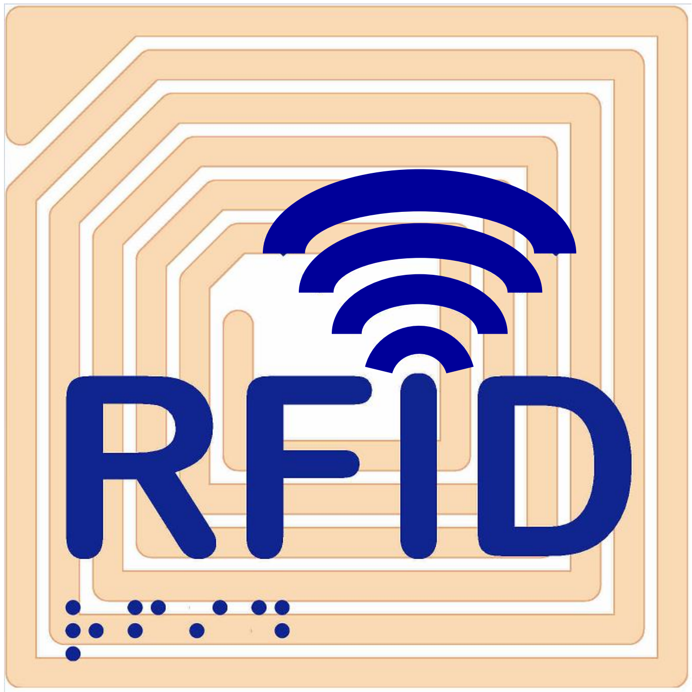
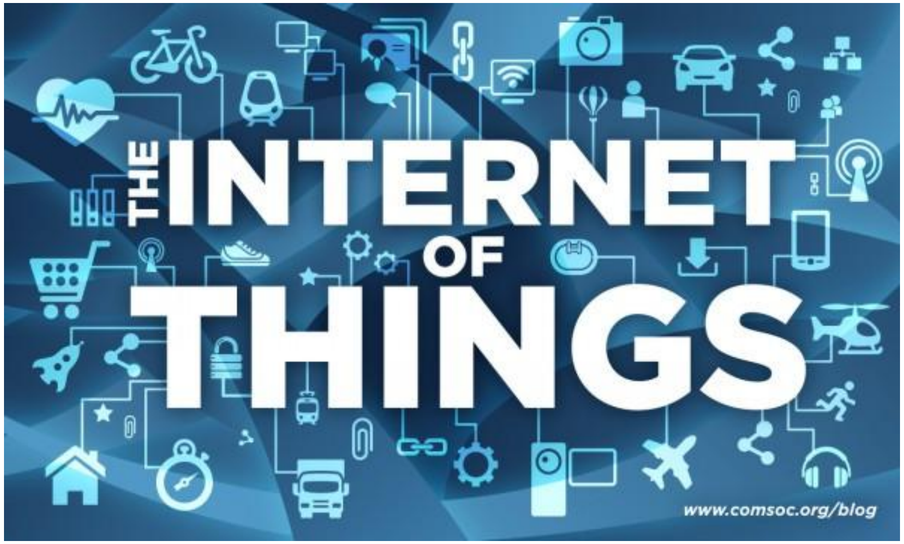
The Role of RFID in IoT





Khaled ElMahgoub

ThingMagic, A Division of Trimble Navigation

Auto-ID Labs, Massachusetts Institute of Technology

AUTO-ID LABS

ThingMagic
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Cairo University, June 30th, 2104

Outlines

- Introduction
- Different RFID Technologies
- UHF RFID and its Applications
- Other Identification Technologies
- Future Trends

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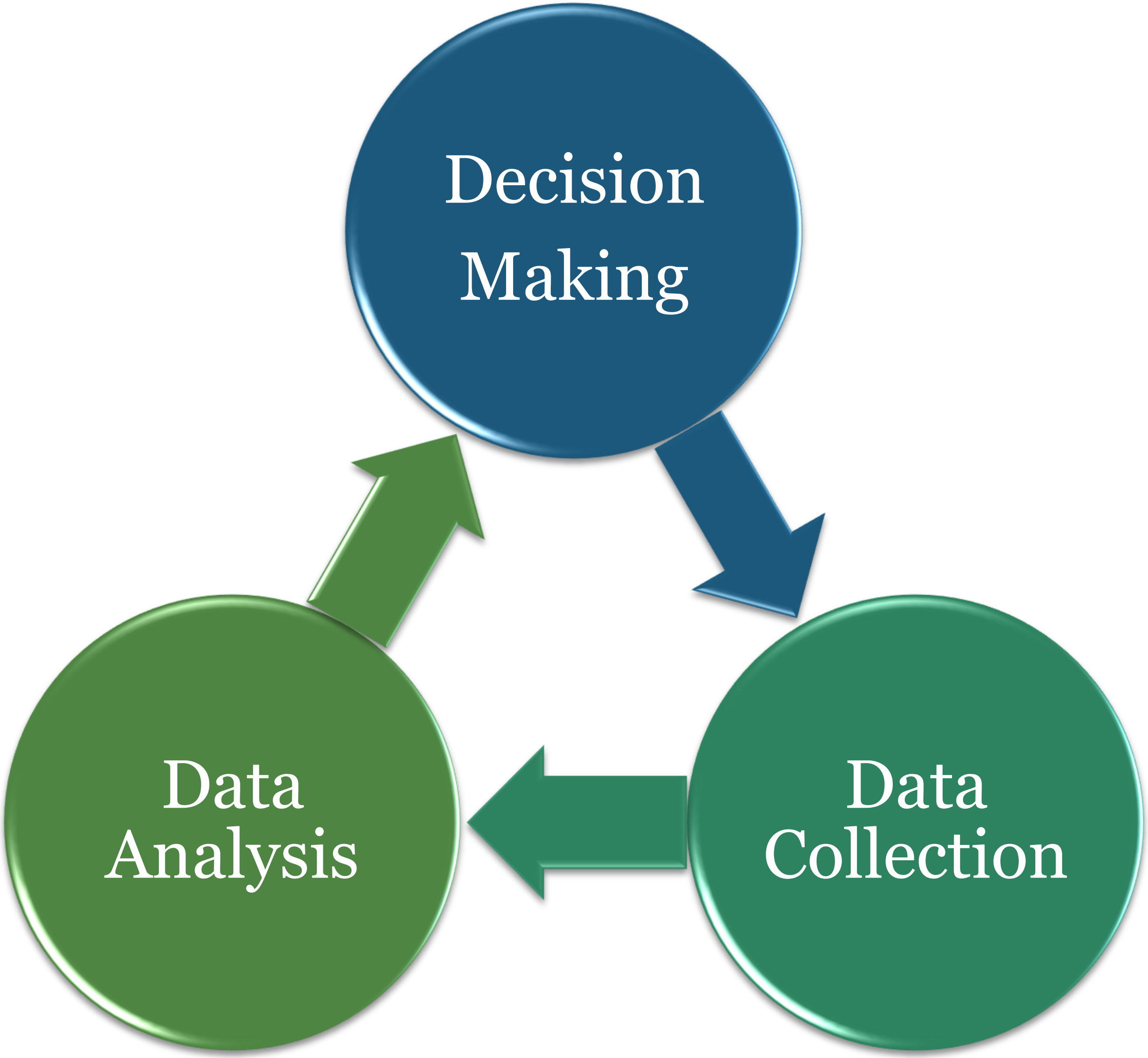
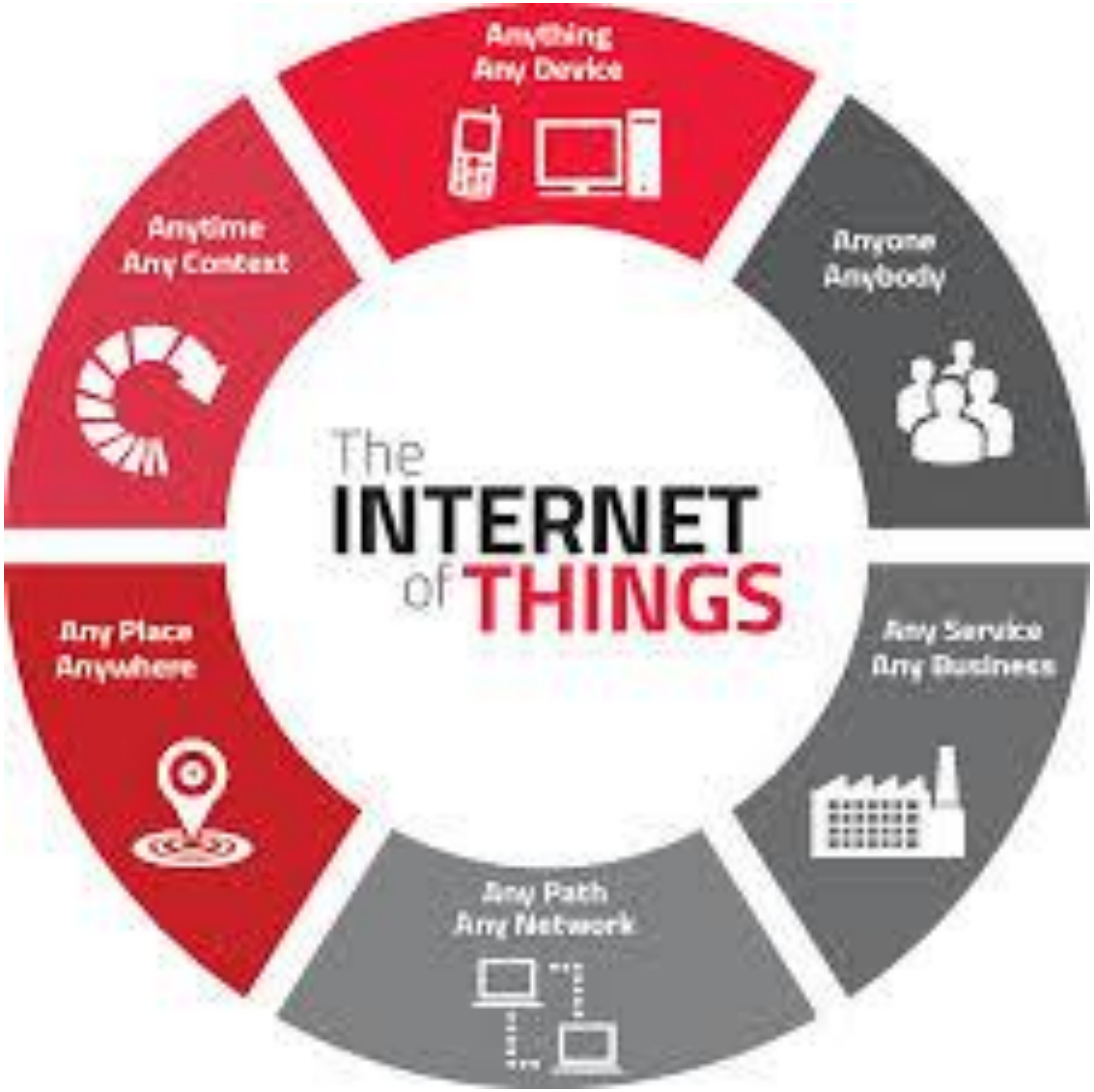
Introduction


Decision Making
Data Collection
Data Analysis



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What Is RFID ?

What Does RFID Stands for?

RFID stands for Radio frequency Identification, and it is technology which uses RF signals for automatic identification of objects.

