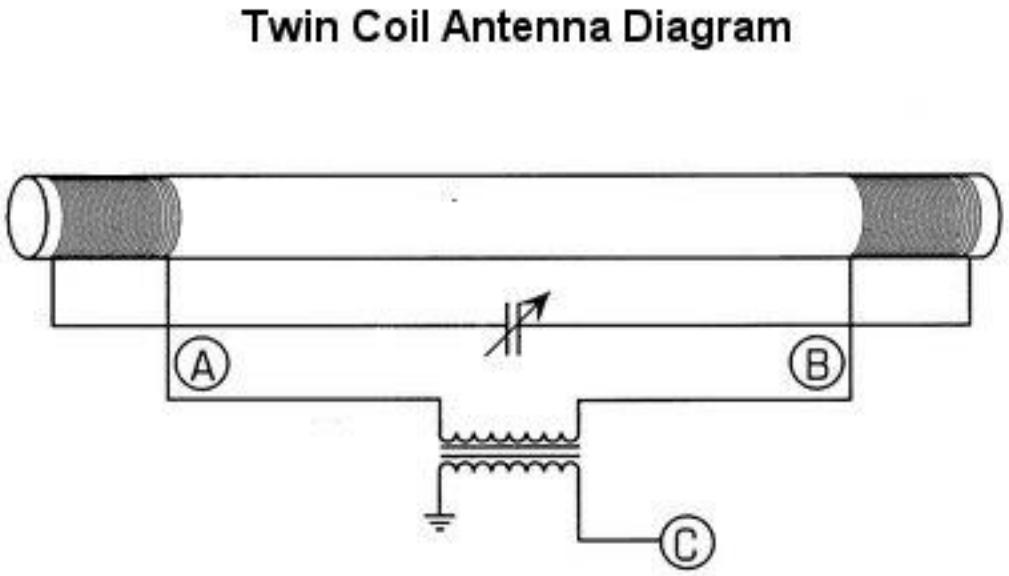


Ferrite and loop antenna

- The ferrite rod increases the magnetic permeability, allowing the physically small antenna to have a larger effective area.
- Usually 125 – 140 kHz

- Usually 13,56 MHz

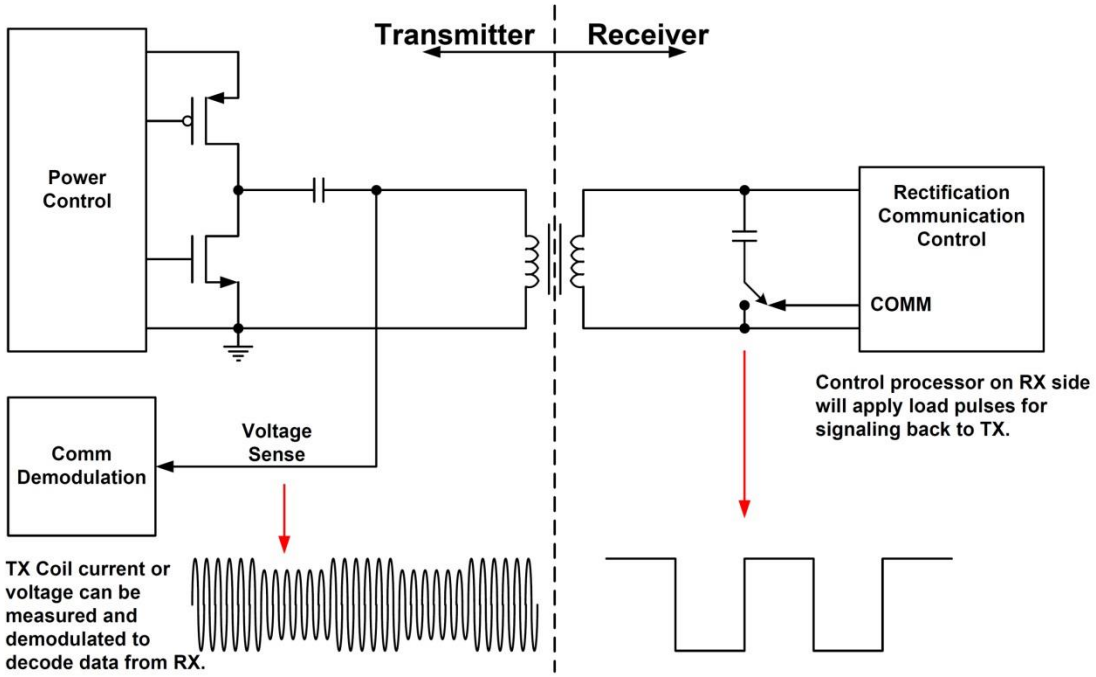
Grandpa's workshop accessory



- This AM radio contains a tunable ferrite antenna under 3 MHz

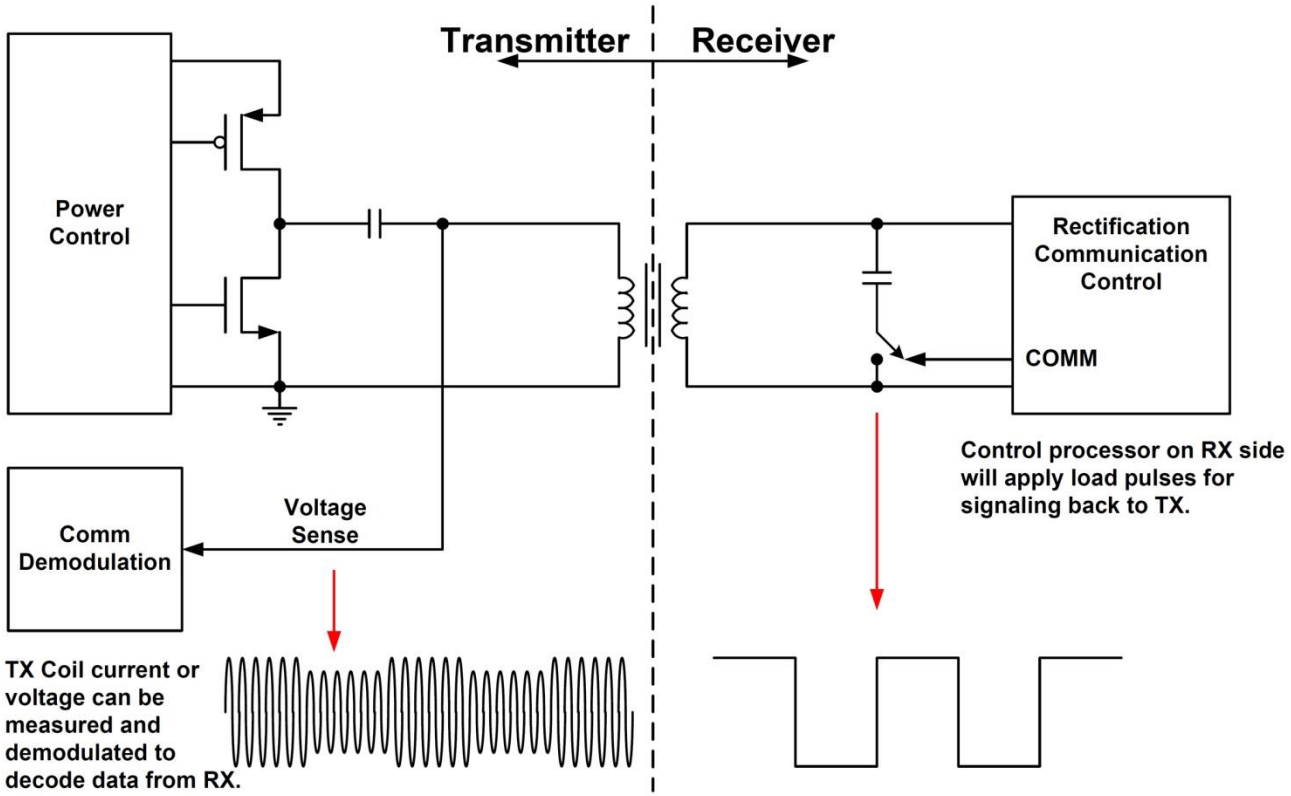
Inductive coupling math

- On LF up to VHF
  30 kHz – 300 MHz
- Why:
- Propagation factor for near field, inductive coupling:
  $c/2\pi f$
- Energy available for creating induction:
  $1/r^3$



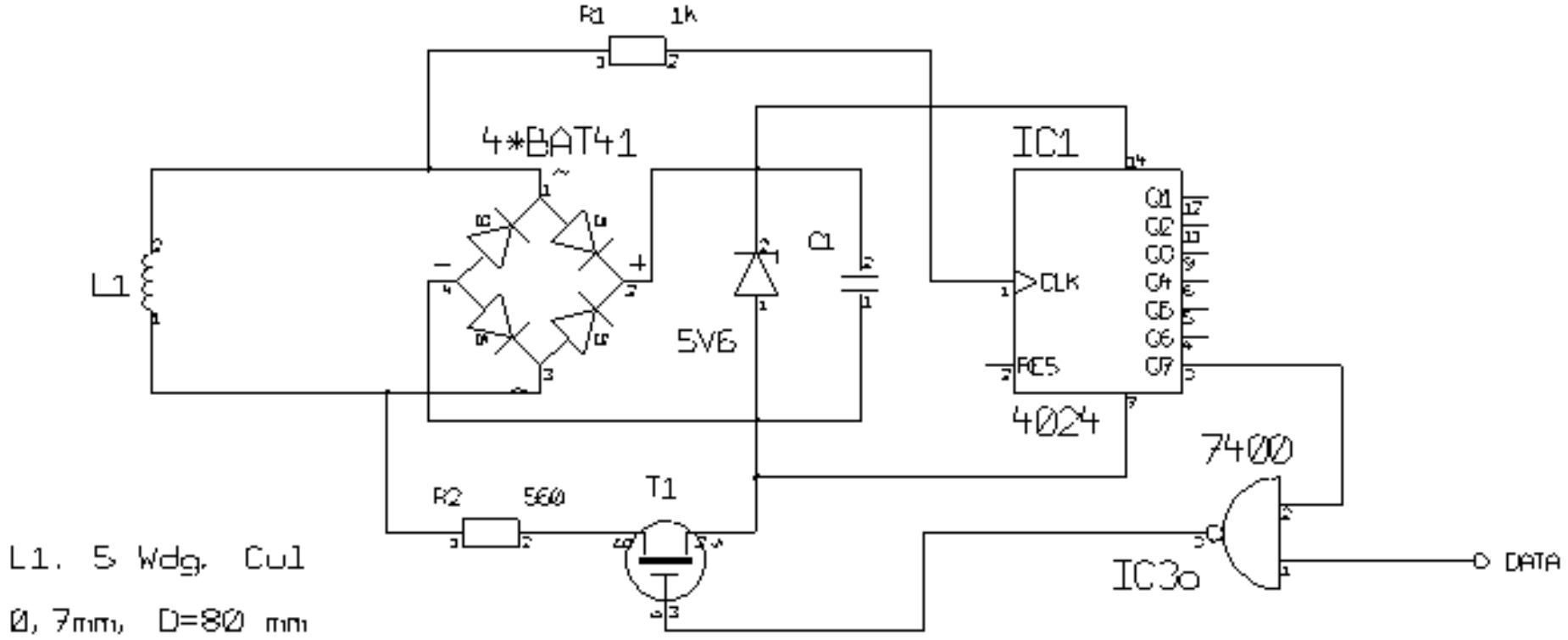
Load modulation

- Transistor switching on and off, creating fluctuation in primary loop current, and voltage.



