Definition of RF-ID

RF-ID: Radio Frequency Identification.

Indicates the use of Electromagnetic waves to detect and identify *TAGS* (i.e. labels) purposely attached to *objects*

Basic components (2)

Interrogator (READER) ⟺ Transponder (TAG)

Functions:

- Automated Wireless Identification
- Transmission of detailed information data
- Programmability
- *Sensing & Data logging*
- *Localization*

Motivations and scenarios

Other identification techniques:

Readable labels (alphanumeric, color codes)

Barcodes

Drawbacks:
Need human operation
Need visibility
Static Information
Slow operation

Where are RF-ID alternative particularly desirable?

Supply chain monitoring (high degree of automation, parallelism, speed)

Animal tracking (small and non-intrusive)

Food security and traceability

Brief hystory of RF-ID (ancient era)

1950-60 Airplane transponders (military, long range, active)

1960-70 First EAS (Electronic Anti-theft Surveillance, short range, passive, 1-bit)

1970-80 First passive Tags for door locks and nuclear fuel tracking. First RFID patents (1973).

1980-90 Development of commercial LF and HF RFID systems for electronic keys and smart-cards.

Early 90' First patents for UHF Tags (IBM). Experiments with Wal-Mart stores.

Mid 90' IBM sold the patents to Intermec (a former barcode supplier). Diffusion of the technology in various sectors but still important limitations due to excessive cost of the tags.

Brief hystory of RF-ID (modern era)

1999 Auto-ID center formed at MIT (with industries and USA + EU product code councils). New Ideas: simple tags (only small ID codes) to reduce costs. Emphasis on the infrastructure (network).

2003 Auto-ID center closed (while Auto-ID labs were still working) after creation of several standard protocols. Creation of the EPCglobal (EPC: Electronic Product Code, including also bar-codes).

2004 EPCglobal released the 2nd generation protocol for UHF tags.

Related concept: Internet of Things (IoT)

The term Internet of Things was first used by **Kevin Ashton** (Contributor to the Auto-ID center) in 1999 .

Target: providing **all** objects of interest for humans with a unique ID code

Motivation: Internet has grown impressively, but most of the information it stores and manipulates is generated by voluntary human activity and, often, does not provide a valid representation of the real world (“made of things, not ideas”)

RF-ID technologies made possible the conception of the IoT idea and are a **prerequisite** for its fulfillment

Limitation of the IoT concept:

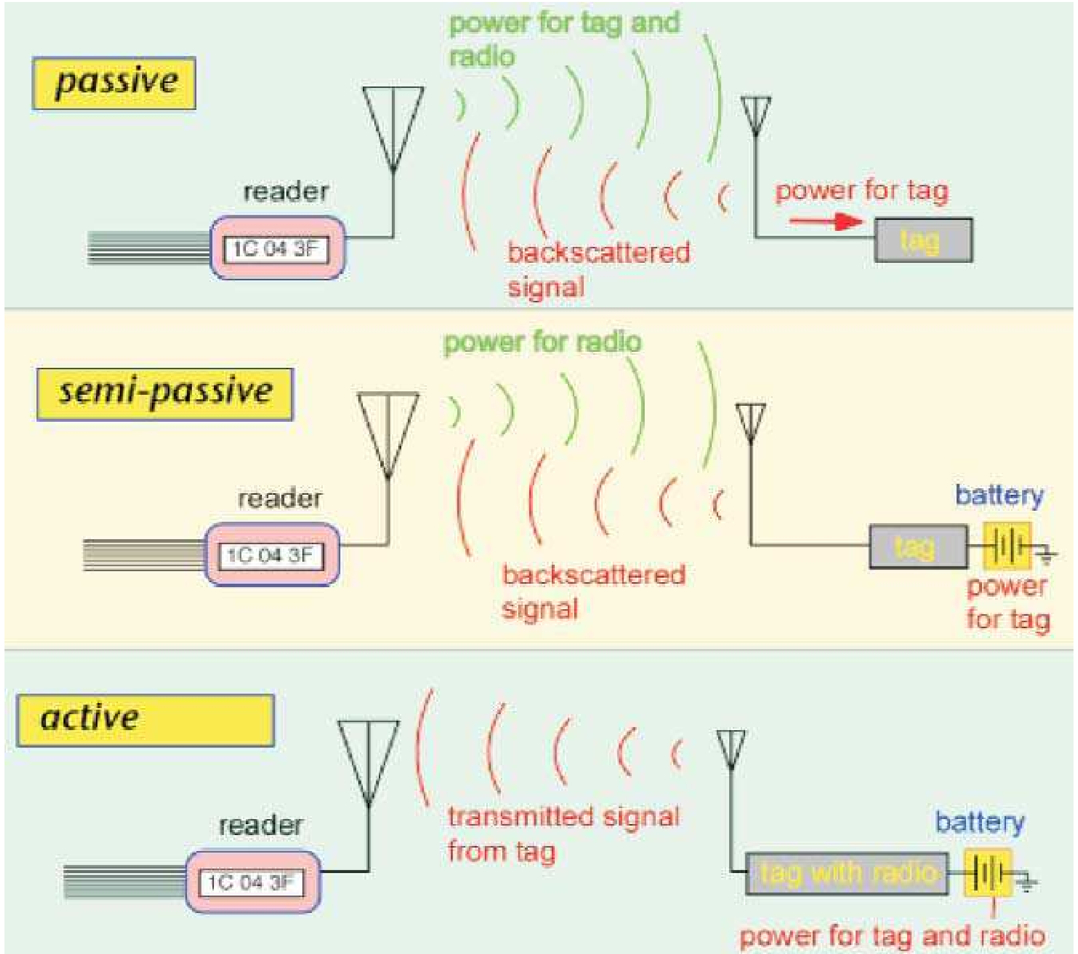
- Privacy infringements
- Real commercial usefulness