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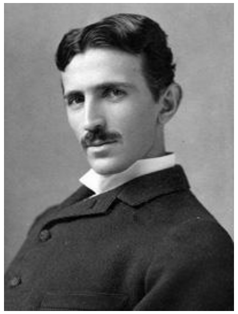
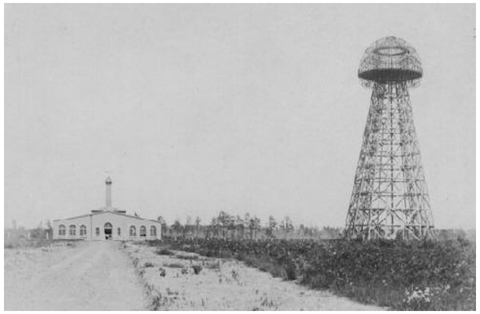
RFID History

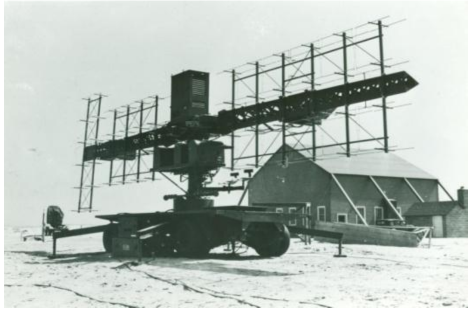


Nikola Tesla
1865-1945



Wireless transmission
1908

Robert Watson-Watt
1892-1973



Radar 1935, Identify friend

Electronic Article Surveillance (EAS) → **Animal Tracking LF System** → **HF System** → **1990 IBM UHF** → **1999 Auto-ID Center** → **2003 EPCglobal Established** → **2003 -2005 Wal-mart & DoD** → **More to Come**

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Current RFID Applications

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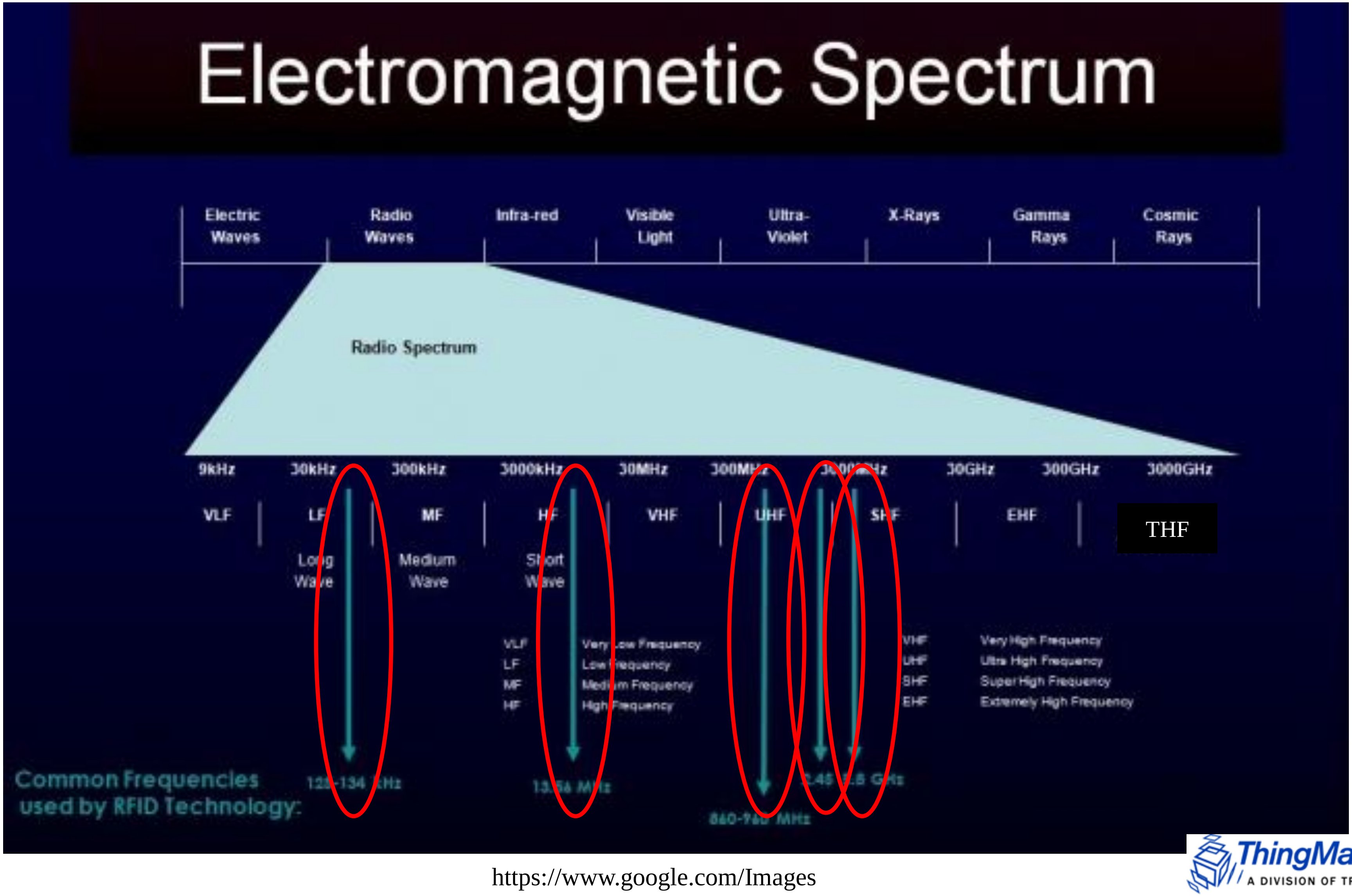
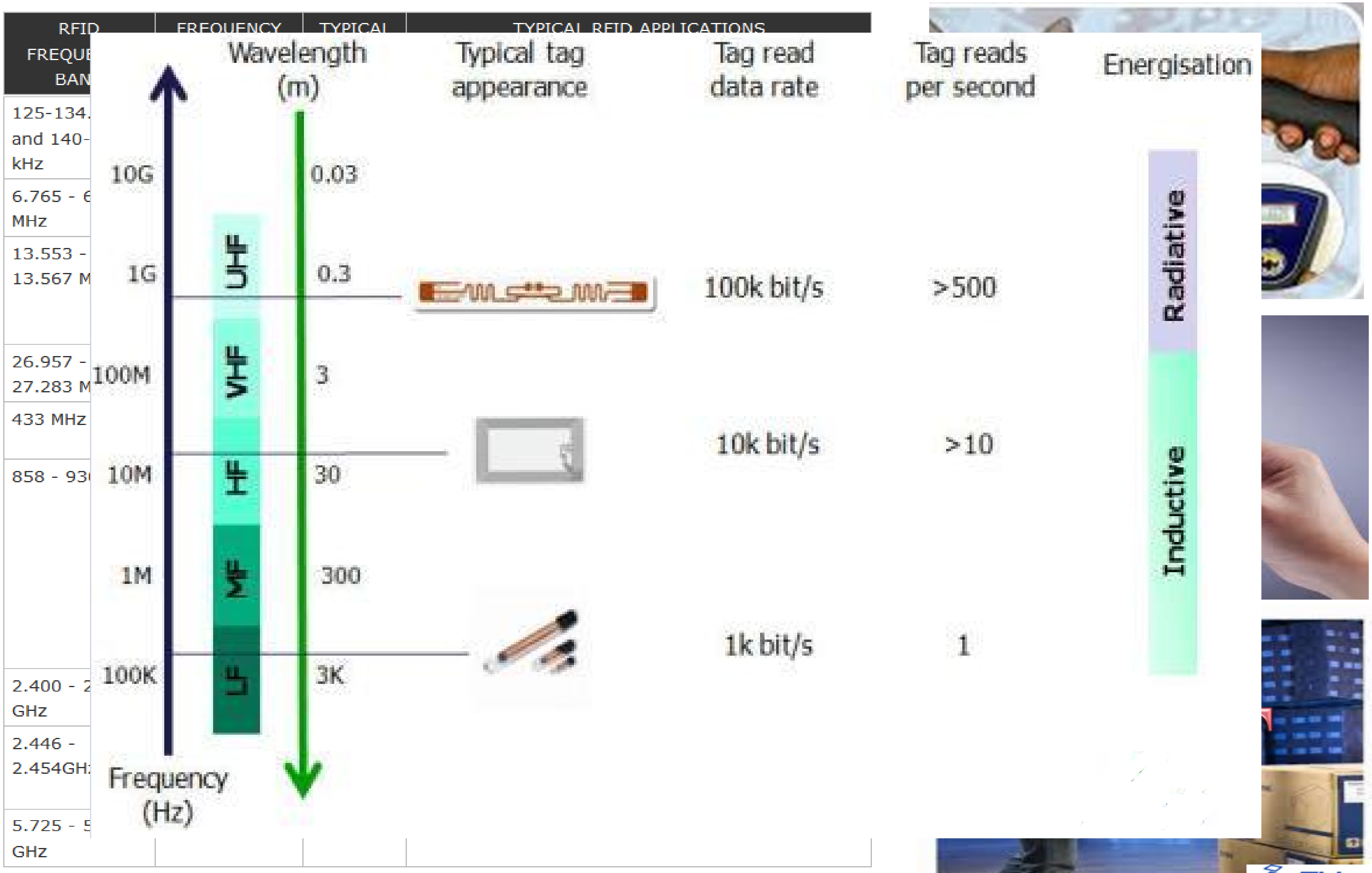
RFID Frequency Bands



https://www.google.com/Images

RFID Frequency Bands Overview



http://www.radio-electronics.com/info/wireless/radio-frequency-identification-rfid/low-high-frequency-bands-frequ

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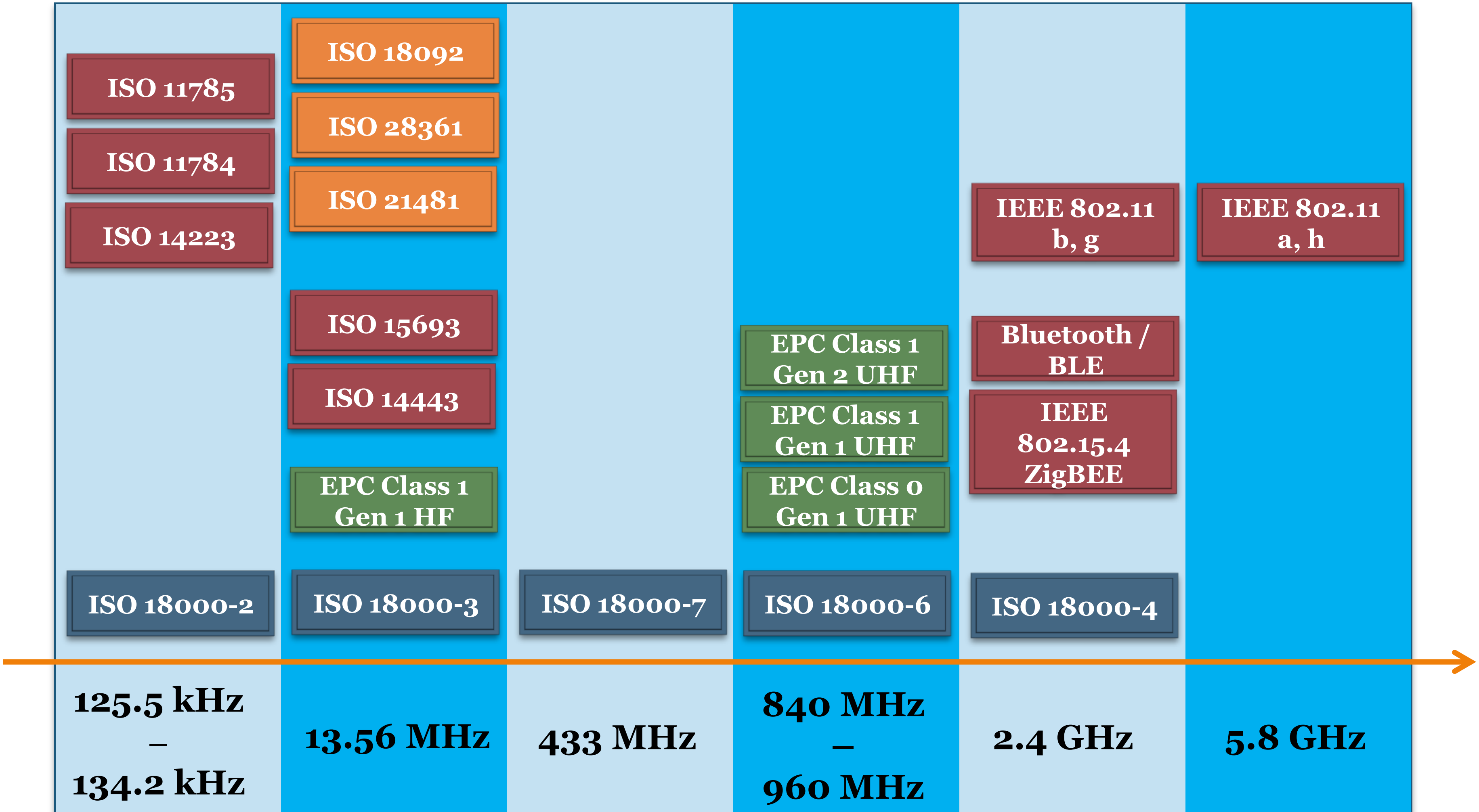
RFID Standards Overview