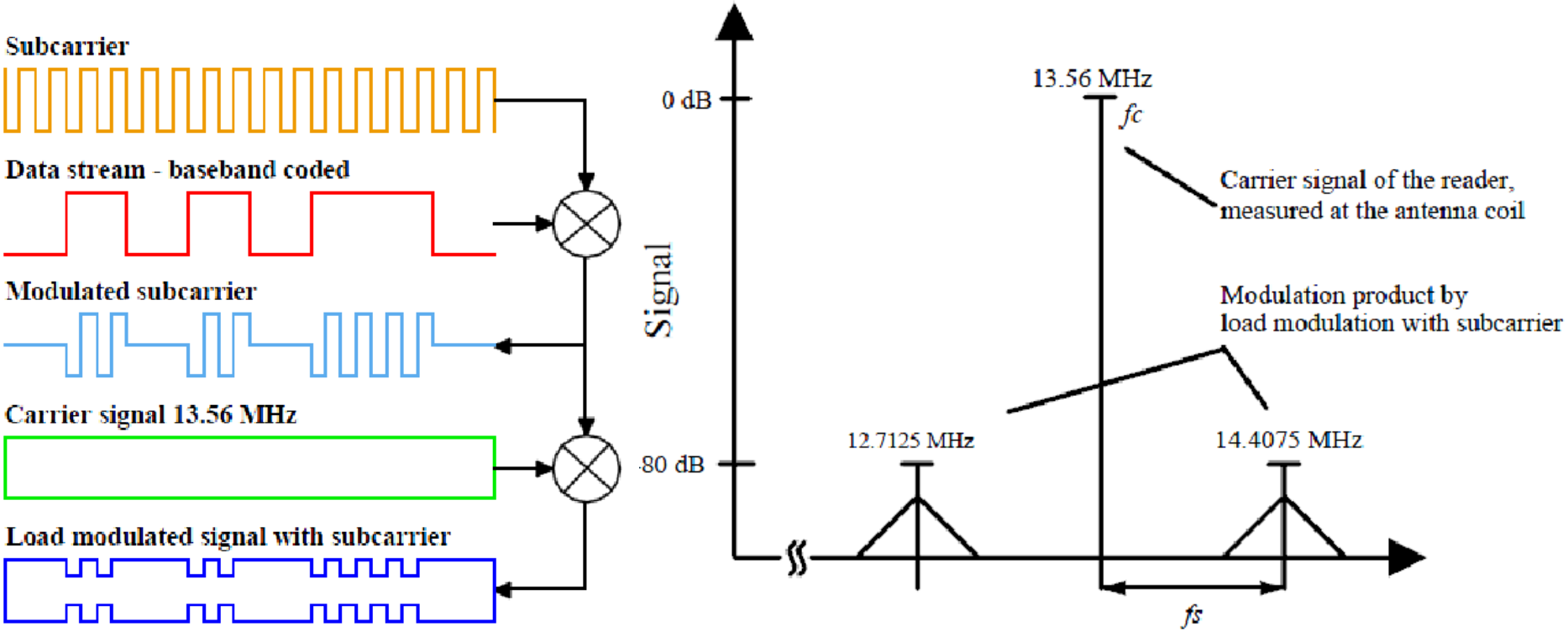
Load modulation

- A frequency divider method helps to create a subcarrier frequency. Example: divide it with 16. This will be the switching freq.



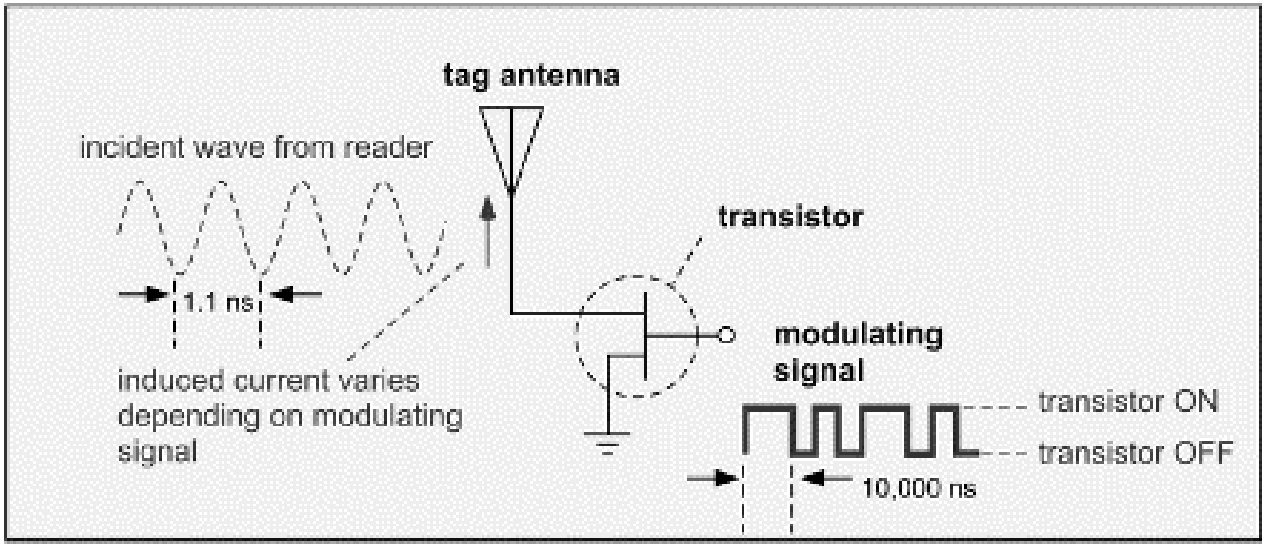
Load modulation

- Using the subcarrier to modulate the carrier, the AM modulated sideband signal comes closer.
- The receiver has more time to recognize the symbol 1 or 0.
- Nyquist – Shannon law



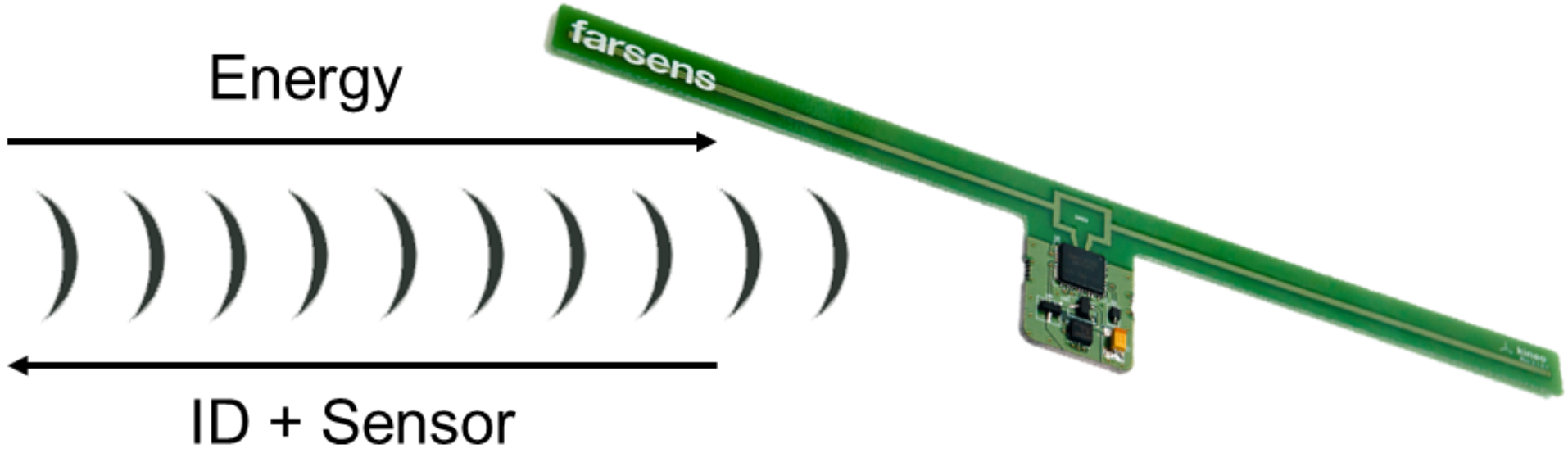
Backscattering

- Using UHF, more than 300 MHz means: c/2πf factor is very low, inductive coupling needs too much energy.
- Use diploes then!
- Matched antenna radiates half of the received power back



- The tag can capture energy with dipole antennas, but load modulation is not an option.
- Use antenna tuning to varying the backscattered RF power, digital AM modulation created.

Tag with dipole antenna



Two separate concept

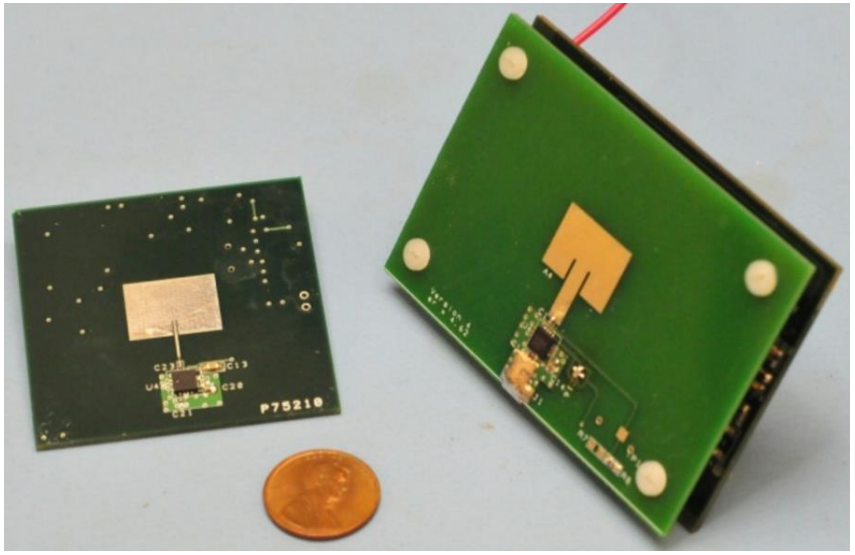
- Inductive coupling
- Near field theory
- Load modulation
- „Almost touch” reading
- Up to 300 MHz
- Loop, coil, magnetics
- Low data transfer because of low freq.
- Slow interrogation

- Radiative
- Far field emission
- Backscattering
- Longer range query
- f greater than 300 MHz
- Dipole, bent-dipole
- Higher data transfer because of wider bands.
- Faster interrogation

- Passive and semi-active cases!