RF-ID device classification (1)

Three parameters are mainly important for claccifications of RF-ID systems:

1. Tag power (passive / active)
2. Frequency (→ coupling method, inductive or radiative)
3. Communication protocol

Passive, semi-passive and active Tags



Passive, semi-passive and active Tags. Comparison

Passive Tags:

Power required to operate basic tag functions: 10-100 μW
Typical sensitivity of an active radio (e.g wi-fi receiver) 1 pW

10^7-10^8 factor

High reader power (watts)
Low detection range (1-3 m max, depending of frequency and coupling)

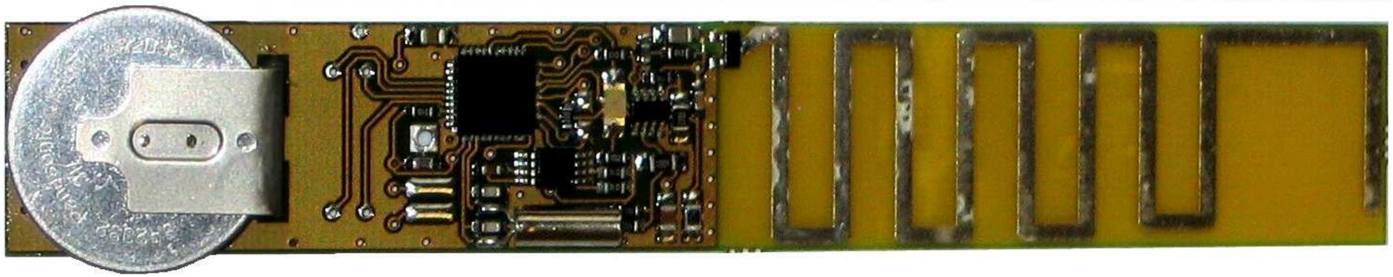
Advantages. All of them derives from the absence of a battery!

- Cost (10 cents for mass sale, HF and UHF passive tags)
- Miniaturization (very flat tags)
- No maintainance
- Long field lifetime – more environmental robustness

Semi-passive Tags

Other designations: Battery Assisted Passive RFID Tags,
Semi-Active RFID Tags

Example: UHF semipassive tag of CAEN



Battery Circuits Antenna

Other examples: Telepass transponder (5.8 GHz)

Characteristics of semi-passive tags

Battery: used for: low power, infrequent tasks, for example:
- Data logging
- Signal reception (reader triggered)

Data transmission: still uses backscattering of reader power

Advantages vs passive tags:

Autonomous functions (e.g. sensing, data logging) when out of reader field

More complicated tasks can be performed (e.g. data encryption)

Much wider memory space for detailed information retention

Longer range (up to 30 m)

Active TAGs

Active tags are architecturally-conventional radios that use the battery power for all functions:

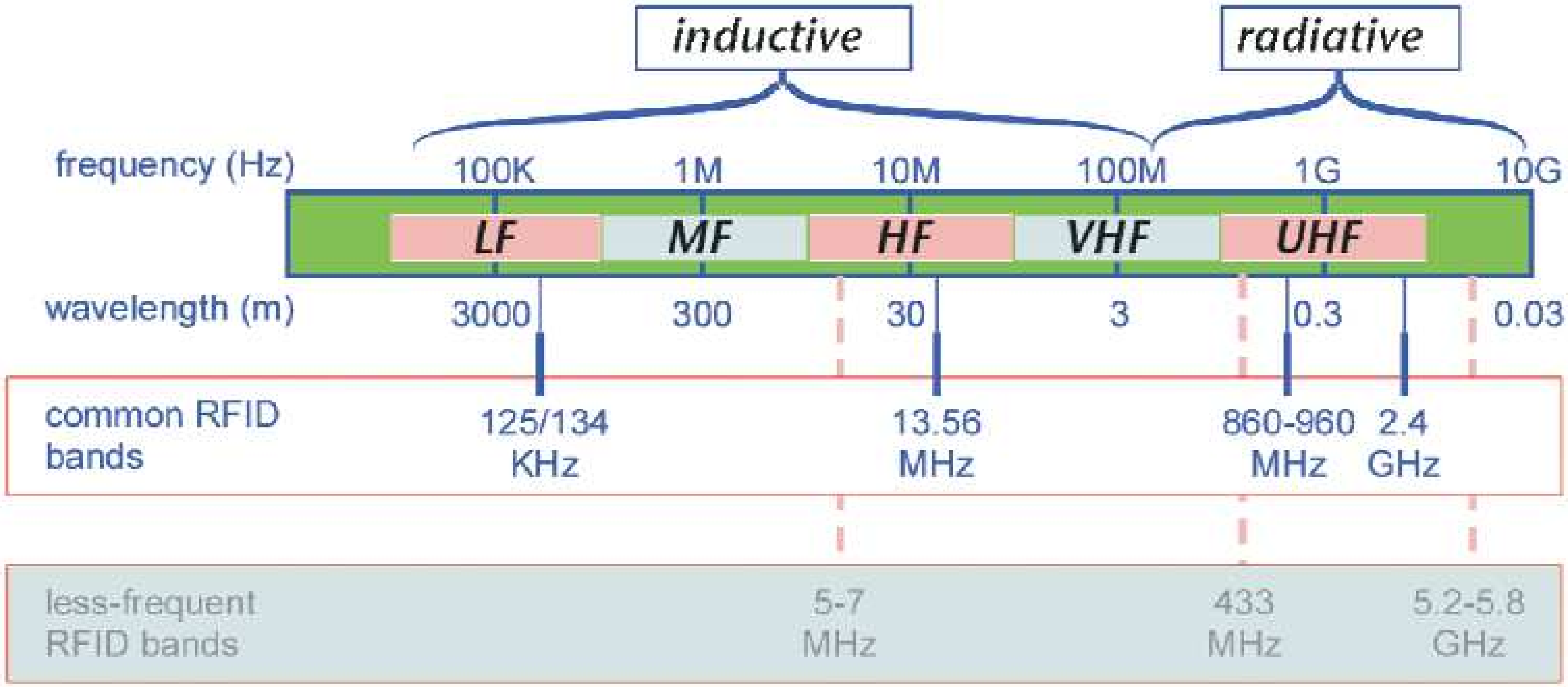
- Data logging
- Telemetry and localization
- Data processing (encryption, compression, redundant encoding, etc.)
- RX subsystem
- TX subsystem

Advantages:
More versatile (More functions allowed)
Longer range (> 100 m).
Higher data rates

Drawbacks

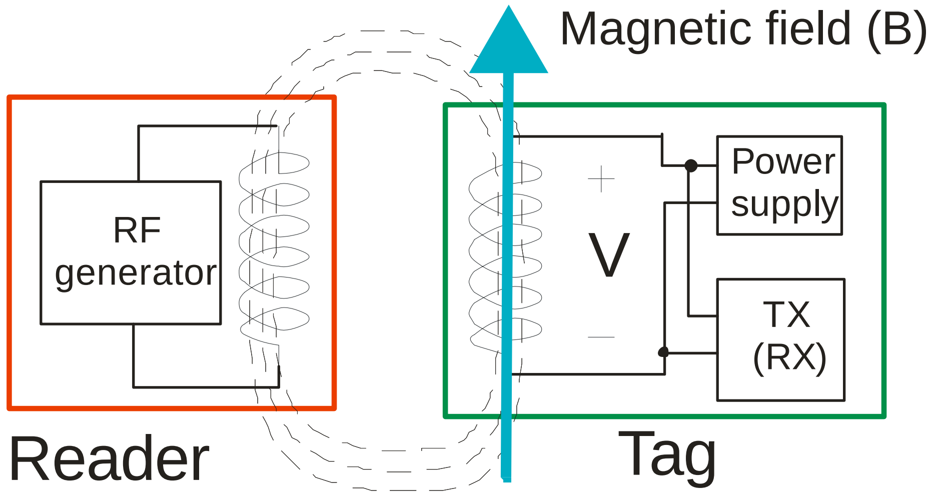
- Cost! (> 10 €)
- Not compatible with standard readers (designed for passive and semi-passive tags) → Exception: Multimode tags
- Battery duration (max 1-2 years, but few weeks are common)