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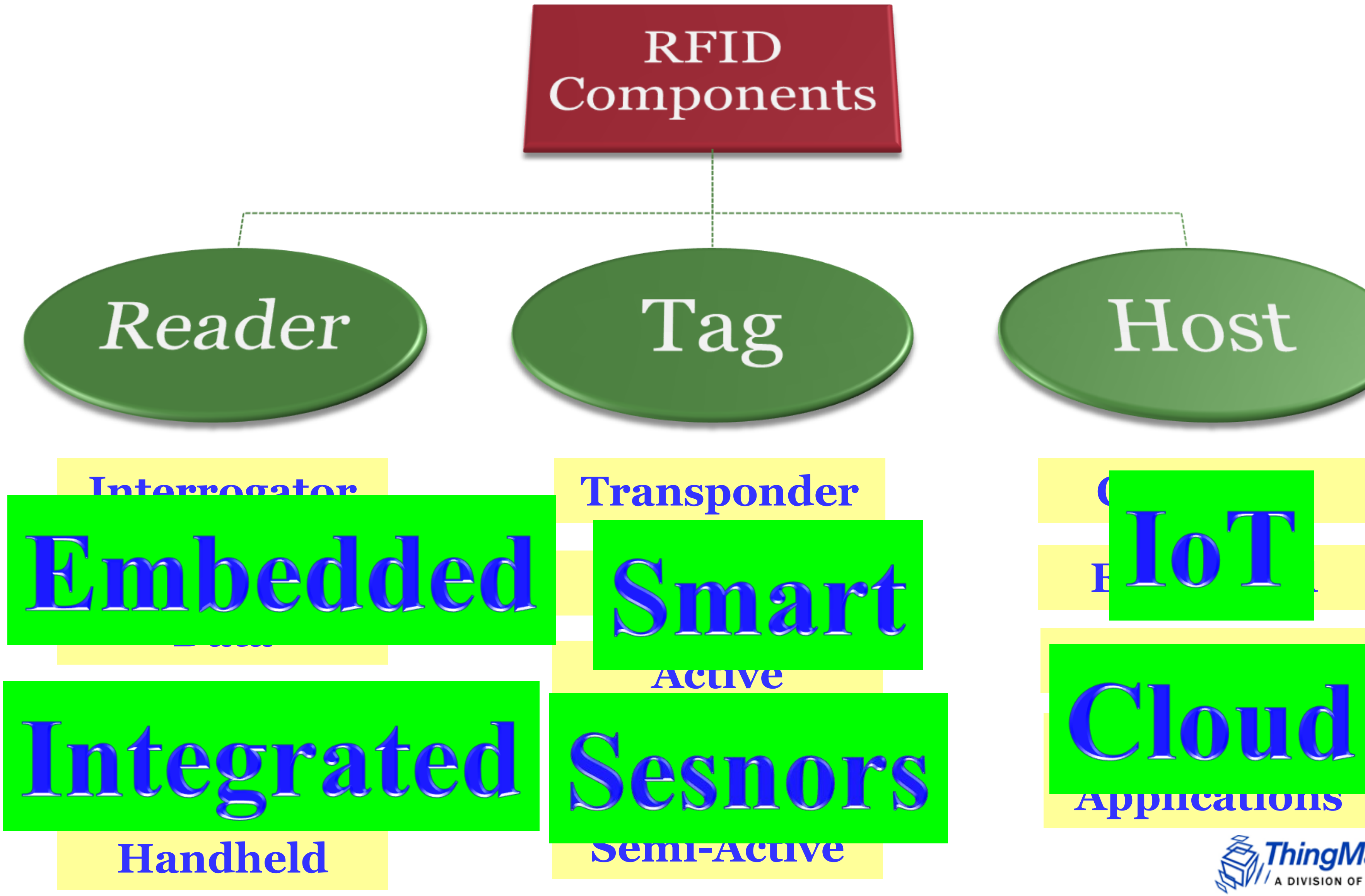
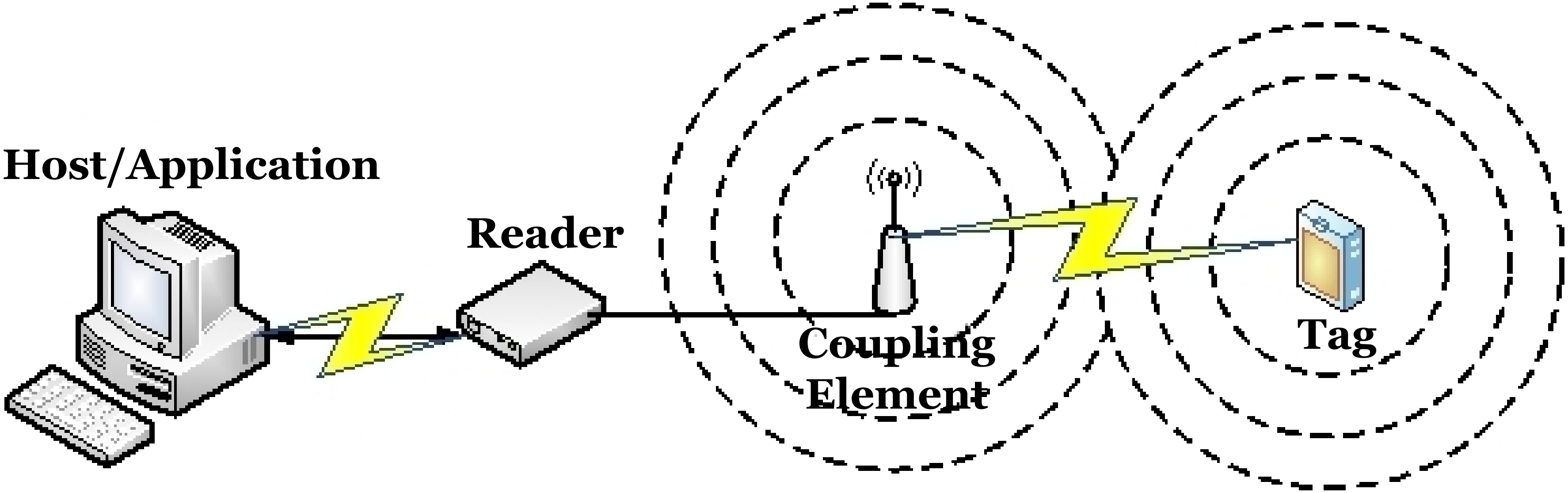
RFID Main Components



RFID Operation Overview



1. Reader Communicate with the tag through the coupling element.

2. Tag Sends its data back to the reader.

3. The reader sends the tag data to the Host/Application, and the this data is processed.

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Different RFID Technologies

RFID System Categorization

RFID Systems Can Be Categorized Based on

- *Mode of Operation*
  - **Full / Half Duplex**
  - **Sequential**
- Transponder Formats
  - **Chip / Chipless**
  - **Active / Passive**
- Frequency, Range, Coupling
  - **LF / HF / UHF /SHF**
  - **Short / Long Range**
  - **Magnetic / Electrical Coupling**

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Inductive Coupling RFID Systems

The inductive coupling RFID system is widely used in today's market and it has the following properties:

- Frequency of Operation: Such as 13.56 MHz
- Coupling: Inductive Coupling (Magnetic Coupling)
- Range: Short Range (<= 1 m)
- Passive Tags (energized by the reader)
- Tag with Chip (the tags has an ASIC)

Proximity Smart Cards (13.56 MHz)
Range = 4 inches (10 centimeter)
ISO 14443

Vicinity Smart Cards (13.56 MHz)
Range = 3 feet (1 meter)
ISO 15693

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Near Field Communication (NFC)

NFC Forum, was founded in 2004 by Nokia, Philips Semiconductors (became NXP Semiconductors since 2006) and Sony.

It's a short-range, low power wireless link based on inductive coupling RFID tech that can transfer small amounts of data between two devices held a few centimeters from each other.

Used in smartphones and it is less complex compared to Bluetooth and WiFi technologies

Modes of Operations

NFC Applications

NFC Market

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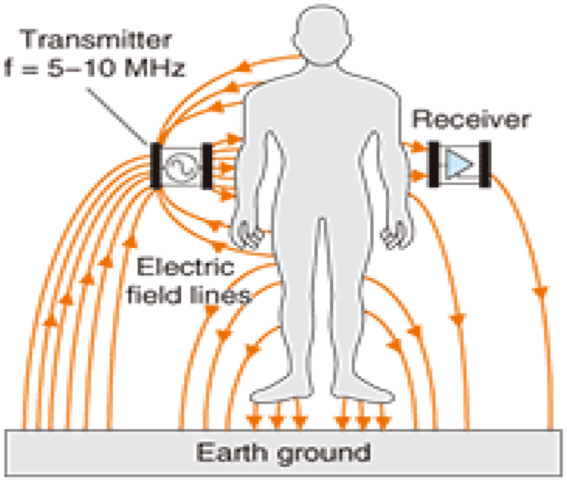
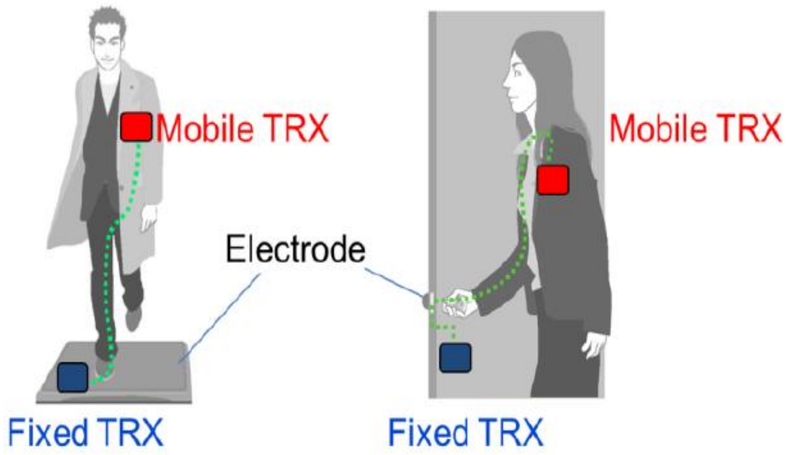
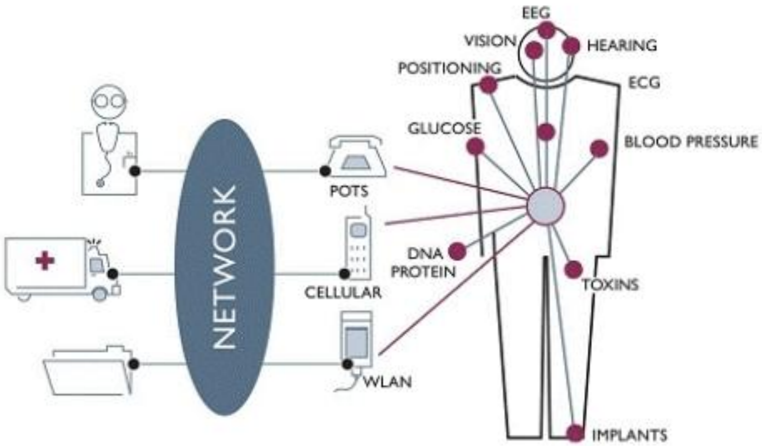
Body Coupled Communication





Coupling could be capacitive or inductive

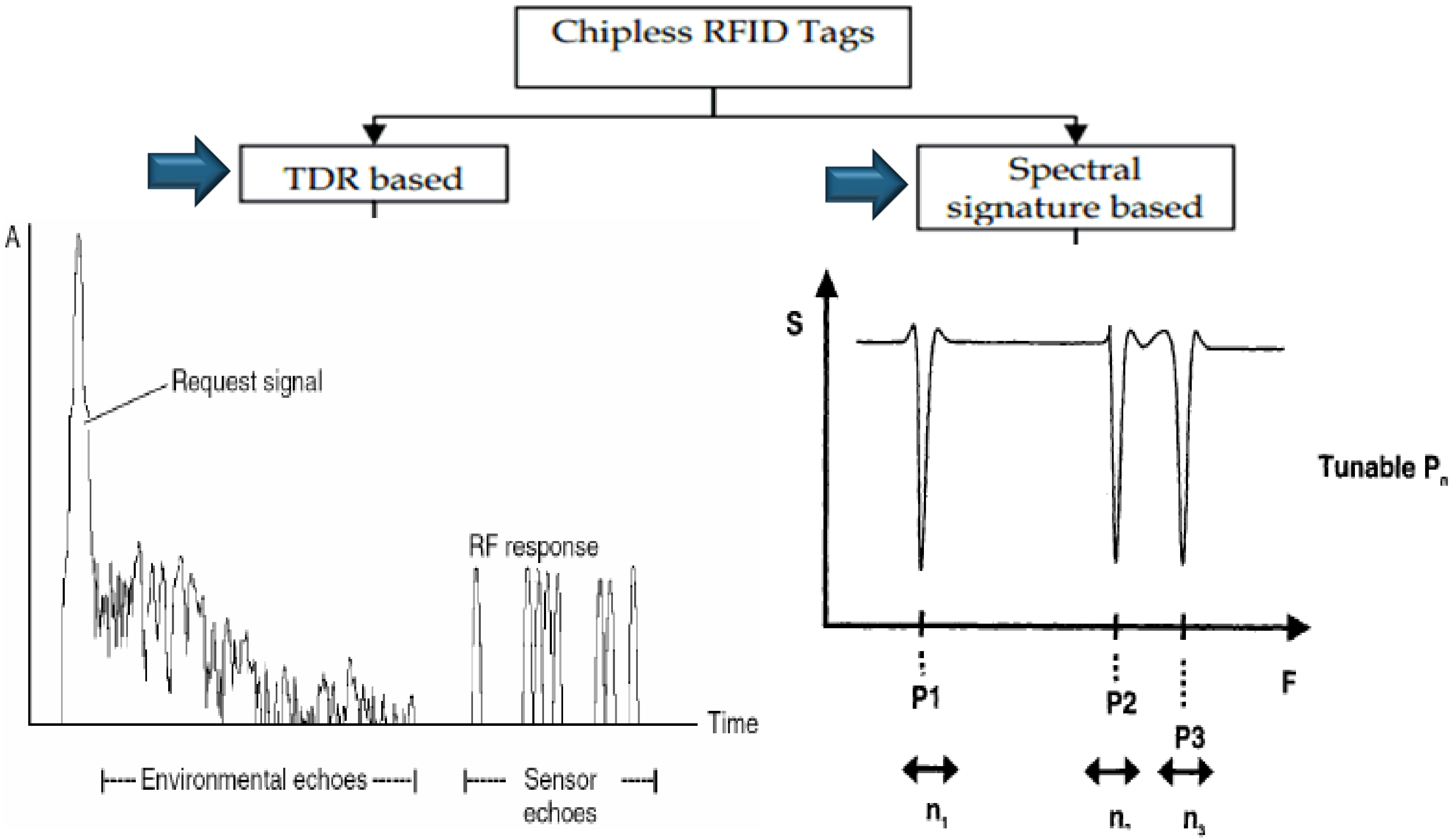


Body Area Network

BAN

https://www.google.com/Images

Chipless RFID



http://en.wikipedia.org/wiki/Chipless_RFID
http://cdn.intechopen.com/pdfs/14423/InTech-Fully_printable_chipless_rfid_tag.pdf
https://www.google.com/Images