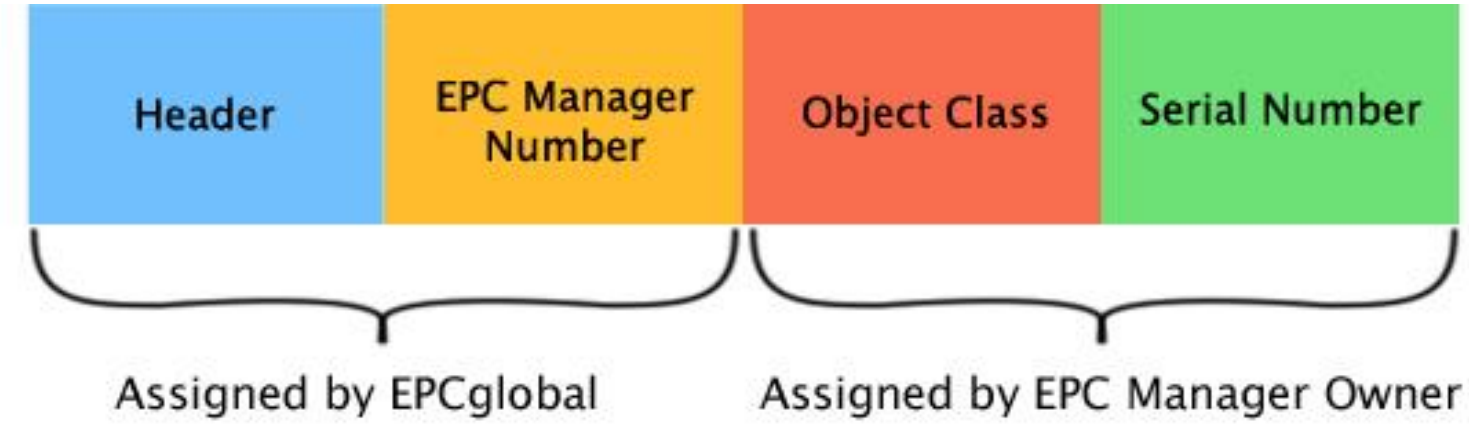
Microwave frequency challenges

- Small and accurate electronical parts and welding methods are expensive -> manufacturing is expensive
- Only **active** tag can respond
- Obstacles have greater influence almost “direct line of sight needed”
- 2,45 GHz and 5,8 GHz bands are unlicensed, but full of interference.



RFID

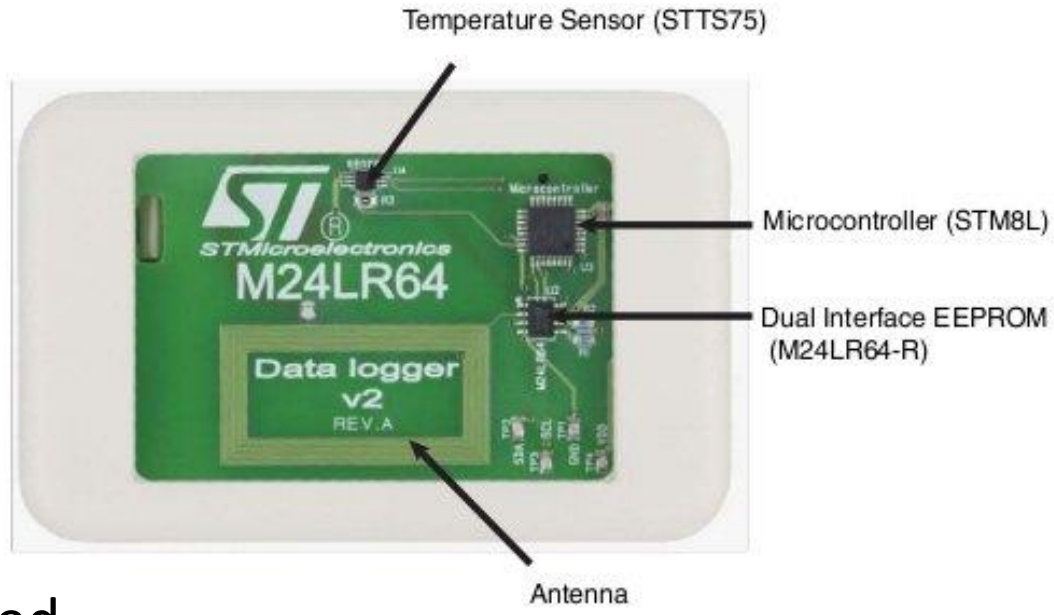
- EPCglobal standard
- A 96-bit tag can label over 50 quadrillion, 50×10^{15}
  Its every manufactured item for the foreseeable future!



- Remember IPV4? They thought something similar: 4 294 967 296 IPv4 adress.

Data storage capacity

- IC
  - Memory to store data
  - Processing unit
- Memory
  - Read only
  - Read / write
  - Factory preprogrammed
  - Optional: permanently locked, password protected

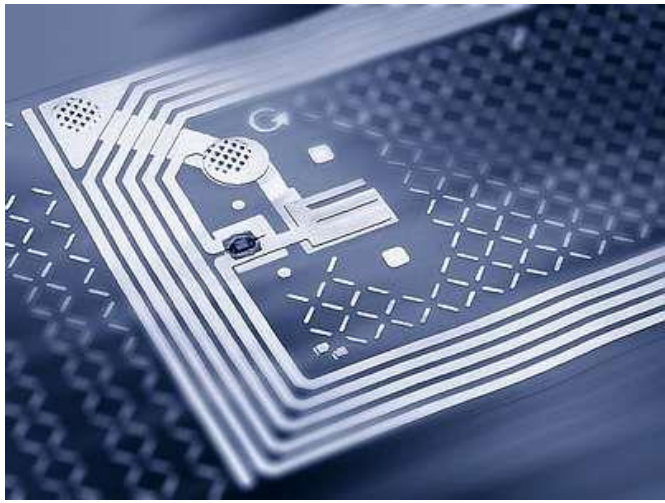


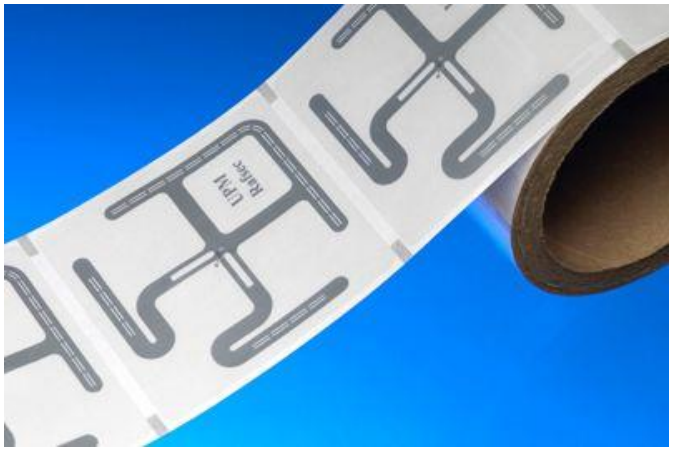
Tag categories

- Power source
  - Passive tags: receive power from the reader
  - Semi-passive tags: battery for chip, backscatter for data transmitting
  - Active tags: power source for chip and transmitting
- Frequency
  - LF
  - HF
  - VHF
  - UHF
  - µW
- Form factor
  - Labels
  - Wristbands
  - Buttons
  - Embedded

Inlay

- Dry inlay
  - Parts are attached to a solid substrate
- Wet inlay
  - Pressure sensitive liner
  - Sticker
  - Adhesive added on one side
  - 5k-10k pieces of RFID label on 1 roll





RFID printing

- Wet inlay
- Baggages manufacturing supply chain

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Frequency bands for RFID applications

Frequency allocation

- Space
- Time
- Frequency
- Who pays more
- Societal benefits

Frequency allocation

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NEMZETI FREKVENCIA-FELOSZTÁS

HUNGARIAN FREQUENCY ALLOCATIONS

RÁDIÓSZOLGÁLATOK SZÍNJELZÉSEI

RADIO SERVICE COLOR LEGEND

NEMZETI FELOSZTÁS JELLEGE:

ACTIVITY CODE

POLGÁRI (CIVIL)

NEM POLGÁRI (NON CIVIL)

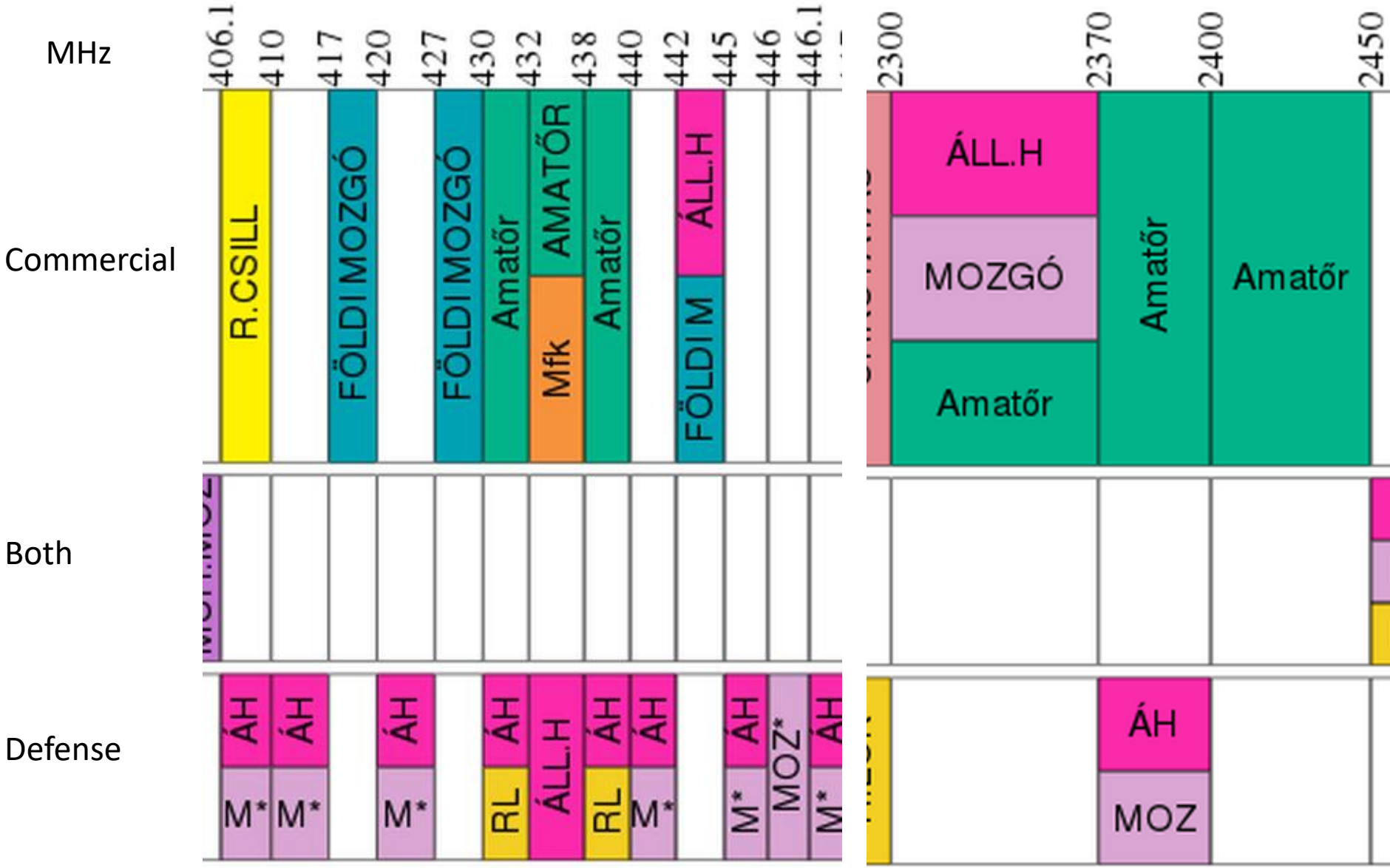
EGYÜTTES (CIVIL / NON-CIVIL COMMON)

A SZOLGÁLAT JELLEGE:

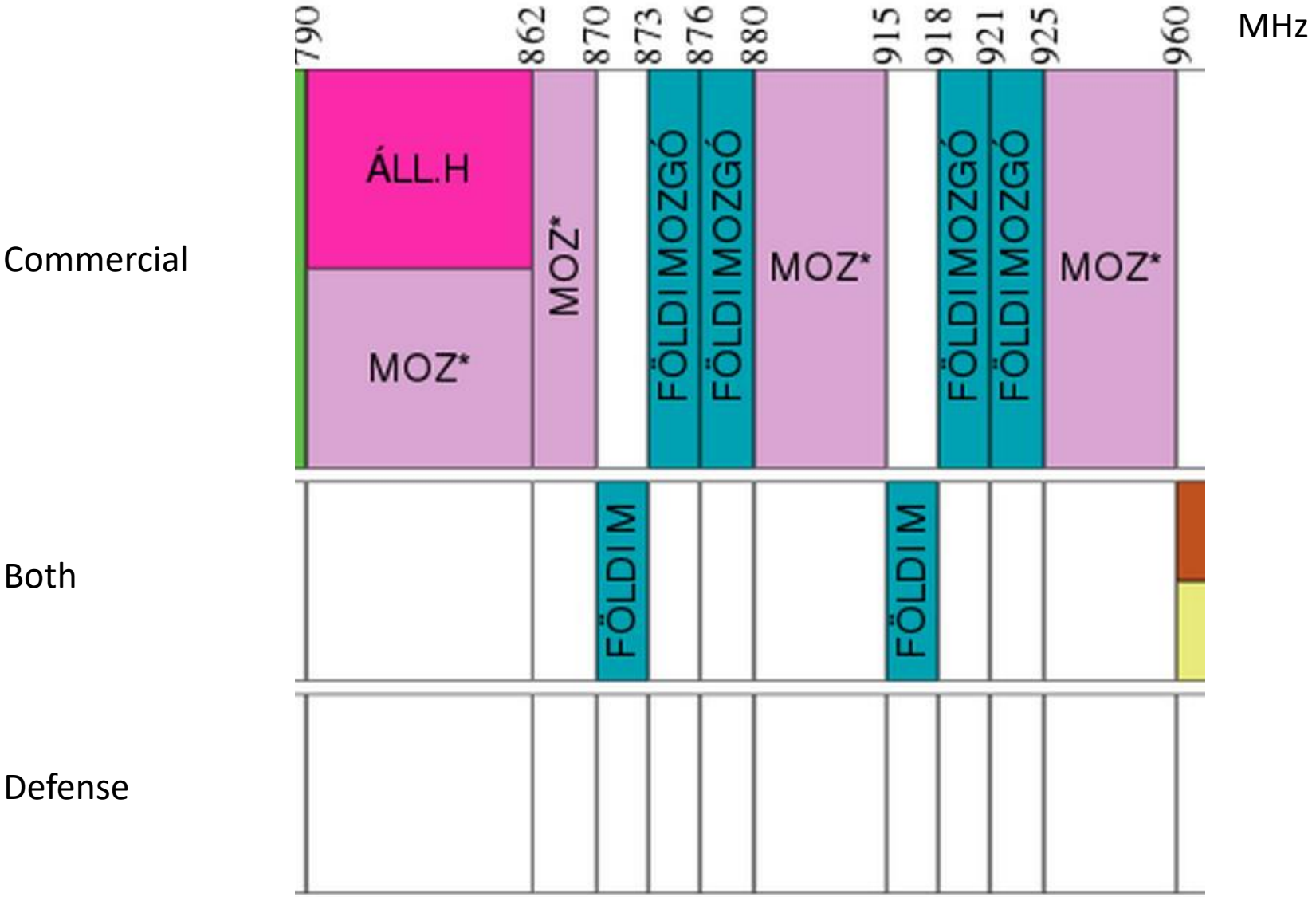
ALLOCATION USAGE DESIGNATION

NMH Nemzeti Média- és Hírközlési Hatóság

Unlicensed band



Licensed band



Frequency utilization aspects

- Government regulations
- Host material
- Read range
- Speed of data transfer
- Cost

Frequencies for RFID

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Freq Bands	Antenna	Data & Speed	Read Range	Common application
LF 125 – 134 kHz	Induction coil on ferrite core	Low read speed, small amount of data	1 – 2 m	Access control, Animal tagging Inventory control, Car immobilizer
HF 13,56 MHz	Induction flat coil, 3 – 9 loop	Medium read speed Small – medium amount of data	1 m	Smart cards, Item or box tagging Proximity cards, Vicinity cards
VHF (Active) 433 MHz	Electric antenna	High read speed Large amount of data	300 m	Asset tracking, Locationing Container tracking, Car key
UHF 860 - 960 MHz (Active-Passive)	Single or folded dipole	High read speed Small – medium amount of data	1 – 15 m	Pallet or box tagging, Paypass (passive)
Microwave (Active) 2,45 GHz 5,4 GHz	Single dipole	High read speed Medium amount of data	100 m	Container rail car, Auto toll roads Pallet tracking

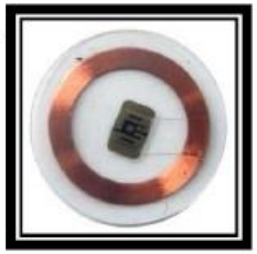
Frequencies for RFID

Freq Bands	Multiple tag read	By near metal obstacles	Tag price	Common application
LF 125 – 134 kHz	Poor	Not affected	High	Access control, Animal tagging Inventory control, Car immobilizer
HF 13,56 MHz	Good	Moderately affected	Moderate	Smart cards, Item or box tagging Proximity cards, Vicinity cards
VHF (Active) 433 MHz	Very good	Affected	Low	Asset tracking, Locationing Container tracking
UHF 860 - 960 MHz (Active-Passive)	Very good	Fading phenomenon great (known by GSM technology)	Low	Pallet or box tagging
Microwave (Active) 2,45 GHz 5,4 GHz	Good	Standing waves in the space, worst case. Minimum – maximum strength points are close.	High	Container rail car, Auto toll roads Pallet tracking

Frequencies for RFID

© RFIDTrakker

© Sokymat



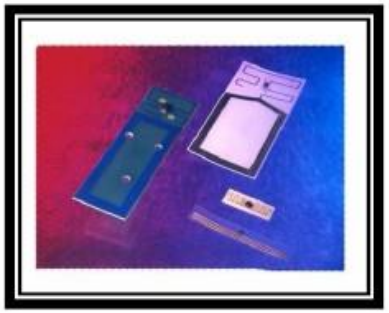
LF

(Low Frequency)

© Tagsys

HF

(High Fréquency)



© Alien

© Rafsec

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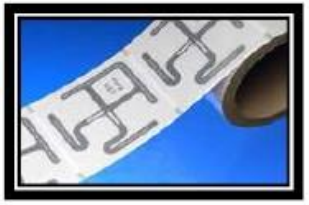

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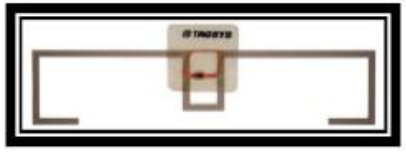

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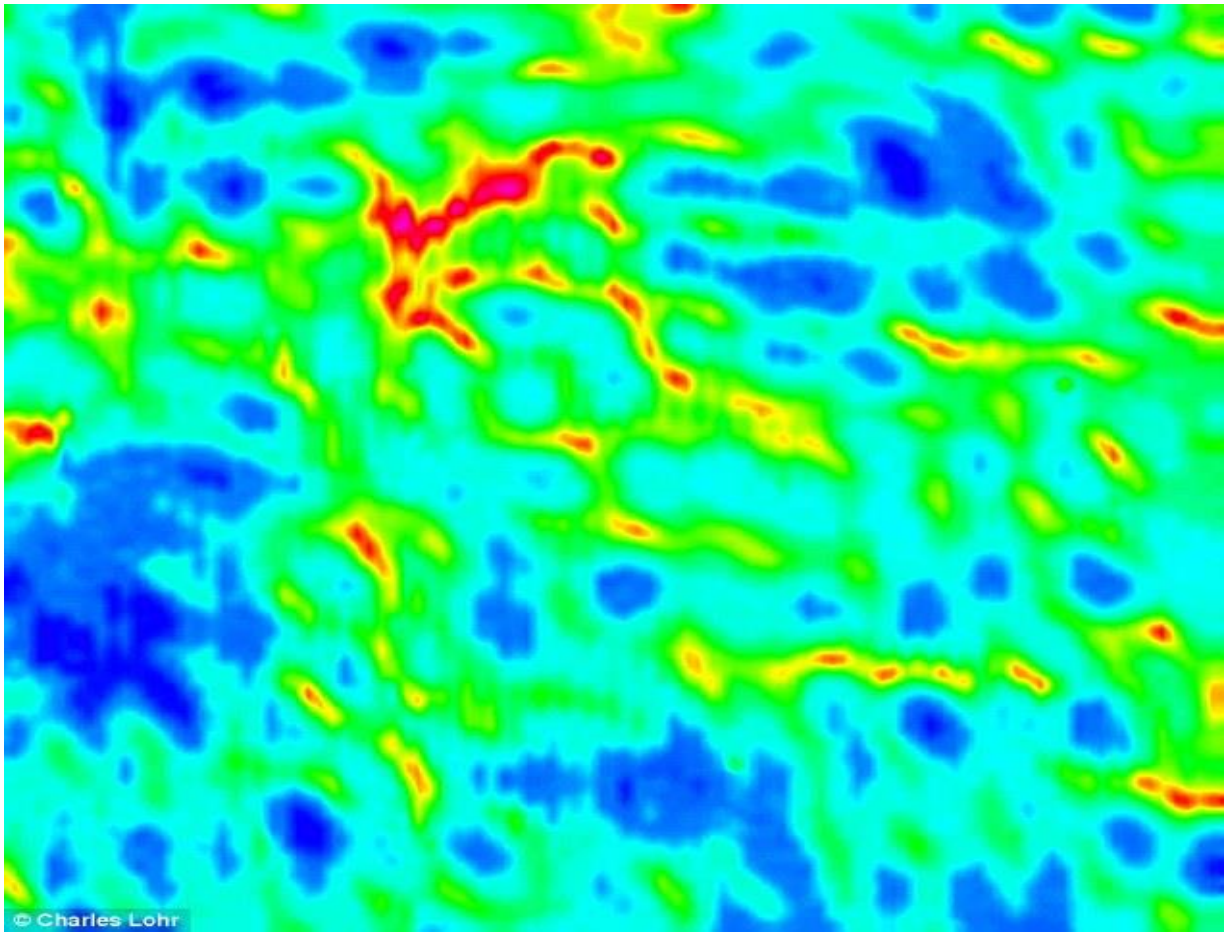
UHF

(ultra High Frequency)