Operating frequencies of RF-ID systems



Inductive coupling

Condition: antenna size is << λ



125 kHz -> λ=2.4 km
13.56 MHz -> λ=22.1 m

P: power received by the tag
d: tag-reader distance
$\omega=2\pi f$, *f*=frequency

$$|V| = \omega B N_S \qquad P \propto V^2 \qquad B \propto \frac{1}{d^3} \Rightarrow P \propto \frac{1}{d^6}$$

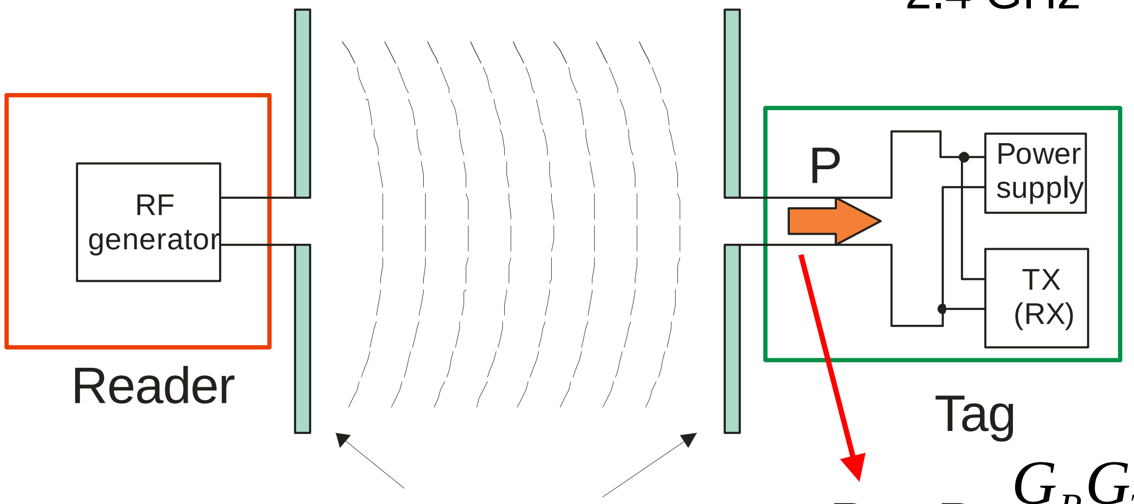
Low frequencies: Large number of turns (N_S) is required

Only small distances < 1 m are typically allowed

Radiative coupling

Condition: antenna size is of the same order of magnitude as λ

900 MHz -> λ=33 cm
2.4 GHz -> λ=12.5 cm



$$P = P_R \frac{G_R G_T \lambda^2}{(4\pi)^2 d^2} P_{LF}$$

Where: G_R,G_T: antenna gains
P_R : reader power
d : tag-reader dstance
P_{LF} : polarization loss factor <1

E.g. P_R=1 W, G_R=G_T=1.5 (dipoles)
f=900 MHz, d=3 m, P_{LF}=1

P=140 μW

LF Tags (Inductive)

LF (125-134 kHz)

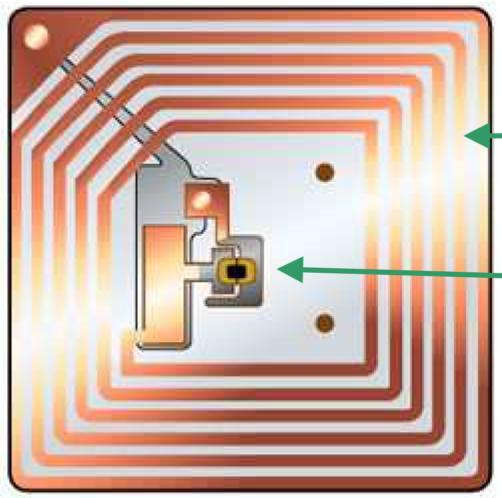
LF penetration depth

Water: 2 m
Aluminum foil: 0.2 mm

Ideal for:
Animal tracking
Car key transponders
Conductive objects
Health care

Problems: Cost, range, low data-rates

HF passive tags (inductive)



Coil (planar)