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UHF RFID and its Applications

UHF RFID Systems

Mode of Operation: Half duplex

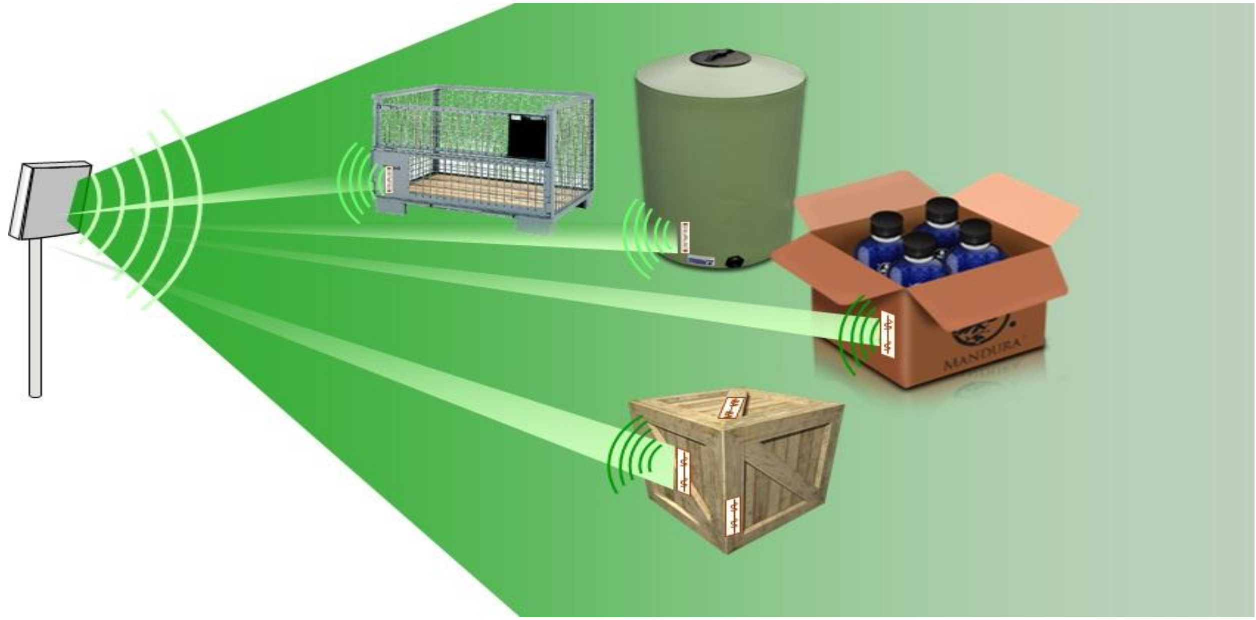
Frequency : 840 – 960 MHz

Range: Long Range (>1 m)

Tags: Chip (with an ASIC)

Tags: Passive & Semi-Passive

Coupling : Electromagnetic Backscattering Far Field



https://www.google.com/Images

UHF RFID Readers

Handheld Readers

Embedded Readers

Fixed Readers

Integrated Readers

https://www.google.com/Images

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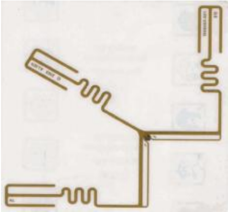
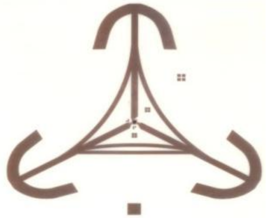
UHF RFID Tags

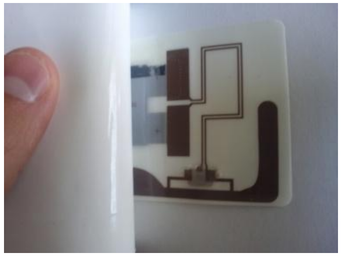
Passive Tags

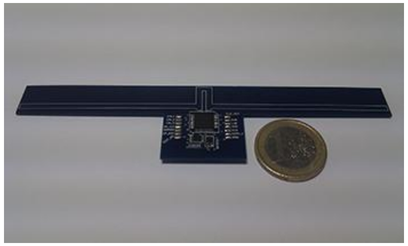


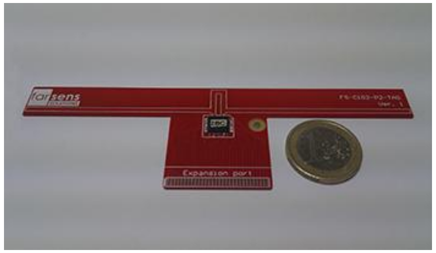


Semi-Passive

Sensor Tags







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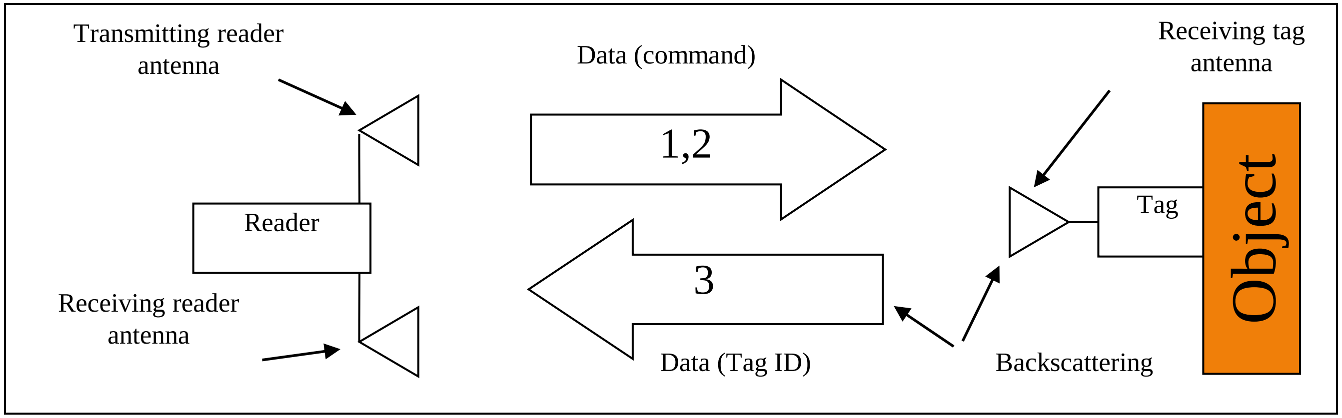
https://www.google.com/Images

Passive UHF RFID System Operation



The reader transmits modulated signal with periods of un-modulated carrier

The RF voltage developed on the tag antenna terminals during un-modulated period is converted to dc, this voltage powers up the chip .

The chip sends back the information by changing its impedance between 2 different states, effectively modulating the back-scattered signal.

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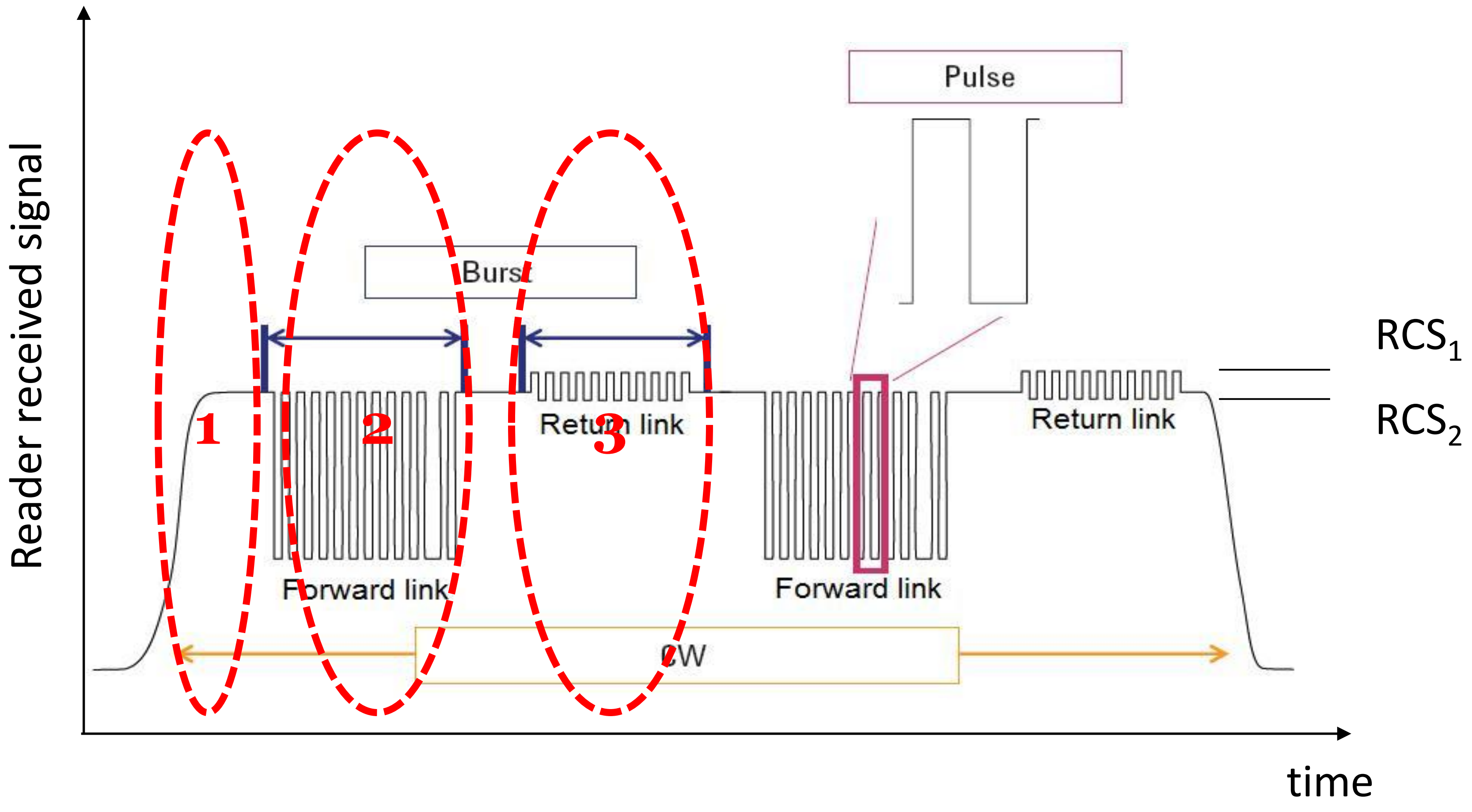
Passive UHF RFID Data Exchange



Data exchange between an RFID reader and a tag

https://www.google.com/Images

Passive UHF RFID vs. Barcode

Property	UHF RFID	Barcode
Scanning	Simultaneous	Sequential
Read Rate	1200 Tag/sec	1 Tag/sec
Communication	Non-line of sight	Line of sight
Temperature threshold	Higher/Lower	Less tolerant
Read Accuracy	98%	80%
Data	Storage and Processing	None
Sensors	Any	None

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Let's See a Demo

UHF RFID Read Range and Limitations

Tag Limitations

Read range which can be calculated using Friis free space formula as:

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t(\theta,\phi) G_r(\theta',\phi')\, p \left|T_{tag}\right|^2}{P_{th}}}$$

and

$$\left|T_{tag}\right|^2 = 1 - \left|\Gamma_{tag}\right|^2$$

$P_t G_t$? P_{th} ? ➡ For r_{max}

Reader Range

- **Transmitted power**
- **Sensitivity**

Environment Effect

- **Multi-path effect**
- **Path loss**
- **Metallic objects**

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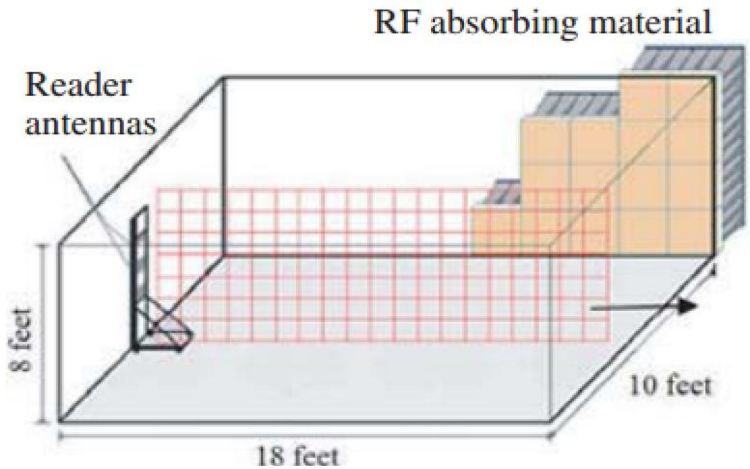
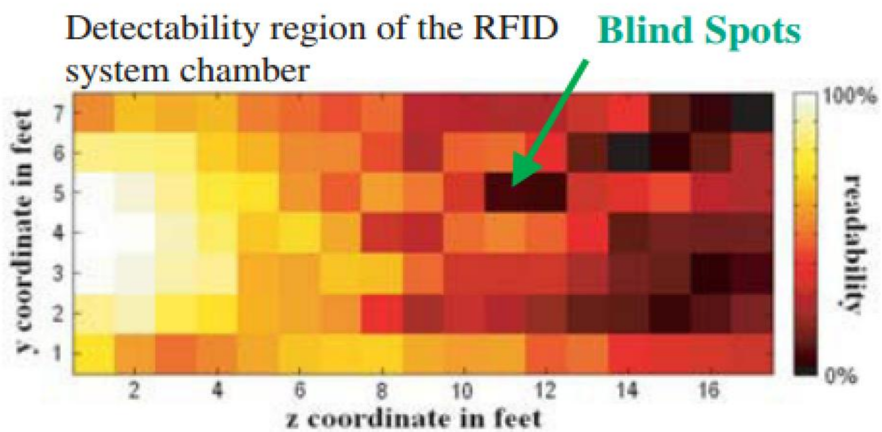
Environment Effect

Multi-path effect





C. H. Loo, A. Z. Elsherbeni, F. Yang & D. Kajfez, “Experimental and Simulation Investigation of RFID Blind Spots”, JAMWA, Vol. 23, Issue 5-6, 2009.

Path Losses

Object Tags Attached To

https://www.google.com/Images

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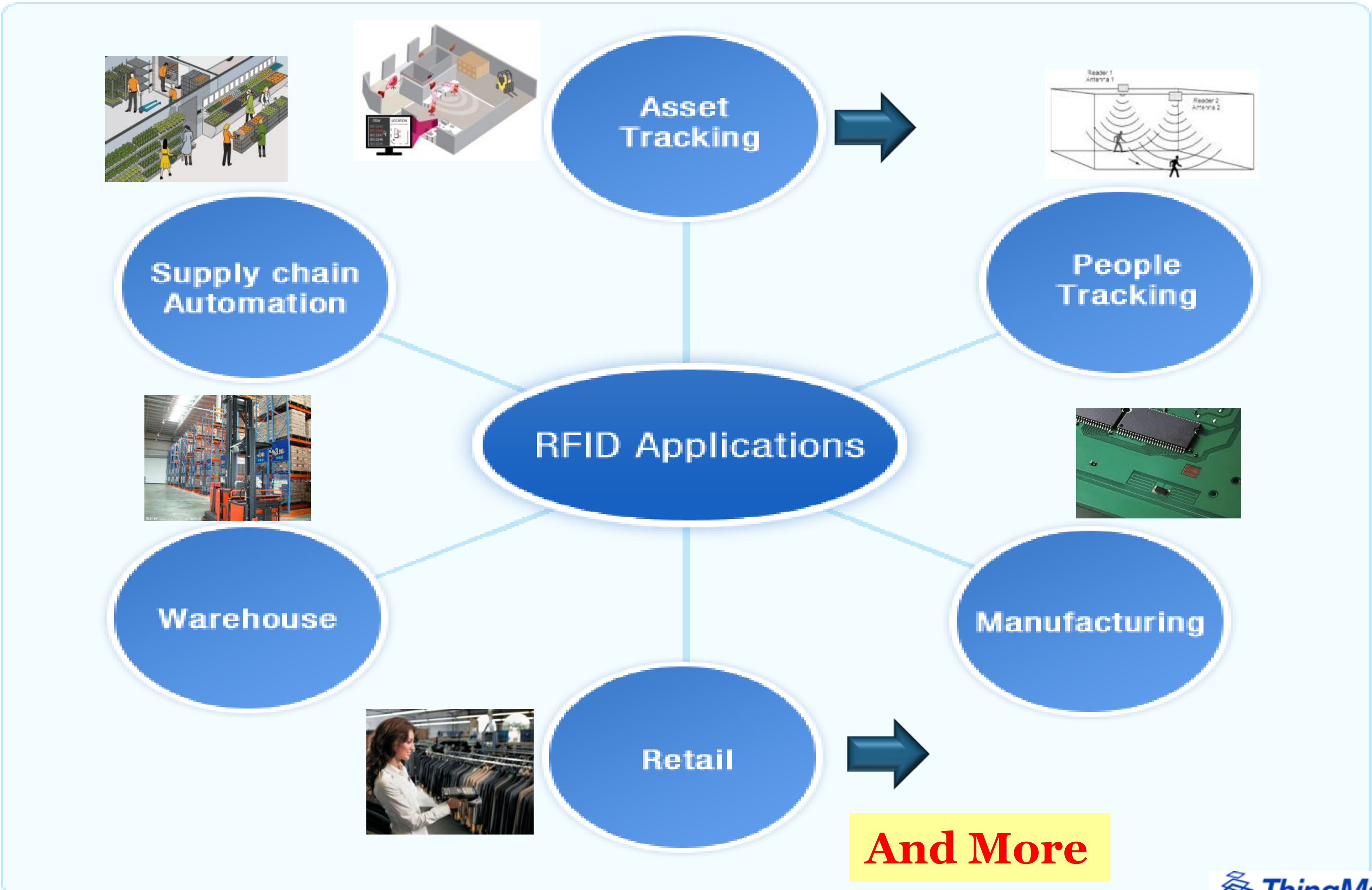
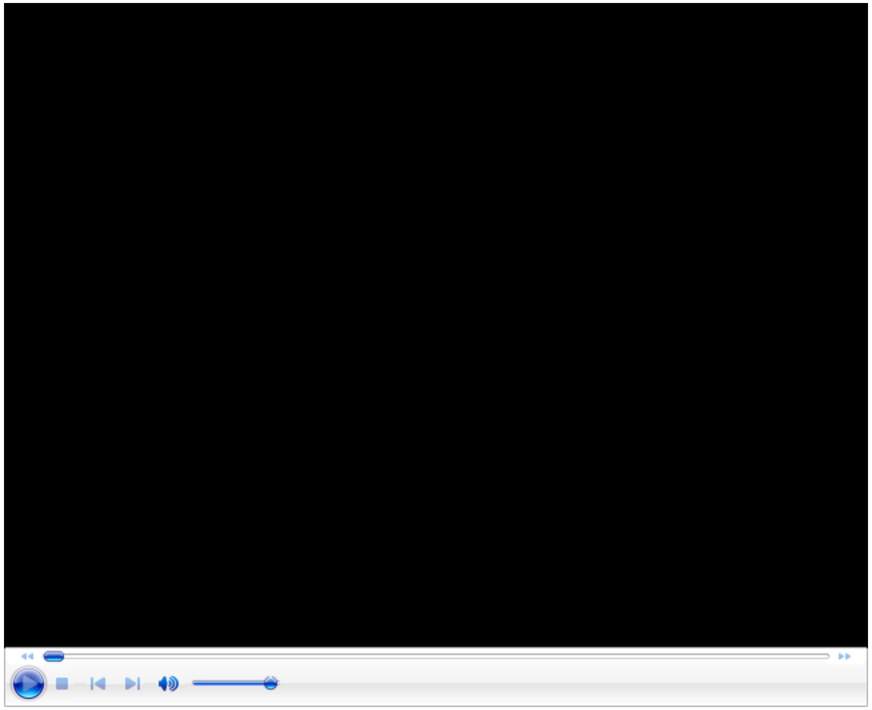
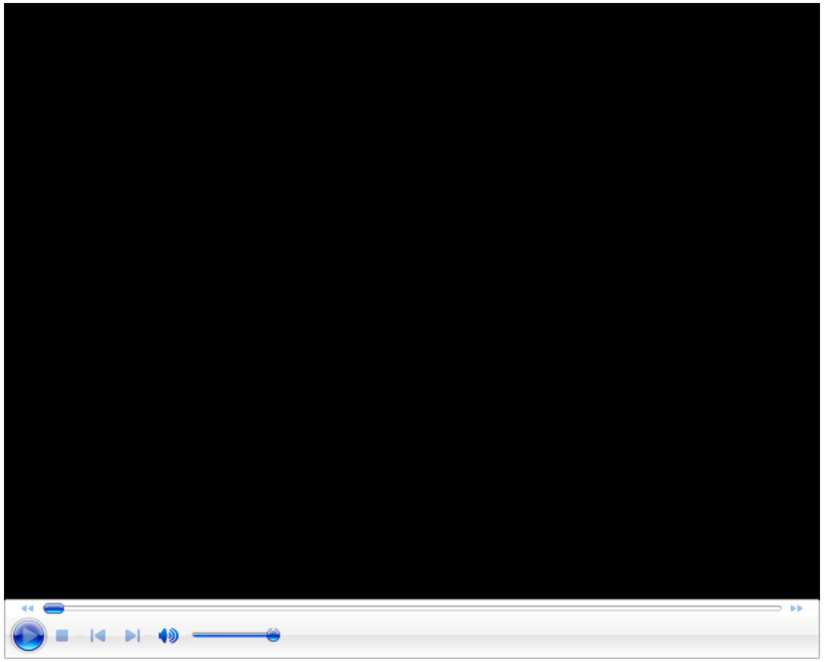
UHF RFID Current Applications



https://www.google.com/Images

UHF RFID Applications Videos





https://www.google.com/Vdieos

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Other Identification Technologies

Other Identification Technologies

Do Other Identification Technologies Exist?

Yes for sure, technologies evolve rapidly here are examples for technologies that can be used for identifications .

Wi Fi
Bluetooth
ZigBee
BLUETOOTH LOW ENERGY
LINK HERE ANT+
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https://www.google.com/Images

WiFi for Identification (Wi-Fi ID)

Wi-Fi ID is technically an active RFID system that uses the 802.11 standard of air communication in the 2.45GHz frequency spectrum.

Does not need any special hardware or firmware modifications required. Can easily co-exist with Wi-Fi clients such as laptops

To determine location: Radio Signal Strength Information (RSSI) and Time Difference Of Arrival (TDOA) can be used.

Things to be aware of:
1- Network Traffic and Network Null spots
2- Battery life
3- Tag Cost ($35-$50)

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http://rfid.net/basics/rtls/123-wi-fi-how-it-works

Bluetooth Low Energy (BLE)

BLE implements an entirely new protocol stack along with new profiles and applications. Its core objective is to run for a very long time on a coin-cell battery

BLE was defined as part of the most recent standard specification Bluetooth v4.0.

Operates in the 2.4GHz ISM band with only 40 channels spaced 2MHz apart. BLE also is known as Bluetooth Smart

It is capable of transmitting at a rate of 1Mbit/s. Other BLE features include a 0-dBm (1 mW) power output and a typical maximum range of 50 meters.

http://rfid.net/basics/rtls/123-wi-fi-how-it-works
http://electronicdesign.com/mobile/what-s-difference-between-bluetooth-low-energy-and-ant

Bluetooth® SMART

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ZigBee

Based on IEEE 802.15.4 Standard. It was introduced by ZigBee alliance in 2003.

Frequency and data rates: 868 MHz / 20 kb/s; 915 MHz / 40kb/s; 2.45 GHz 250 kb/s .

Utilizes Mesh, Star, and Tree Networking. Standard specifies that each device shall be capable of transmitting at least 1 mW.