Fading, standing waves



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Standards

RFID standards

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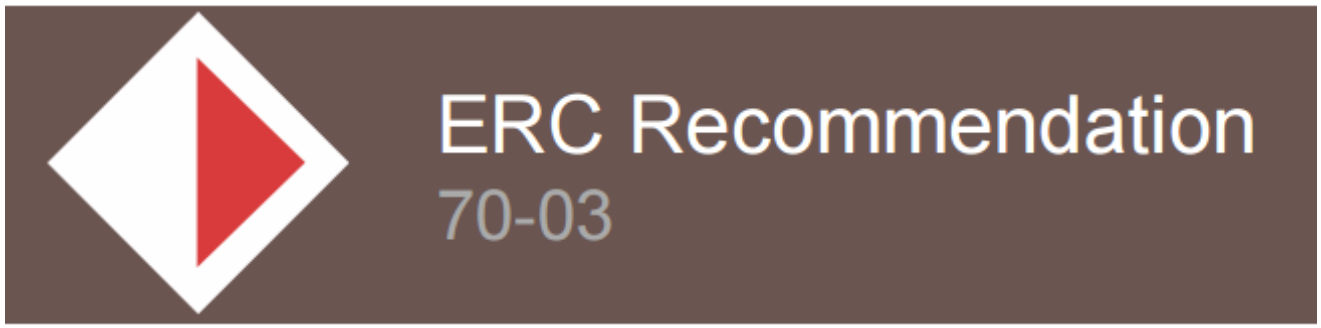
RFID STANDARD	DETAILS
ISO 10536	ISO RFID standard for close coupled cards
ISO 11784	ISO RFID standard that defines the way in which data is structured on an RFID tag.
ISO 11785	ISO RFID standard that defines the air interface protocol.
ISO 14443	ISO RFID standard that provides the definitions for air interface protocol for RFID tags used in proximity systems - aimed for use with payment systems
ISO 15459	Unique identifiers for transport units (used in supply chain management)
ISO 15693	ISO RFID standard for use with what are termed vicinity cards
ISO 15961	ISO RFID standard for Item Management (includes application interface (part 1), registration of RFID data constructs (part 2), and RFID data constructs (part 3).
ISO 15962	ISO RFID standard for item management - data encoding rules and logical memory functions.
ISO 16963	ISO RFID standard for item management - unique identifier of RF tag.
ISO 18000	ISO RFID standard for the air interface for RFID frequencies around the globe
ISO 18001	RFID for item management - application requirements profiles.
ISO 18046	RFID tag and interrogator performance test methods.
ISO 18047	The ISO RFID standard that defines the testing including conformance testing of RFID tags and readers. This is split into several parts that mirror the parts for ISO 18000.
ISO 24710	Information technology, automatic identification and data capture techniques - RFID for item management - Elementary tag license plate functionality for ISO 18000 air interface.
ISO 24729	RFID implementation guidelines - part : RFID enabled labels; part 2: recyclability of RF tags; part 3: RFID interrogator / antenna installation.
ISO 24730	RFID real time locating system: Part 1: Application Programming Interface (API); Part 2: 2.4 GHz; Part 3: 433 MHz; Part 4: Global Locating Systems
ISO 24752	System management protocol for automatic identification and data capture using RFID
ISO 24753	Air interface commands for battery assist and sensor functionality
ISO 24769	Real Time Locating System (RTLS) device conformance test methods 53/XX
ISO 24770	Real Time Locating System (RTLS) device performance test methods

RFID standards

ISO 18000 STANDARD	DETAILS OF THE PARTICULAR ISO 18000 SERIES STANDARD
ISO 18000-V1	Generic parameters for air interfaces for globally accepted frequencies
ISO 18000-V2	Air interface for 135 KHz
ISO 18000-V3	Air interface for 13.56 MHz
ISO 18000-V4	Air interface for 2.45 GHz
ISO 18000-V5	Air interface for 5.8 GHz
ISO 18000-V6	Air interface for 860 MHz to 930 MHz
ISO 18000-V7	Air interface at 433.92 MHz

Recommendation -> Standard



- European Conference of Postal and Telecommunications Administrations
- http://www.cept.org/ecc/

ERC Recommendation

Consessions:

- RFID tag emissions responding to RFID interrogators operating on centre frequencies 916.3 MHz, 917.5 MHz, 918.7 MHz and 919.9 MHz are not duty cycle limited.
- Certain channels may be occupied by RFID operating at higher powers. To minimise the risk of interference from RFID, SRDs should use LBT with AFA or observe suitable separation distances.
- In the high power RFID channels typically these may vary from 918 m (indoor) to 3.6 km (rural outdoor)
- Adaptive frequency agility
- Listen before talk

ERC Recommendation

Frequency Band	Power / Magnetic Field	Notes
9-90 kHz	72 dBµA/m at 10m (note 1)	In case of external antennas only loop coil antennas may be employed. Field strength level descending 3 dB/oct at 30 kHz
90-119 kHz	42 dBµA/m at 10m	In case of external antennas only loop coil antennas may be employed
119-135 kHz	66 dBµA/m at 10m (note 1)	In case of external antennas only loop coil antennas may be employed. Field strength level descending 3 dB/oct at 119 kHz
135-140 kHz	42 dBµA/m at 10m	In case of external antennas only loop coil antennas may be employed
140-148.5 kHz	37.7 dBµA/m at 10m	In case of external antennas only loop coil antennas may be employed
400-600 kHz	-8 dBµA/m at 10 m	For RFID only. In case of external antennas only loop coil antennas may be employed. The maximum field strength is specified in a bandwidth of 10 kHz. The maximum allowed total field strength is -5dBµA/m at 10 m for systems operating at bandwidths larger than 10 kHz measured at the centre frequency whilst keeping the density limit (-8dBµA/m in a bandwidth of 10 kHz.) These systems should operate with a minimum operating bandwidth of 30 kHz

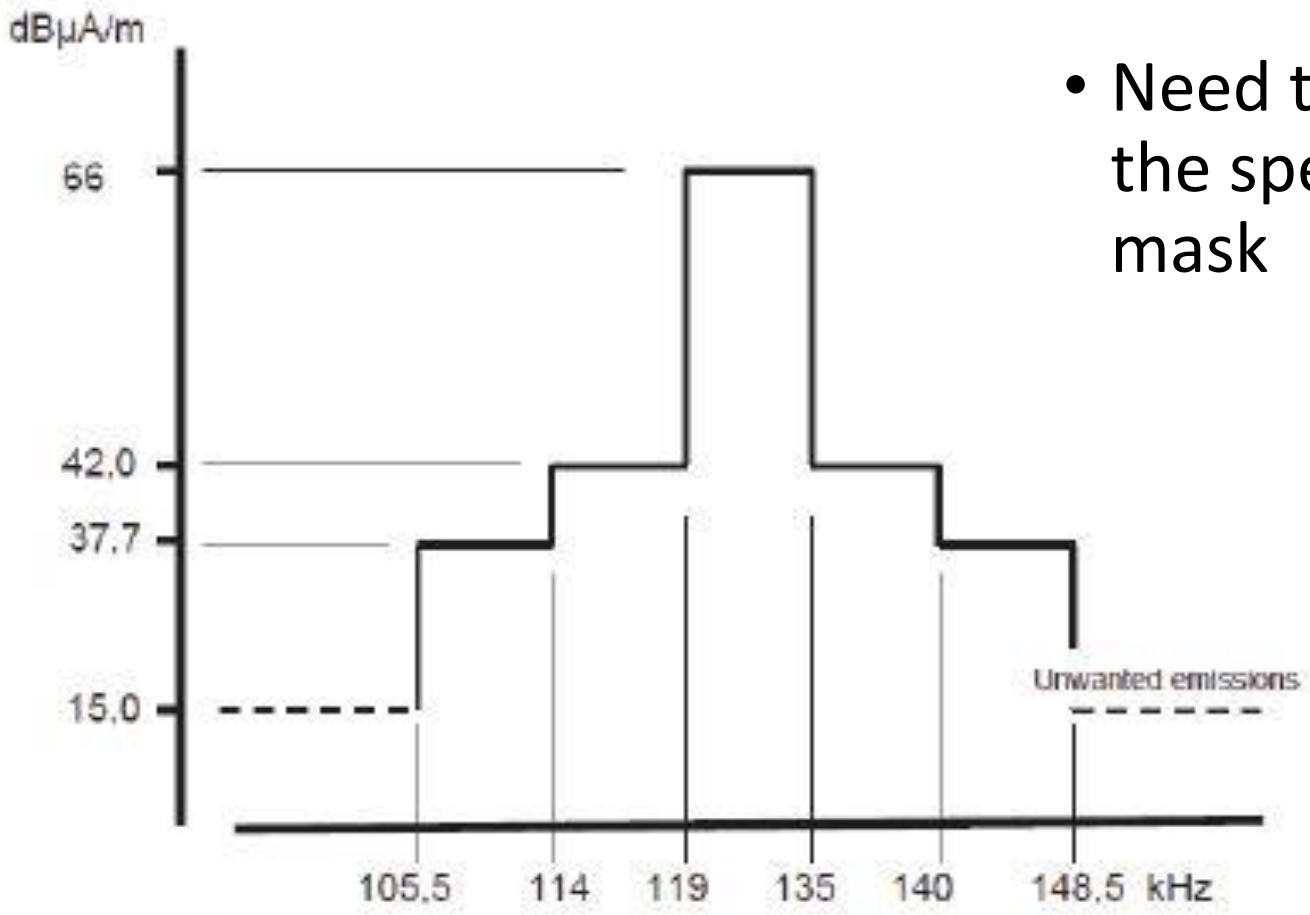
- Measuring distance 10 m
- Maximal inductive field -> Near field example
- Higher freq. needs meet lower requirement

ERC Recommendation

- Not inductive measurements
- Effective radiated power -> Far field example

Frequency Band	Power / Magnetic Field	Spectrum access and mitigation requirements	Modulation / maximum occupied bandwidth	Notes
865-868 MHz	2 W e.r.p. (note1)	(note 4)	≤ 200 kHz	Operation only when necessary to perform the intended operation, i.e. when RFID tags are expected to be present
865-865.6 MHz	100 mW e.r.p.	No requirement	≤ 200 kHz	(note 3)
865.6-867.6 MHz	2 W e.r.p.	No requirement	≤ 200 kHz	(note 3)
867.6-868 MHz	500 mW e.r.p.	No requirement	≤ 200 kHz	(note 3)
915-921 MHz	4 W e.r.p. (note 2)	For ER-GSM protection (918-921 MHz, where applicable), DAA is required	≤ 400 kHz	The frequency band is also identified in Annexes 1 and 10. Operation only when necessary to perform the intended operation, i.e. when RFID tags are expected to be present
2446-2454 MHz	≤ 500 mW e.i.r.p.	No requirement	Not specified	
2446-2454 MHz	> 500 mW to 4 W e.i.r.p	≤ 15% duty cycle FHSS techniques should be used	Not specified	Power levels above 500 mW are restricted to be used inside the boundaries of a building and the duty cycle of all transmissions shall in this case be ≤ 15 % in any 200 ms period (30 ms on /170 ms off)

EN 300 330 standard



NOTE: The limit at 129,1 kHz ± 500 Hz is maximum 42 dBµA/m at 10 m.