Chip

Frequency 13.56 MHz

HF penetration depth
Water: 0.2 m

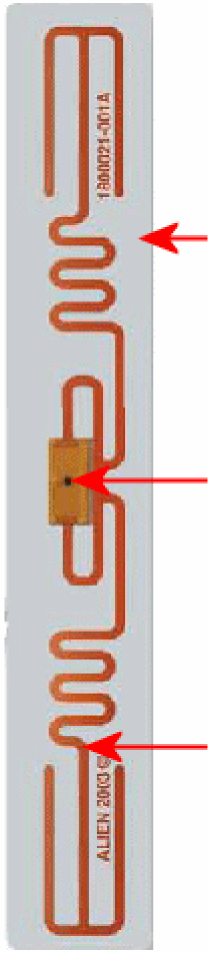
Typical range: 1 m

Advantages:

- Inexpensive (the antenna can be fabricated by means of flexible PCB technologies)
- Very flat
- Increased range with respect to LF Tags

Usage: Smart cards, Library Book tracking, Baggage tracking

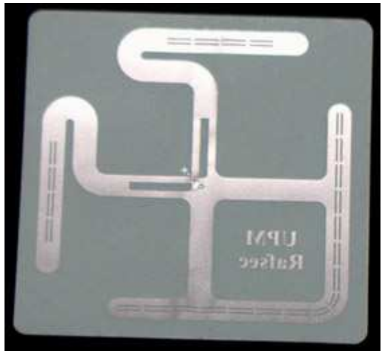
UHF Tags (radiative)



Substrate
(flexible, adhesive)

Chip
(only two connections)

Antenna
(metal foil)