Typical devices (1mW) are expected to cover a 10-20 m range Standard requires a receiver sensitivity of -85 dBm.

http://www.cse.yorku.ca/~dusan/Zigbee-Standard-Talk.pdf

ANT/ANT+

ANT is a Proprietary wireless network protocol and RF solution designed for use in ultra-low power PANs and WSN applications.

Designed for operation in the 2.4 GHz frequency band. ANT powered network nodes can operate for years

transmission modes up to a net data rate of 20 kbit/s. Ant's over the air data rate is 1 Mbit/s for low duty cycle operation. With range of 10-30 m.

Typical ANT applications: Heart rate monitors, Speed and distance monitors, Weight scales for the measuring of BMI ,Temperature sensors, etc.

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https://www.arrownac.com/solutions-applications/machine-to-machine/files/atd-ant.pdf

Visible Light Communication (VLC)

VLC enables Internet service to be delivered over your home lighting system, and traffic lights to communicate road conditions to your automobile Based on IEEE 802.15.7 Standard.

In order to transmit data over light, the light source is pulsed on and off rapidly to create a data stream. Optical receivers convert the light pulses to an electronic signal.

How is this related to Identification?

It is used nowadays in indoor localization which is consider an identification process

https://ctc.unc.edu/documents/techbriefs/200911_vlc.pdf

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Future Trends

What Are the Current Barriers

Before looking forward for the future we should ask ourselves about the current barriers for UHF RFID?

1-Infrastructure needed.
2-Physical Limitations.
3-Security Issues.
4-Privacy Concerns.
5-Already Existing Identification Technologies.
6-Cost.
7- Standardization.

Can such Barriers be overcome?

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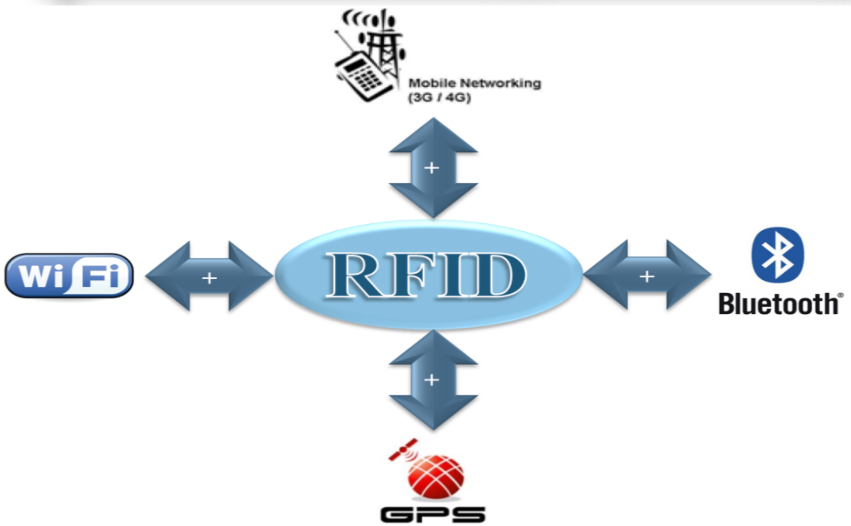
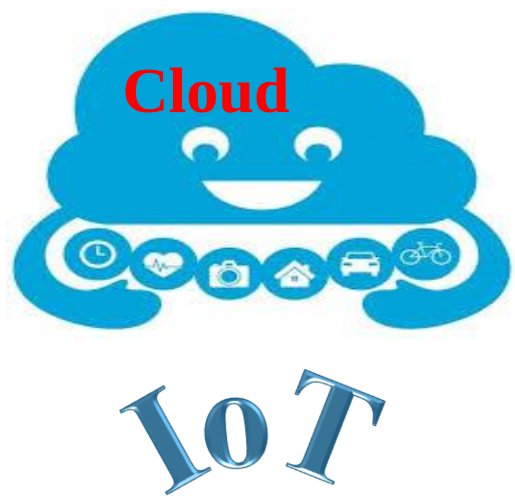
UHF RFID Integration

We should think of UHF RFID as one part of different technologies integration rather than standalone technology.





http://www.rfidjournal.net/masterPresentations/rfid_hightech2012/np/diorio_1100_oct11.pdf

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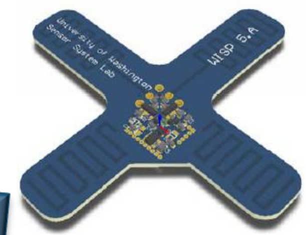
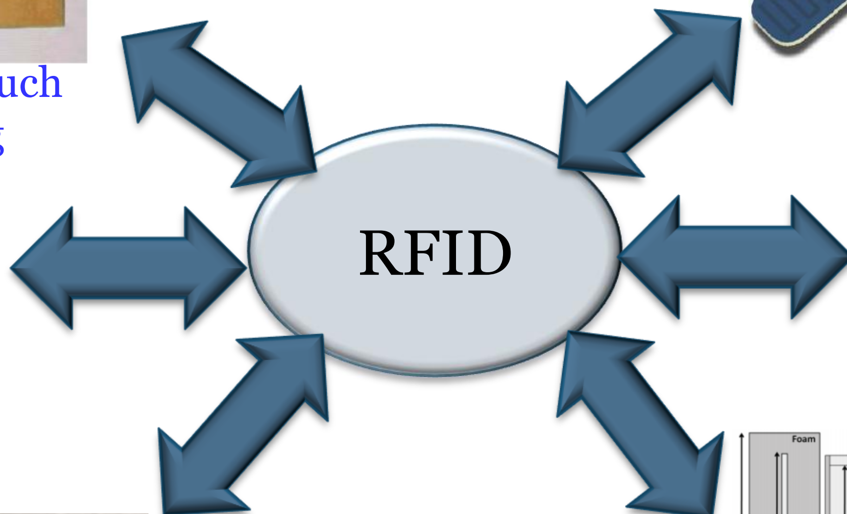
Wireless Sensors

RFID tags can have sensors capabilities for measuring different physical properties.

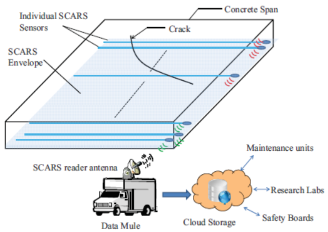
Capacitive Touch Sensor Tag



WISP: A Passively Powered RFID Tag with Sensing and Computation

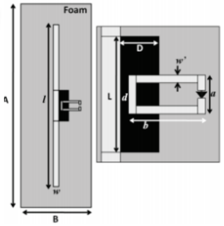


Temperature Sensor Tags



Passive Sensor for Cracks detection

Strain Sensors Tag



Gas Sensor Tag

http://www.spsc.tugraz.at/sites/default/files/file/UWBForum2011/01_IEEEUWBForum2011_Nikitin.pdf
http://ieeexplore.ieee.org.libproxy.mit.edu/stamp/stamp.jsp?tp=&arnumber=6404565
www.src.org/calendar/e004576/smith.pdf
https://www.google.com/Images, http://users.ece.gatech.edu/~etentze/APS11_Cec.pdf

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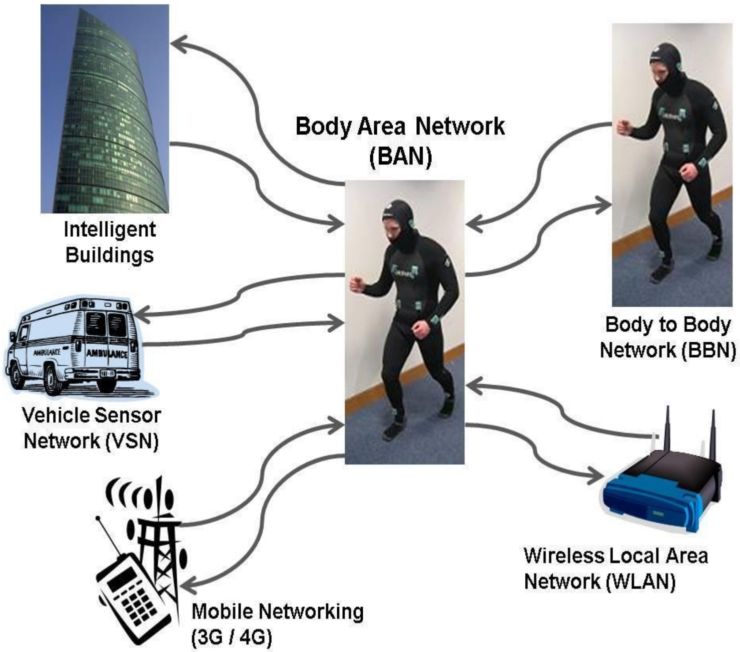
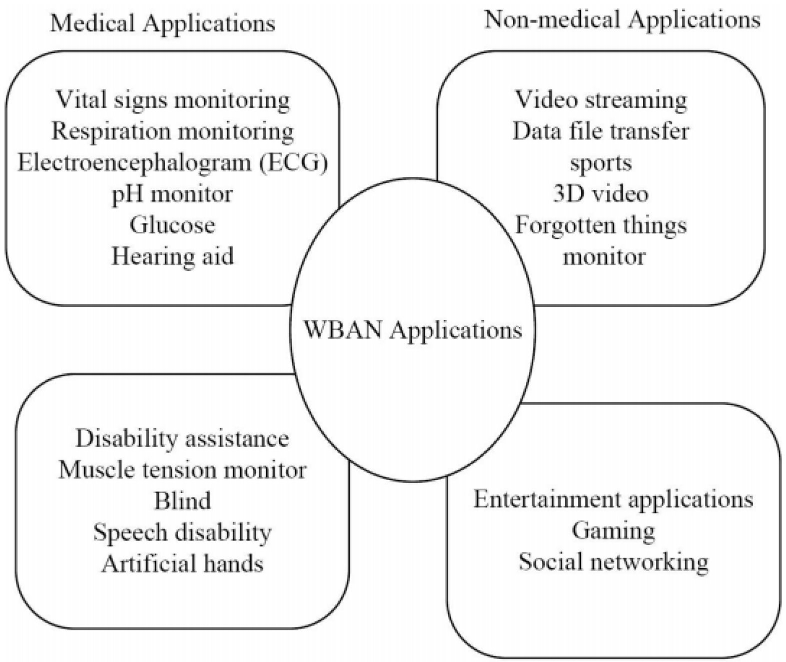
Body Area Network (BAN)

In December 2011, the IEEE 802.15.6 a draft of a standard for BAN technologies was approved.

Low-power and short-range wireless to be optimized for devices and operation on, in, or around the human body.





http://www.youtube.com/watch?v=-zqW3zQO9xg
http://arxiv.org/pdf/1102.4106.pdf

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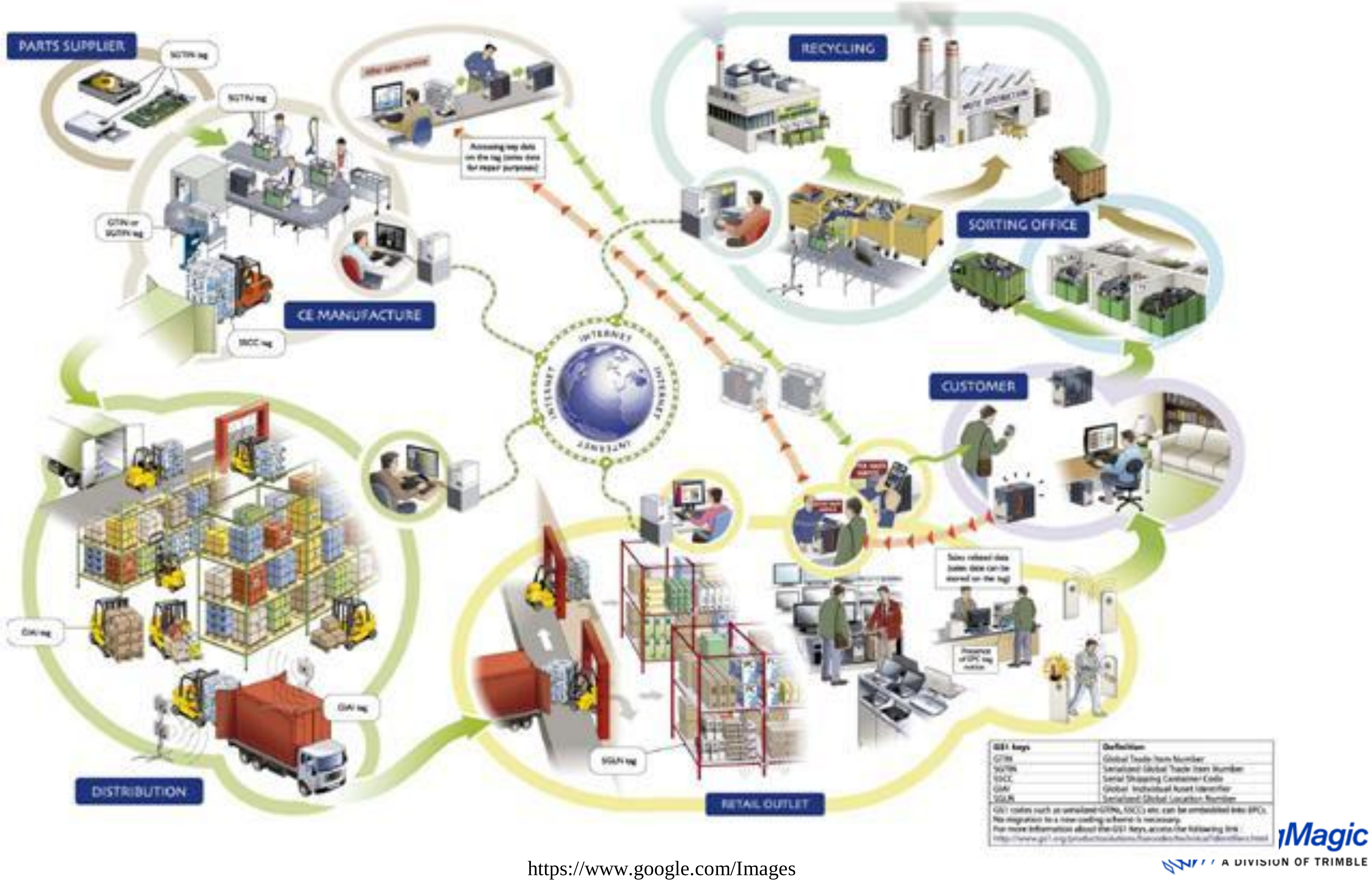
Other Applications