Figure 7: Excerpt from EN300330

- Need to meet the spectrum mask

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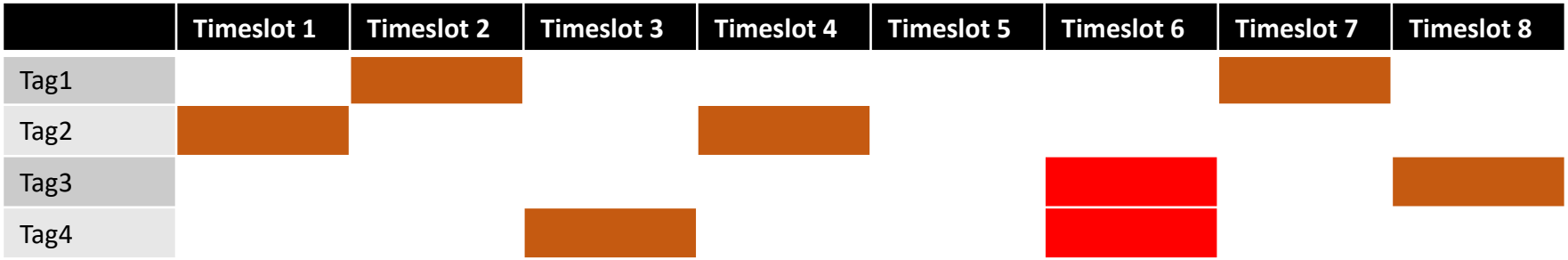
Signalling and protocols

RFID payment

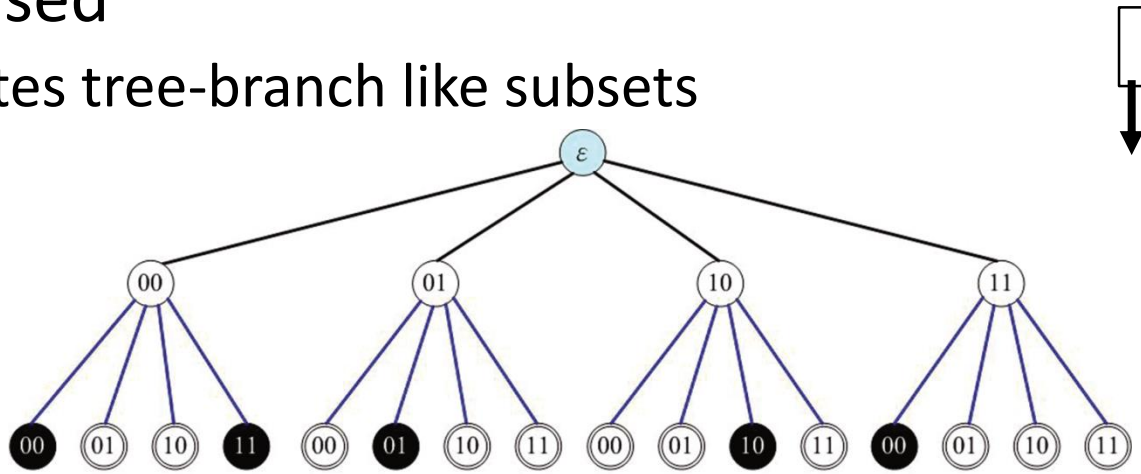
- Supermarket smart payment system (SSPS)
- Replaces bar code
- Lots of tags -> Anti – collision
  - How many tags are there?
  - How to ask them who they are?
- Estimation:
  - How many tags may be there?
  - Interrogation frame lenght determination
- Query:
  - ALOHA (Additive Link On-line HAwaii)
  - Qaternary query tree protocol

Anti-collision protocols

- ALOHA-based
  - Reducing tag collision propability

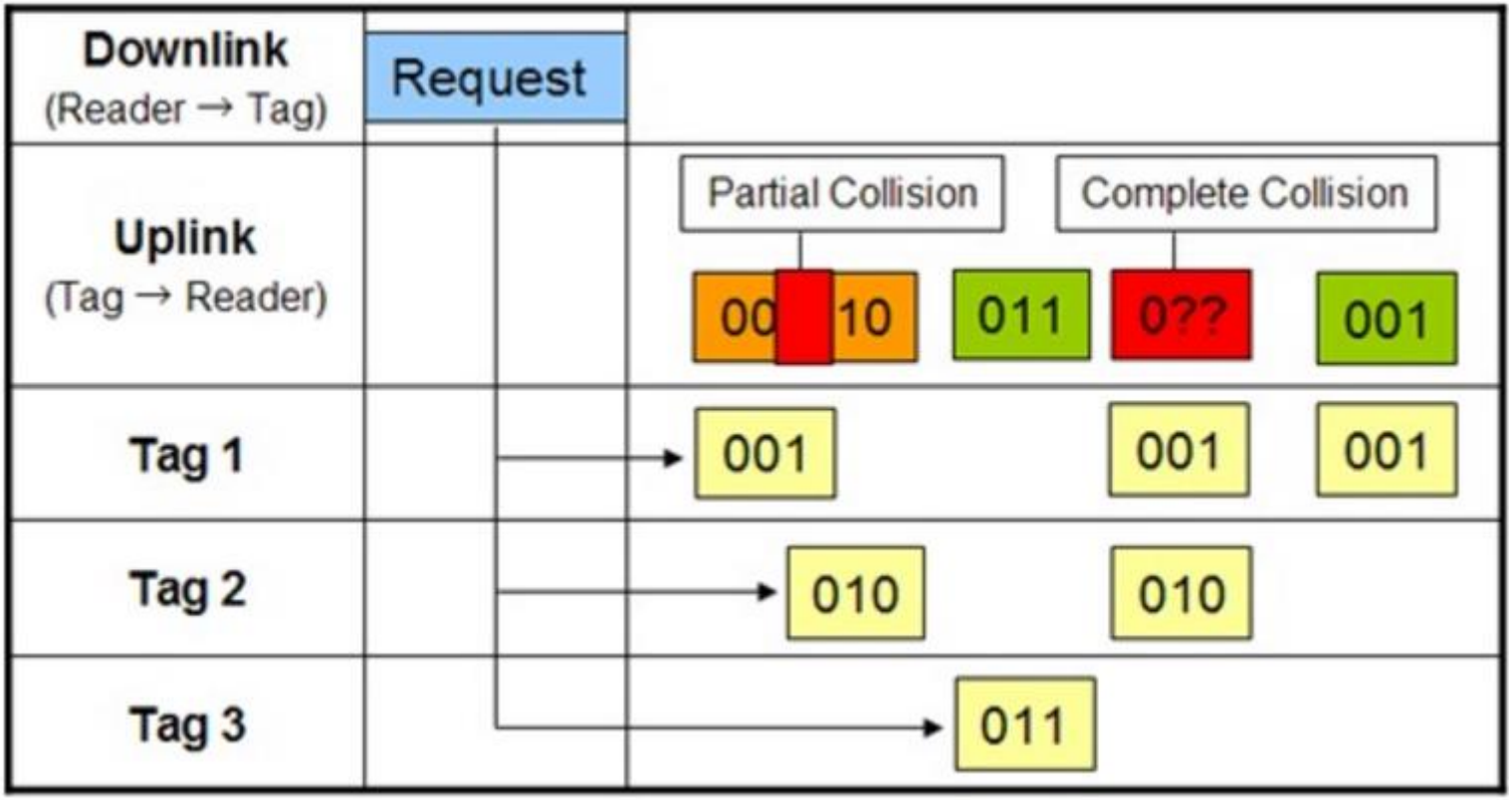


- Tree-based
  - Creates tree-branch like subsets



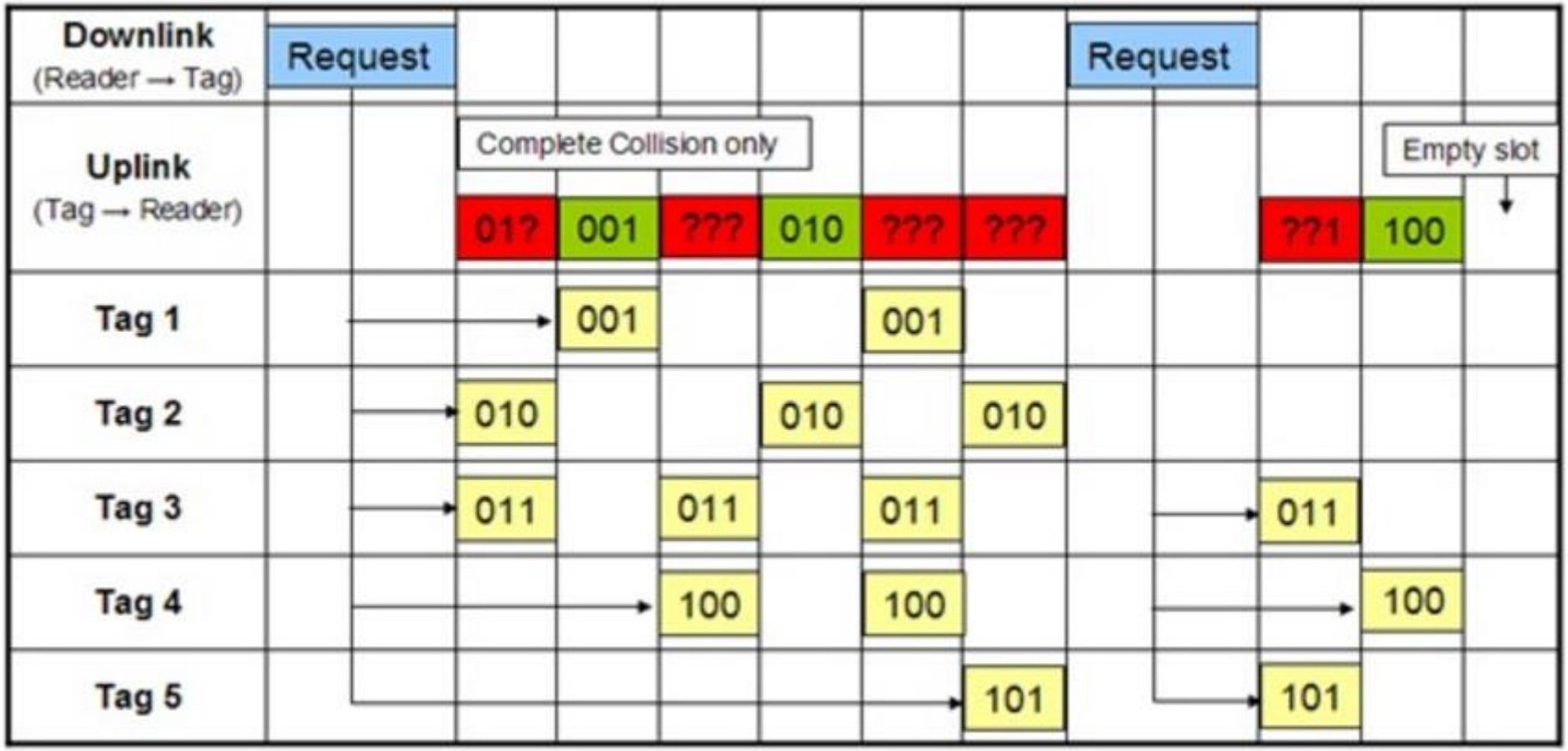
ALOHA-based algorithm

- Random delay



ALOHA-based algorithm

- Slot in the frame delay



Query Tree Protocol (QTA) [1]

- Who is here?

Round	Query (R to T)	Response (T to R)	Tag1 (0001)	Tag2 (0011)	Tag3 (1000)	Tag4 (1101)	Queue
1	-	Collision	0001	0011	1000	1101	00,01,10,11
2	00	Collision	0010	0011	-	-	01,10,11,0000,0001,0010,0011
3	01	Empty	-	-	-	-	10,11,0000,0001,0010,0011
4	10	Success	-	-	1000	-	11,0000,0001,0010,0011
5	11	Success	-	-	-	1101	0000,0001,0010,0011
6	0000	Empty	-	-	-	-	0001,0010,0011
7	0001	Success	0001	-	-	-	0010,0011
8	0010	Empty	-	-	-	-	0011
9	0011	Success	-	0011	-	-	Empty

Capture effect

- Some tag's signal will be stronger at the readers receiver, so its ID will be accepted even though there was a collision
- If reader is not drops this information
  - resolved tag will not be asked again
  - collision is less
  - query is faster.