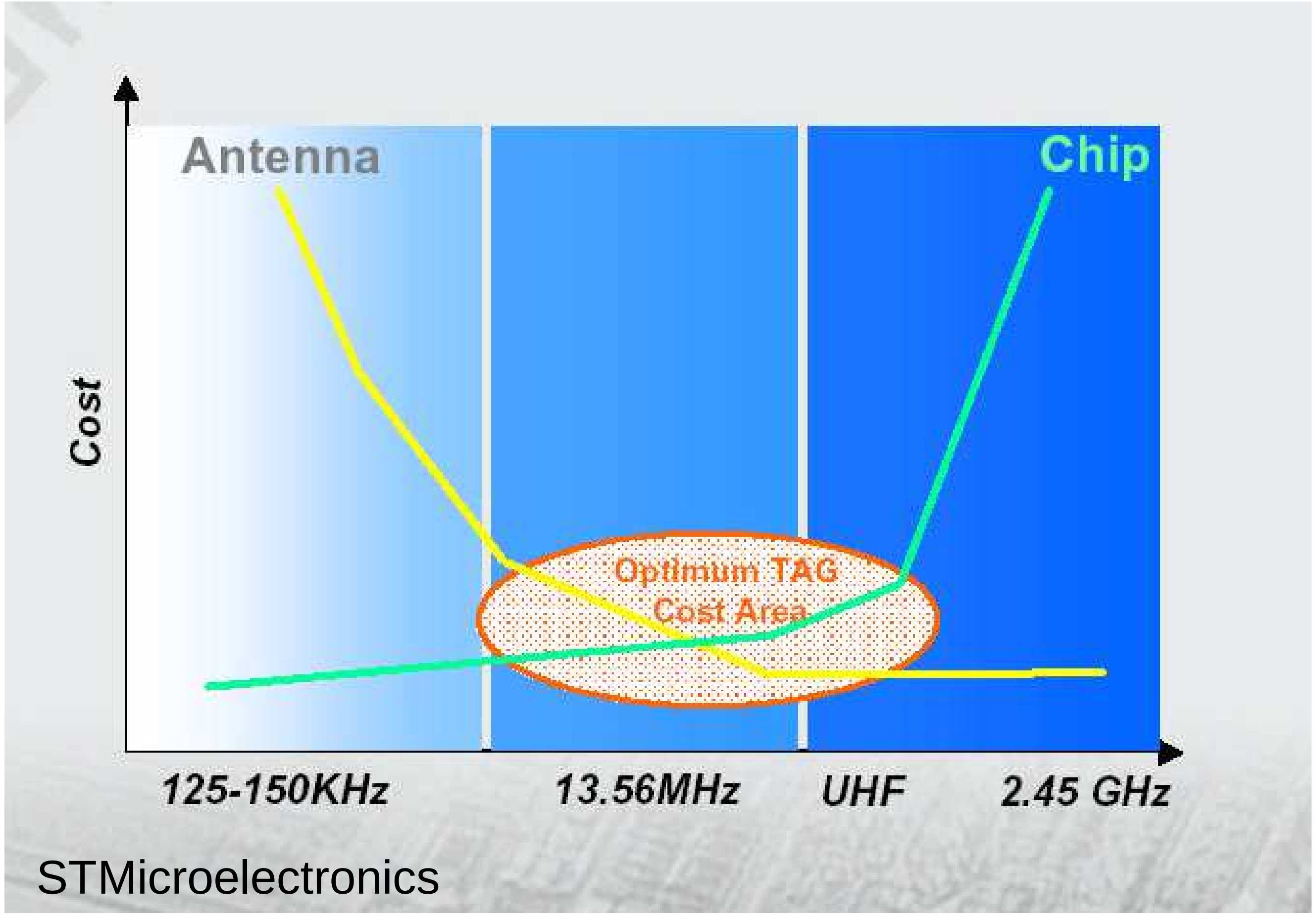


Frequencies: 860-930 MHz
Range > 3 m

Advantages:
•Inexpensive (like HF tags)
•High data-rate
•Highest range among passive tag

Usage: Preferred for logistics
Selected by EPCGlobal organization

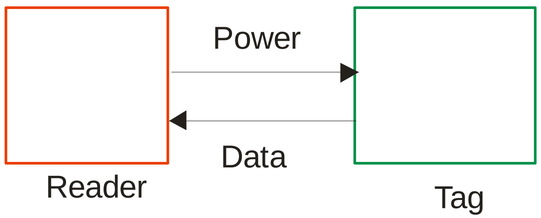
Higher frequencies?



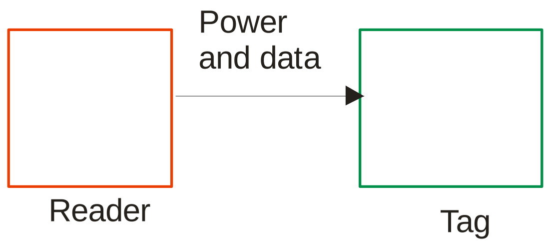
Tag-Reader communication protocols

Read-only tags: only transmit a fixed code to the reader.
Read-write tags: the code can be programmed by the reader

Tag->reader communication

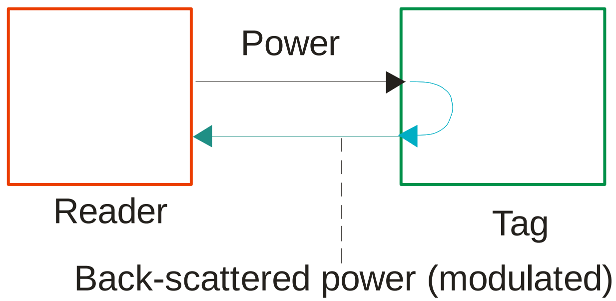


Reader->tag communication



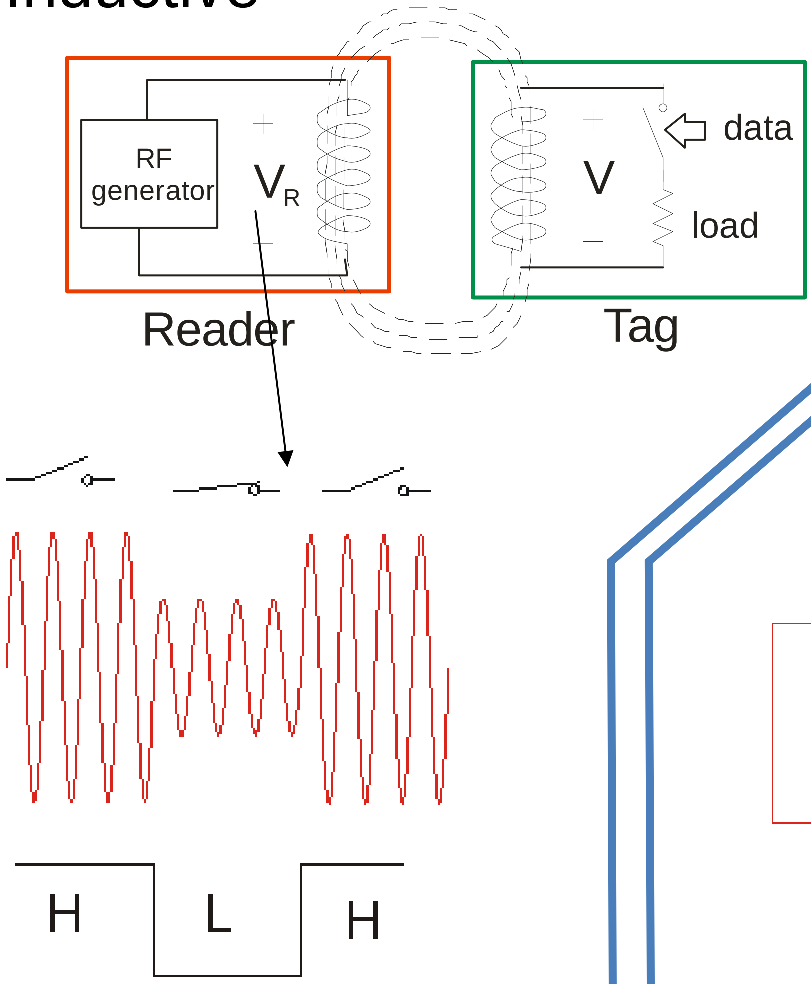
Passive and semi-passive tags do not have a real TX subsystem, due to power limitations