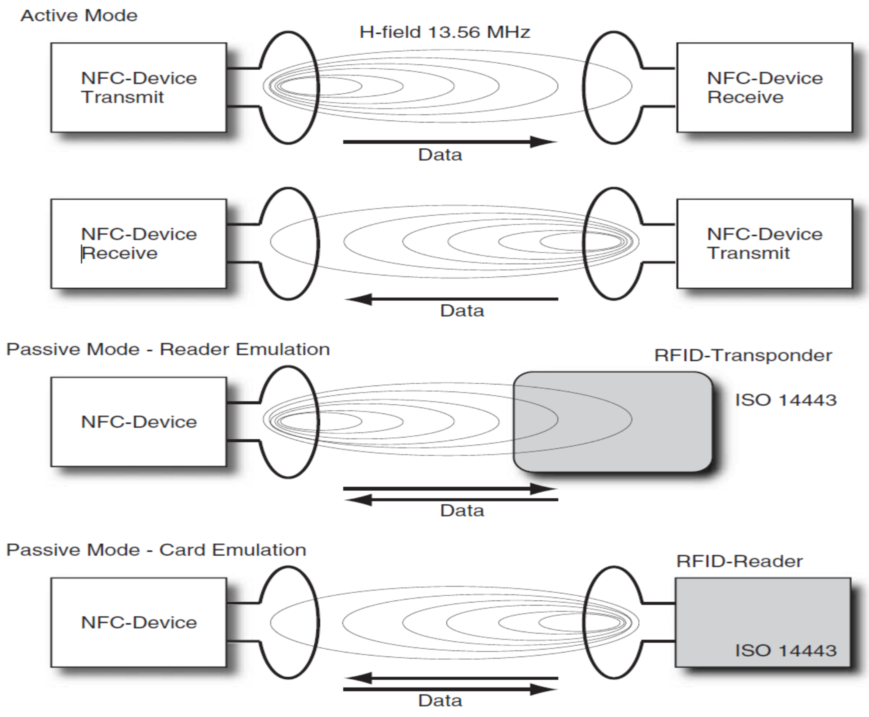


https://www.google.com/Images

Thank you for Listening
Any Questions??

Appendix

NFC Modes of Operation



Active Mode

-At first one of the NFC interfaces activates its transmitter and thus works as the NFC initiator.

- The transmission direction is reversed in order to send data from the NFC target to the NFC initiator.

Passive Mode

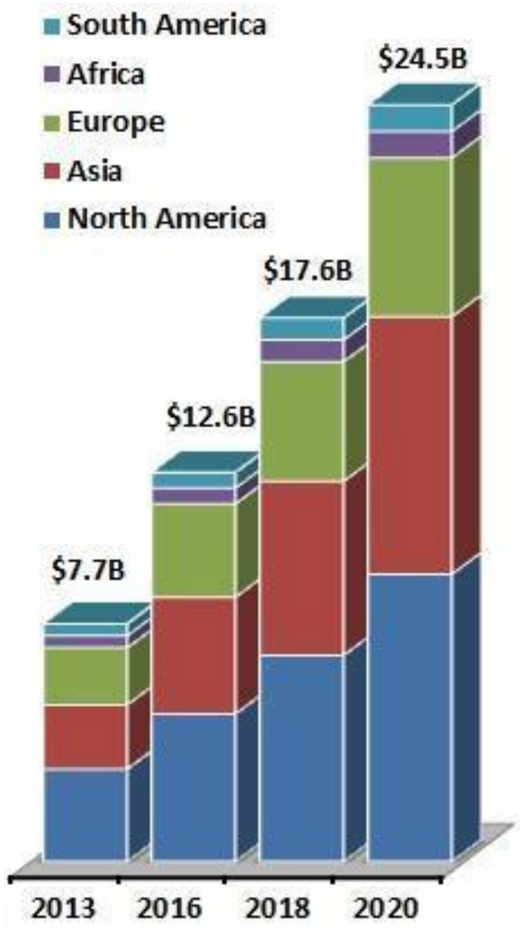
-An NFC interface with weak power supply, can negotiate and adopt the role of the NFC target in order to save power.

-Established for compatibility with passive transponde

NFC Applications

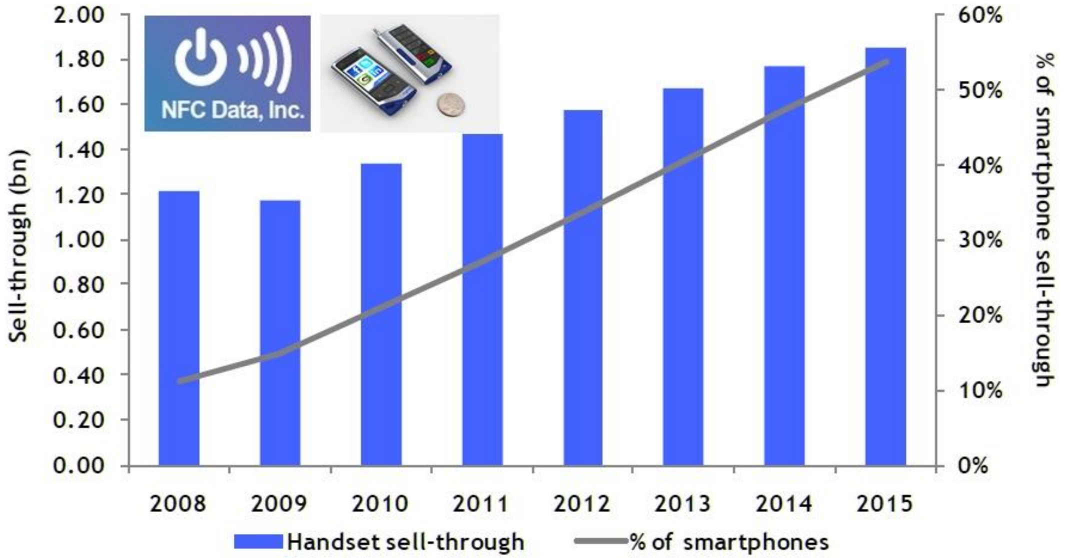
https://www.google.com/Images

Near Field RFID Market



http://www.marketinfogroup.com/explosive-future-forecasted-for-near-field-communication-nfc/

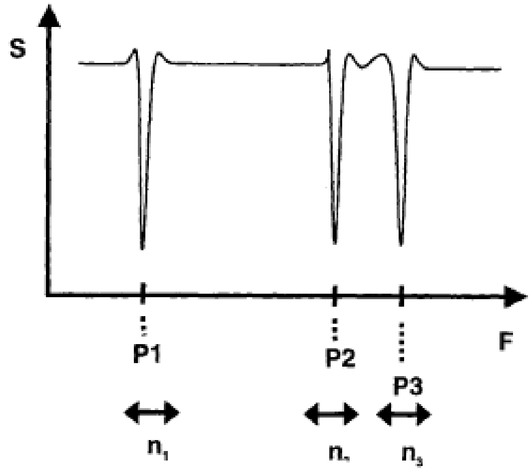
Exhibit: Global NFC-enabled handset sell-through, 2010-2015



Source: Pyramid Research

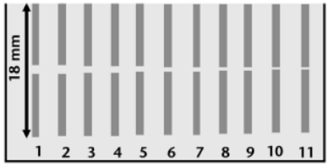
Spectral Signature Based Chipless RFID

Frequency Domain Based

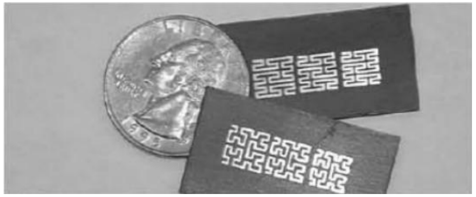


https://www.google.com/Images

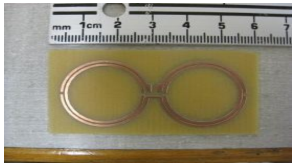
Planar



Capacitively Tuned Dipole

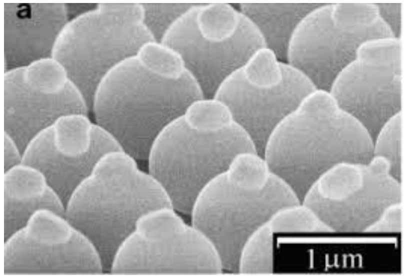


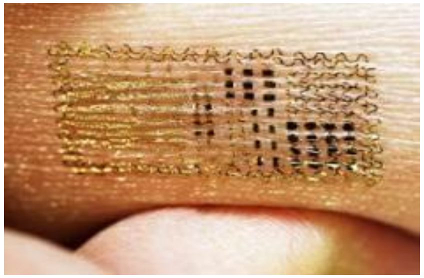
Space Filing Curves



LC Resonant

Chemical



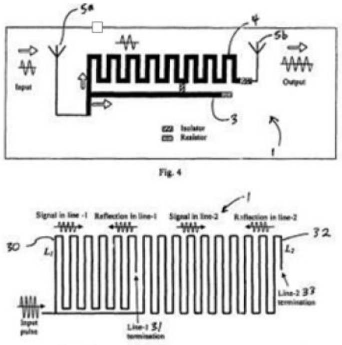


Nanometric Material

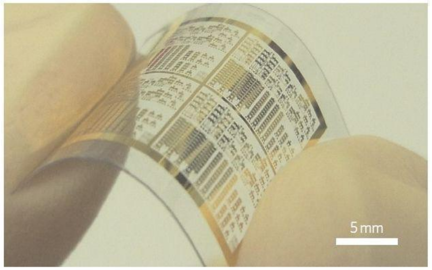
Ink-tattoo

Time Domain Reflectometry (TDR)

Printable

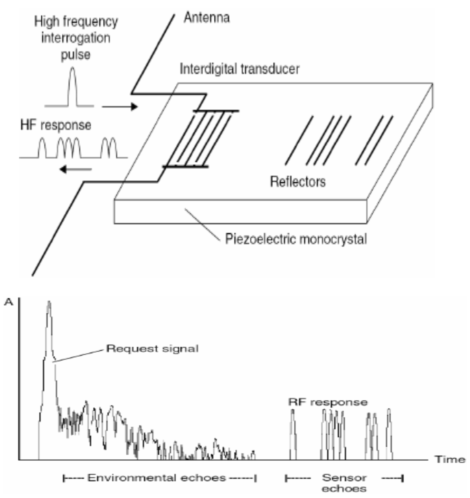


Delayed Line Based Tags



Thin-Film-Transistor Circuits

Non-Printable



Surface Acoustic Wave (SAW)

- Typical operating frequency: 2.45 GHz.
- It has longer range could reach up to few meters.