Tag starvation

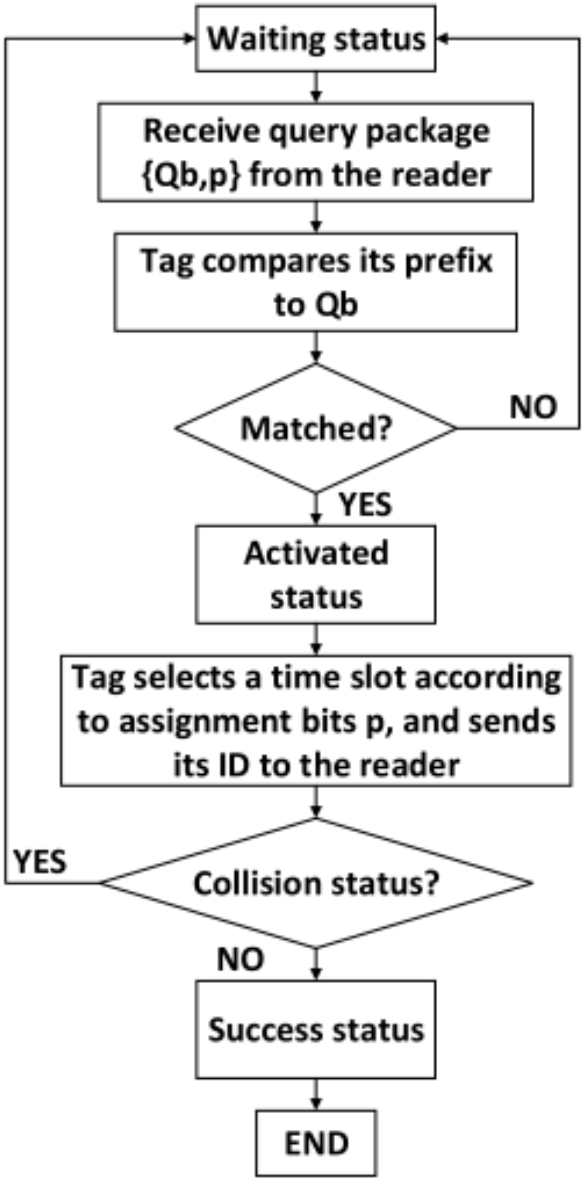
- Reader miss tag response because tag 1 and tag 2 reasponses collides
- Reader ask again, reads tag 1 response successfully, tag 2 collides again with others
- Queries are finite, reader is moving away, leaves some tag unreaded.

Tag starvation (Tag -> Reader)

Query #	F	R	A	M	E
	T. Slot 1	T. Slot 2	T. Slot 3	T. Slot 4	T. Slot 5
#1	1	2 3		4 5	6 7
#2	1	2	3 4	5 6	7
#3	3 7	2	1 6	5	4
#4	5	1 4	7	3 2	6
…#100	3 5	2	1	4	6

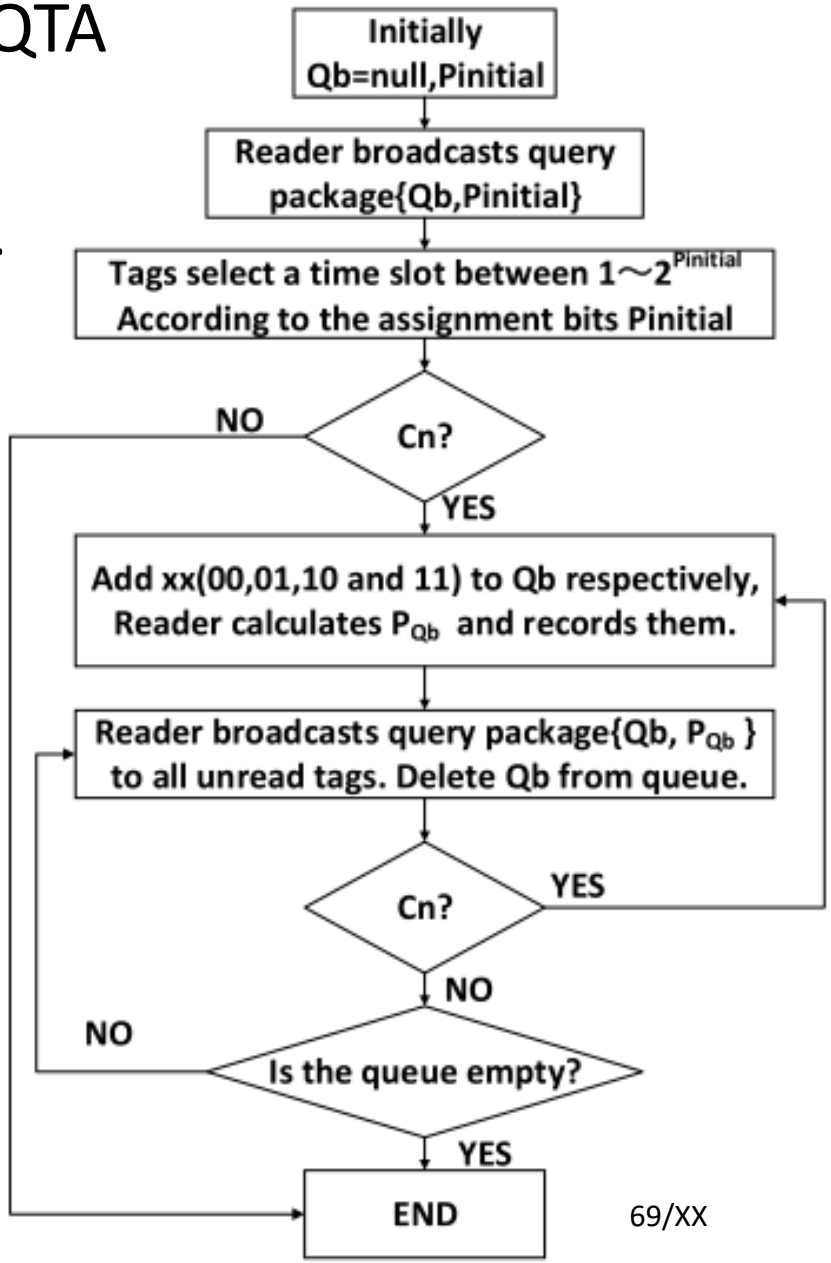
4QTAP [4]

- Combination of ALOHA and QTA



Reader ->

<- Tag



Tag estimation protocol

- Frame length determination is based on tag quantity estimation.
- Too long -> low collision, many time slots unoccupied in the frame, lot of time needed.
- Too short -> high collision, have to repeat query, lot of time spent, reader cannot find the “way out”, starvation caused.
- Optimal -> collision is helps reader to determine next step, time slots are filled, but collision are low.

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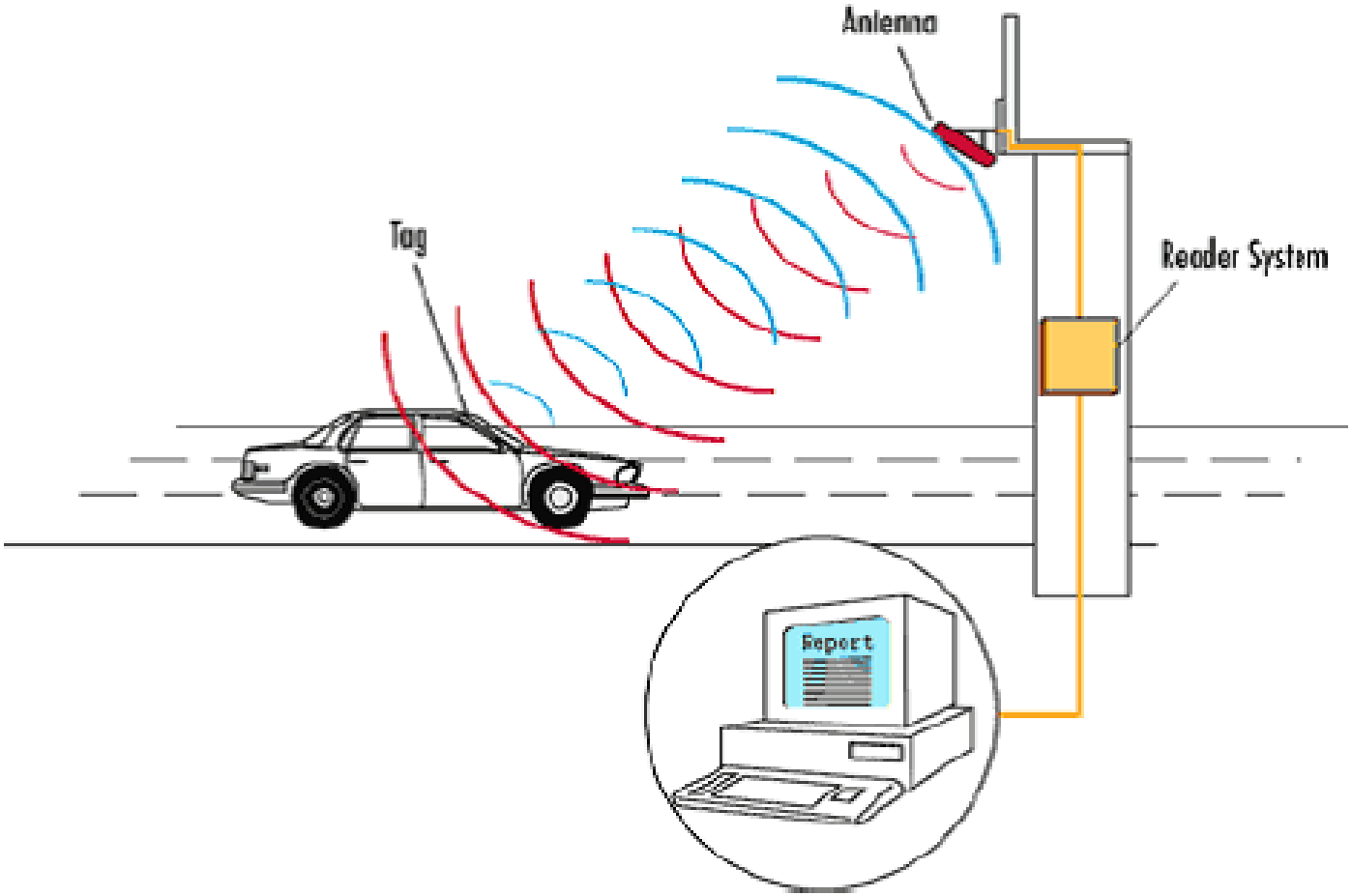
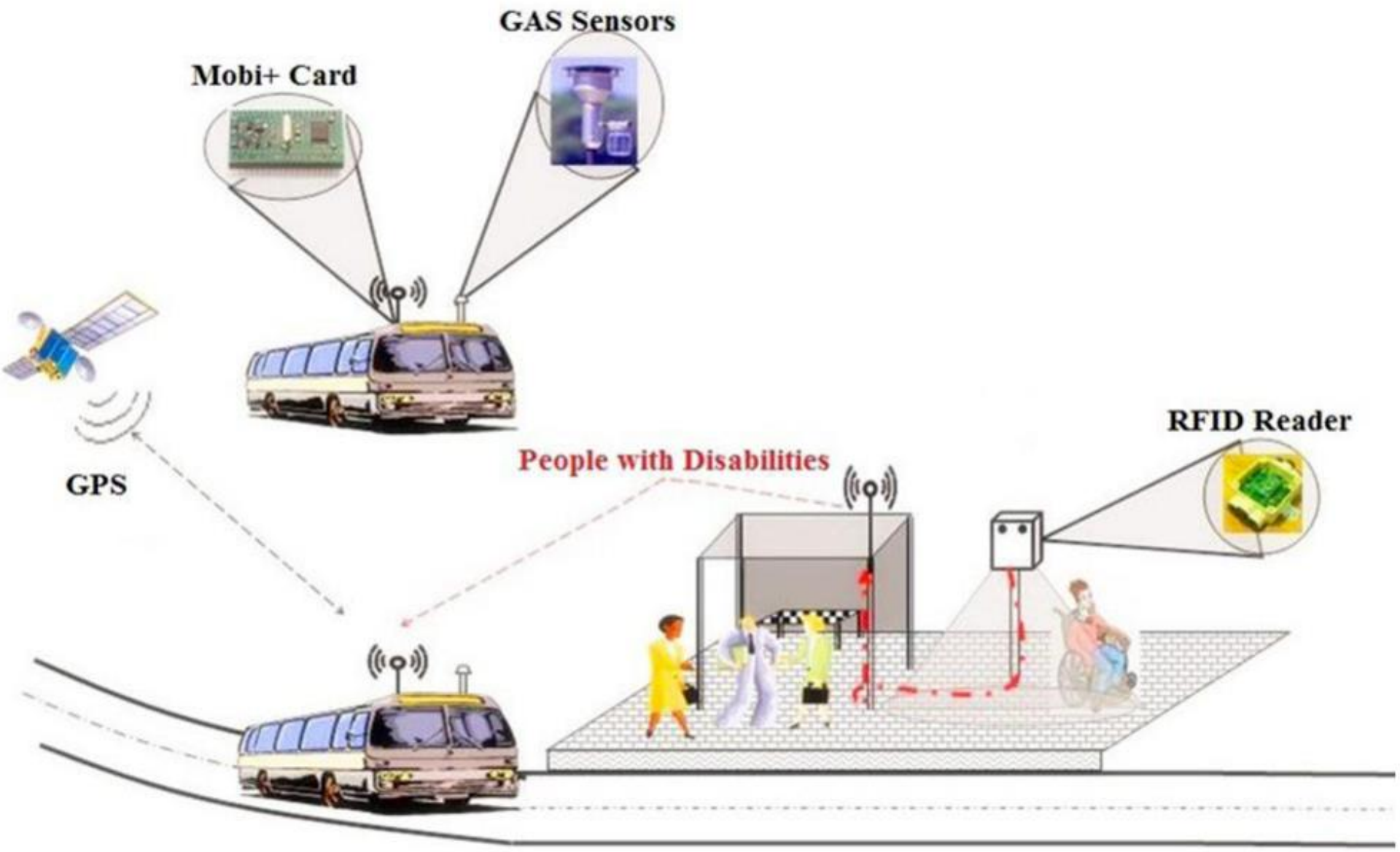
Application examples