The tag-reader data transmission mechanism is Backscattering



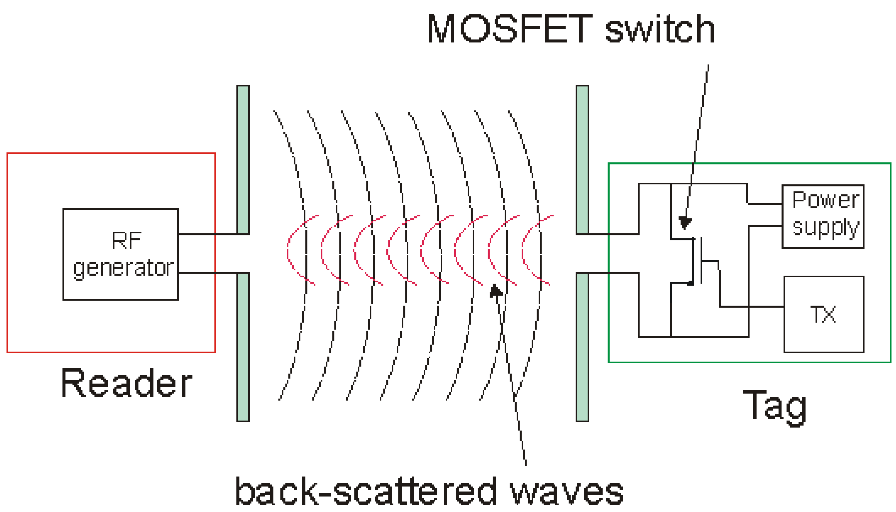
Backscattering mechanisms

Inductive

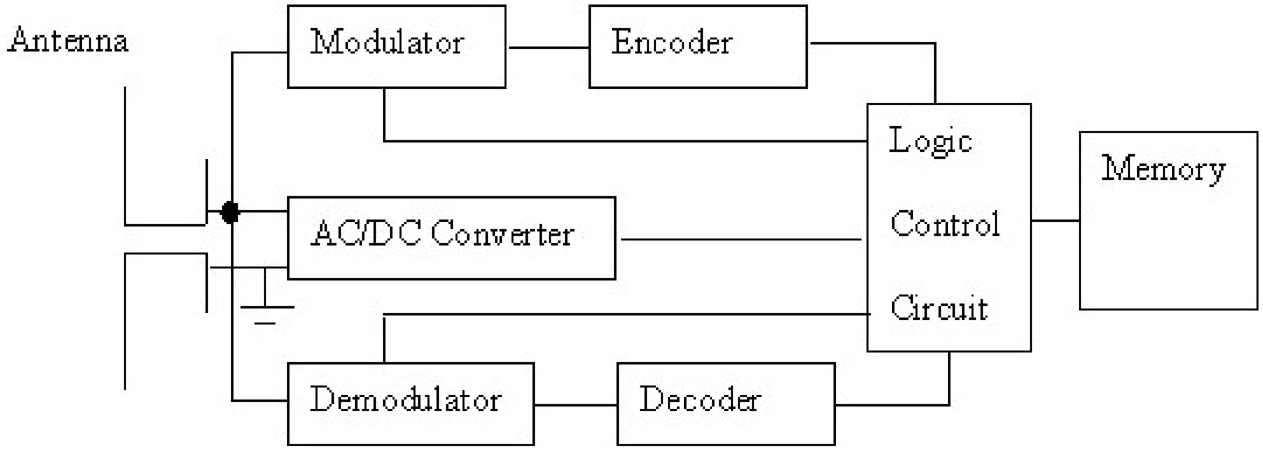


Radiative

When the MOSFET switch is closed, the tag antenna is umbalanced and a larger fraction of the incoming radiation
is reflected back to the reader



Structure of a Passive UHF Tag



Protocols

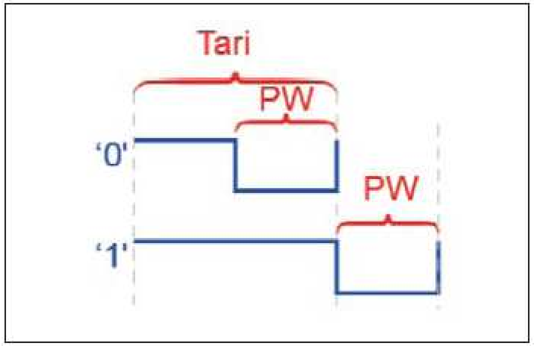
Protocols define reader->tag and tag->reader communication.
Different physical layers are generally associated to different protocols, so that interoperability is generally not possible.

FREQUENCY	**125 kHz**	**5-7 MHz**	**13.56 MHz**	**303/433 MHz**	**860-960 MHz**	**2.45 GHz**
TAG TYPE						
Passive	ISO11784/5, 14223 ISO18000-2	ISO10536 iPico DF/iPX	MIFARE (ISO14443) Tag-IT (ISO15693) ISO18000-3		ISO18000-6 EPC class 0 EPC class 1 EPC GEN II Intellitag tolls (Title 21) rail (AAR S918)	ISO18000-4 Intellitag µ-chip
Semi-passive					rail (AAR S918) Title 21	ISO18000-4 Alien BAP
Active				Savi (ANSI 371.2) ISO18000-7 RFCode		ISO18000-4 WhereNet (ANSI 371.1)

Gen II EPCglobal protocol: Classes

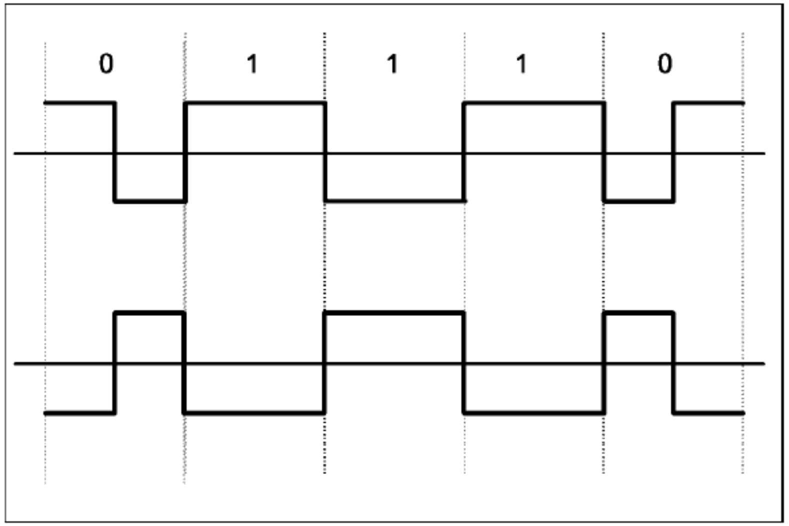
Class 1:	Passive	96-496 Bit	Commonly used
Class 2:	Passive	96-496 Bit	Authentication
Class 3:	Semi-Passive	96-496 Bit	Integrated sensing
Class 4:	Active	96-496	Ad hoc networking

Class 1 – Gen II EPCglobal protocol

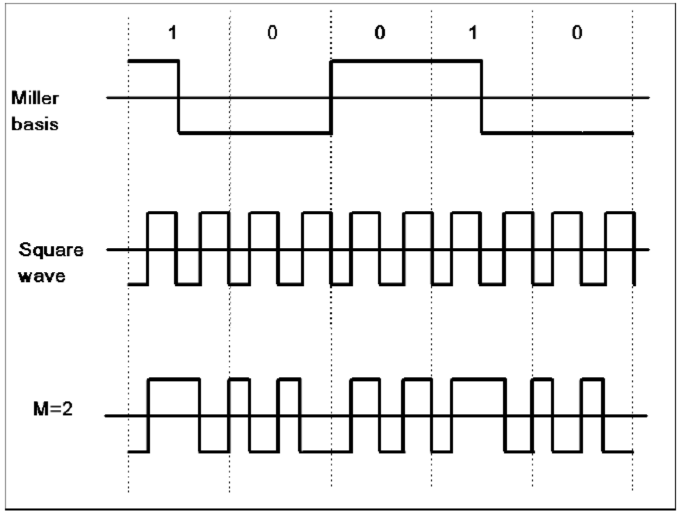


Reader-to-Tag symbols (Tag programming)

Tag to Reader symbols. The particolar method is first communicated by the tag in reader "query" phase



FMO signalling



Miller Modulation
(best noise suppression, lower bit-rate)