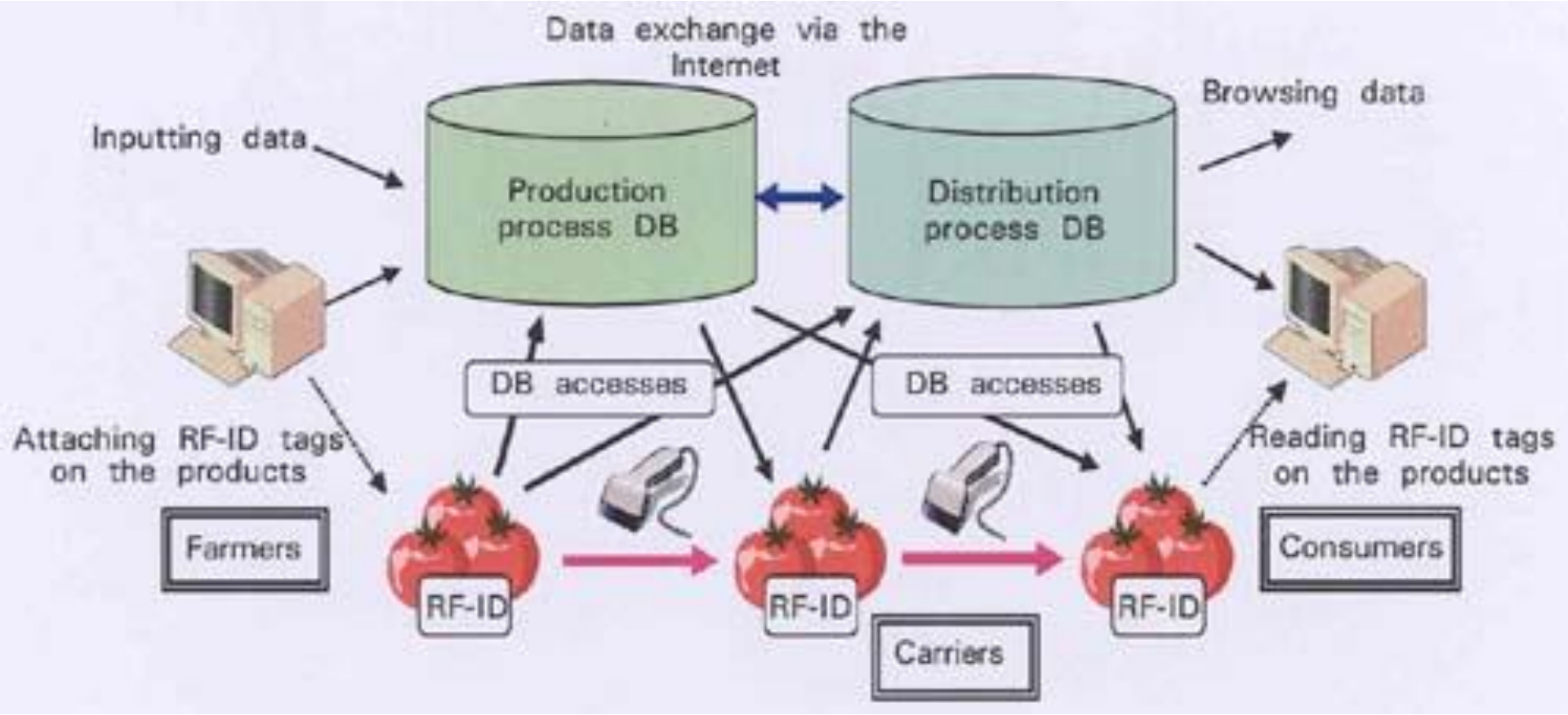
Transportation



Mass transportation



Food chain


Data exchange via the Internet
Inputting data
Production process DB
Distribution process DB
Browsing data
DB accesses
DB accesses
Attaching RF-ID tags on the products
Reading RF-ID tags on the products
Farmers
RF-ID
RF-ID
RF-ID
Carriers
Consumers


RRFID Nail Tag Information Selections
RFID nail tag for bin
Tree,wood,rust-resistant in wet
rust-resistant Chemical environment
Property tracking
Pallet

Healthcare

References

[1] Fu, Zhihui, Fangming Deng, and Xiang Wu. „Design Of A Quaternary Query Tree ALOHA Protocol Based On Optimal Tag Estimation Method". *Information* 8, no. 1 (2016): 5.
[2] Prof. Nithya S, Prof.Asha Jerlin M, Prof. Swarna Priya RM. „Tag Starvation and Tag Collisions in RFID System- A Solution". *IJET, Vol 5 No 3 (2013)*
[3] https://en.wikipedia.org/wiki/Loop_antenna
[4] Fu, Zhihui, Fangming Deng, and Xiang Wu. "Design Of A Quaternary Query Tree ALOHA Protocol Based On Optimal Tag Estimation Method". *Information 8.1* (2016): 5. Web.

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„Aircraft detection": http://electronicsntech.blogspot.hu/2012/10/what-is-radio-frequency-identification.html
„Privacy concerns": http://thefutureofthings.com/3221-hitachi-develops-worlds-smallest-rfid-chip/; http://blogs.dnvgl.com/software/2013/10/it-as-a-game-changer-in-which-direction-can-we-move-in-the-long-term-future/
„RFID history": http://www.rfidjournal.com/articles/view?1338/2
„What is RFID?", „Inlay": https://electrosome.com/rfid-radio-frequency-identification/; http://www.clearspider.com/what-is-rfid/
„Query – response": http://www.animalmigration.org/RFID/index.htm
„RF": http://www.acoustical.co.uk/acoustitips/frequency-velocity-wavelength/
„RF": http://www.srh.noaa.gov/jetstream/remote/remote_intro.html
„Tag types": http://www.coresonant.com/html/rfid-tags-for-solar-module-india.html
"Active and semi-active": http://www.yourdictionary.com/rfid-tag
„Reader types": https://guide.alibaba.com/shopping-guides/rfid-readers-types.html; http://www.web-yp.tw/Business/Business.asp?id=3027
„Inlay": https://en.wikipedia.org/wiki/Inlay; http://www.pcmag.com/encyclopedia/term/56950/rfid-inlay;
„RFID printing": https://www.seagullscientific.com/label-software/uses-for-bartender/rfid-software/
„RFID on 125 kHz? How?"
„Ferrite and loop": https://www.eevblog.com/forum/projects/why-is-my-rfid-range-so-low/; http://www.lzyec.com/222441/628678?page=8
„Grandpa's workshop accesory": http://www.electronicdesign.com/blog/future-am-radio; http://radio-timetraveller.blogspot.hu/2011/01/twin-coil-antenna-patent.html
„Load modulation": http://forum.arduino.cc/index.php?topic=282243.0; http://rfid-handbook.de/about-rfid.html?showall=&start=1; https://www.researchgate.net/figure/283498836_fig22_Figure-413-Generation-of-a-load-modulated-signal-with-a-subcarrier
"Frequencies for RFID": http://www.centrenational-rfid.com/rfid-frequency-ranges-article-16-gb-ruid-202.html
„Backscattering": http://www.eetimes.com/document.asp?doc_id=1276306
„ID": http://www.epc-rfid.info/
"Data storage capacity": http://www.emcu.it/MEMeRFID/MemAndRFID.html
„Tag with dipole antenna": http://www.farsens.com/en/2013/10/18/basic-guide-developing-rfid-sensor-solutions/
"Fading, standing waves": http://www.dailymail.co.uk/sciencetech/article-2956469/What-Wi-Fi-looks-like-Hacker-creates-3D-map-signal-strength-home.html
„Microwave frequency challenges": https://www.slideshare.net/JonathanBecker/becker-iee-esensors2013fin2
"RFID standards": http://www.radio-electronics.com/info/wireless/radio-frequency-identification-rfid/iso-epcglobal-iec-standards.php
"Aloha based algorithm": https://www.intechopen.com/books/current-trends-and-challenges-in-rfid/rfid-model-for-simulating-framed-slotted-aloha-based-anti-collision-protocol-for-muti-tag-identifica
"frequency allocation": http://www.opensourceinstruments.com/Electronics/A3008/M3008.html
"Penetration": https://www.gminsights.com/industry-analysis/printed-chipless-rfid-radio-frequency-identification-market
"ERC Recommendation": http://www.powerguru.org/wireless-power-transmission-with-high-efficiency-and-wide-dynamic-range-for-extensive-applications/
"Food chain": http://www.fftc.agnet.org/library.php?func=view&id=20110721154120&type_id=2

Web:
http://www.mamicode.com/info-detail-1055032.html

Videos:
Video name, Channel: link
RFID Technology Review Part 1, RFID4USolutions: https://www.youtube.com/watch?v=I3K1yBqsojo

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