Reader-to-Tag Communications (R->T)

Modulation: Reader can use DSB-ASK, SSB-ASK, or PR-ASK

Data Encoding: PIE

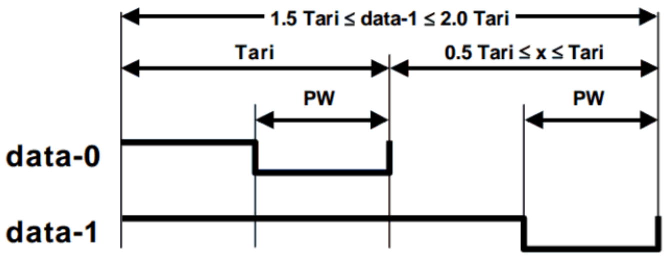
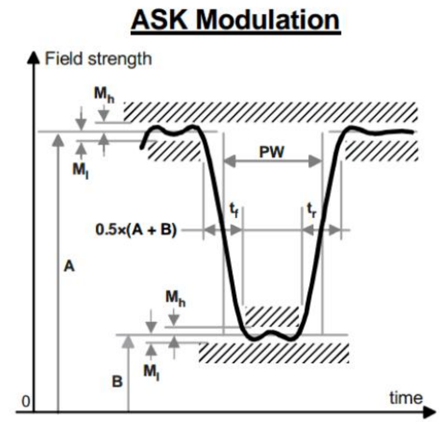


Figure 6.1 – PIE symbols

R=>T RF envelope



Power-up & down waveform

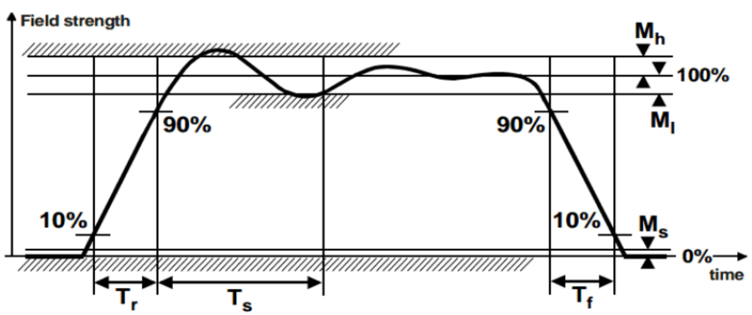
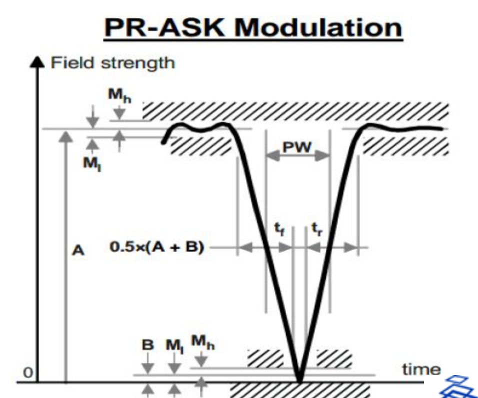


Figure 6.3 – Interrogator power-up and power-down RF envelope



http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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R->T Communications – Continued

R->T preamble and frame-sync

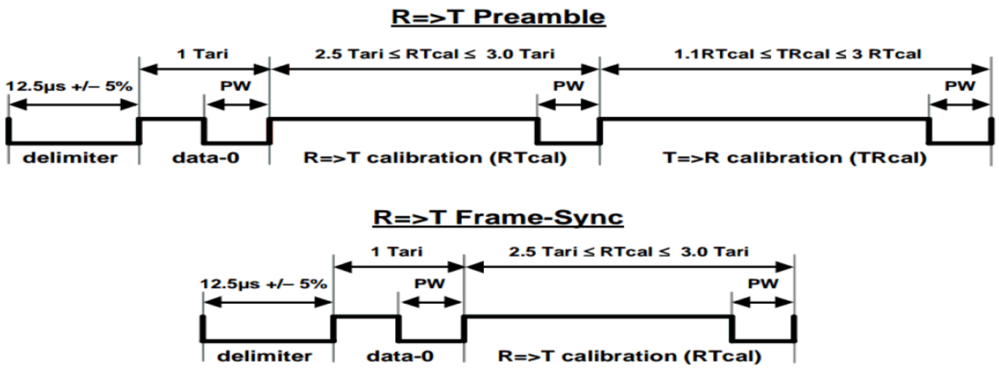

Figure 6.4 – R=>T preamble and frame-sync

Transmit mask

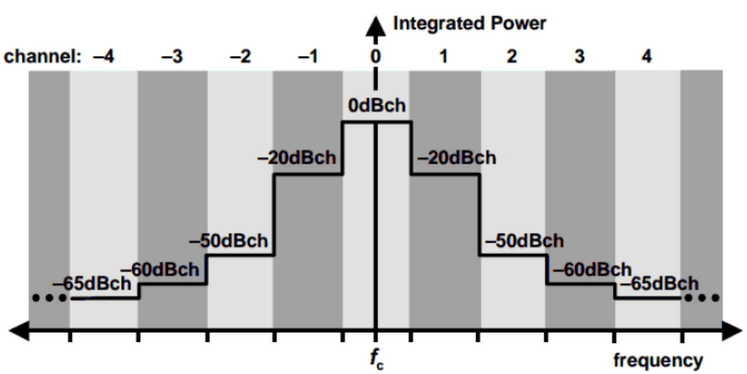

Figure 6.6 – Transmit mask for multiple-Interrogator environments

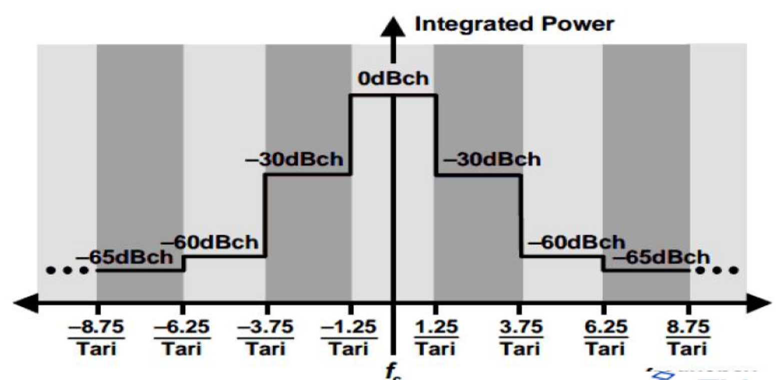

Figure 6.7 – Transmit mask for dense-Interrogator e

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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Tag-to-Reader Communications (T->R)

Modulation: ASK and /or PSK

Data Encoding: FM0 and Miller

Tags shall support all R->T Tari values in the range of 6.25µs to 25µs.

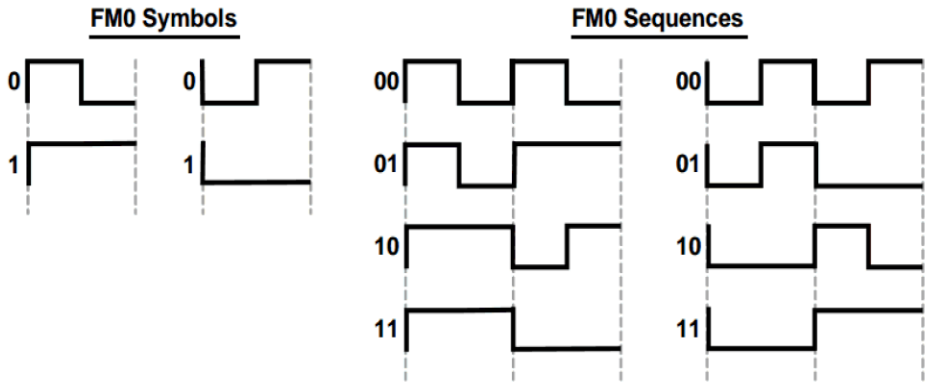

Figure 6.9 – FM0 symbols and sequences

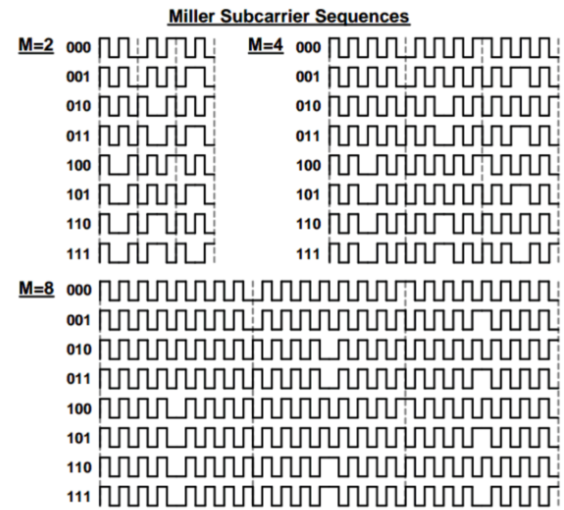

Figure 6.13 – Subcarrier sequences

Backscattering Link Frequency (BLF) 40 to 640 kHz

Table 6.10 – Tag-to-Interrogator data rates

M: Number of subcarrier cycles per symbol	Modulation type	Data rate (kbps)
1	FM0 baseband	BLF
2	Miller subcarrier	BLF/2
4	Miller subcarrier	BLF/4
8	Miller subcarrier	BLF/8

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http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

T->R Communication – Continued

Memory Banks

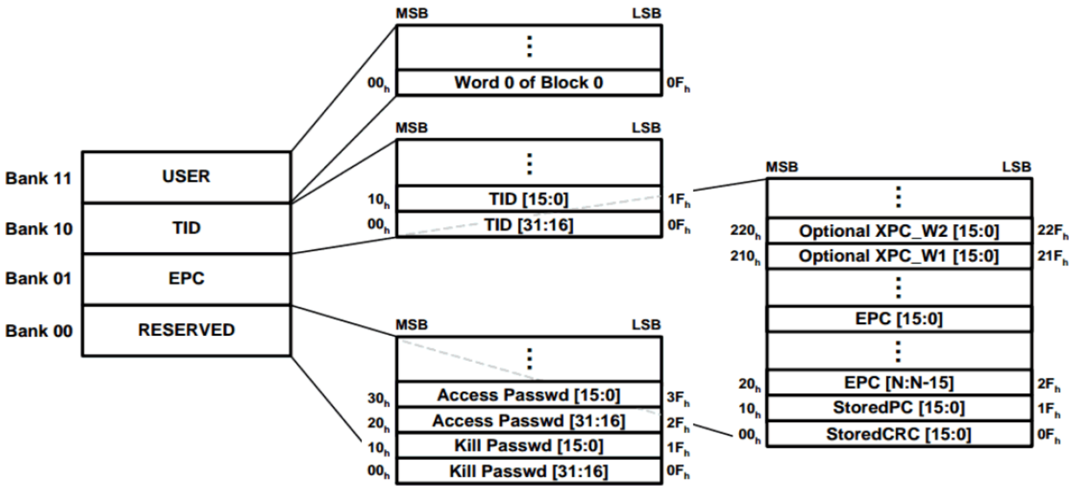

Figure 6.17 – Logical memory map

Reserved memory: contain the kill and and/or access passwords, if passwords are implemented on the Tag.

EPC memory: contain a StoredCRC at memory and EPC that identifies the object to which the Tag is or will be attached.

TID memory: contain an 8-bit ISO/IEC 15963 allocation class identifier, TID memory shall contain sufficient identifying information for an Interrogator to uniquely identify the custom commands and/or optional features that a Tag supports.

User memory is optional.

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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Gen2 Protocol Collision Handling

Random-slotted Collision Arbitration:

-Tags load a random (or pseudo-random) number into a slot counter, decrement this slot counter based on Interrogator commands, and reply to the Interrogator when their slot counter reaches zero.

- Q : A parameter that reader uses to regulate the probability of Tag response.

- Reader commands Tags in an inventory round to load a Q-bit random (or pseudo-random) number into their slot counter.

- Tags reply when the value in their slot counter is zero.

- Q is an integer in the range (0,15); the corresponding Tag response probabilities range from $2^0 = 1$ to $2^{15} = 0.000031$.

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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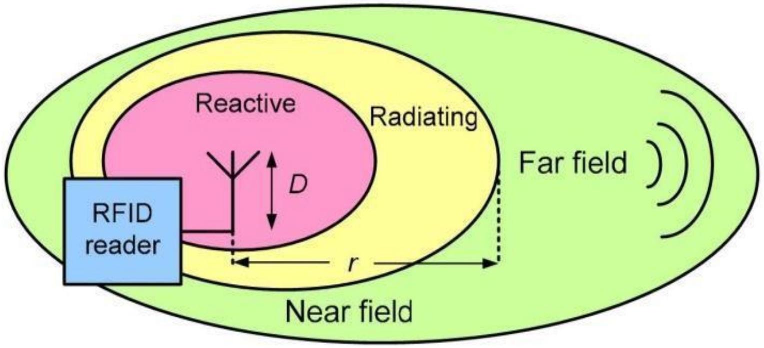
Can UHF RFID be used as NFC?

Near Field vs. Far Field



Based on the antenna dimension and frequency of operation the space around the antenna can be divided in two main regions : Near Field and Far Field.

Property	Near Field	Far Field
Range	< 1 meter	> 1 meter
Power Transfer to Tag	High Power	Low Power
Security	Highly Secure	Less Secure
Cost	Less	More

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.230.194&rep=rep1&type=pdf

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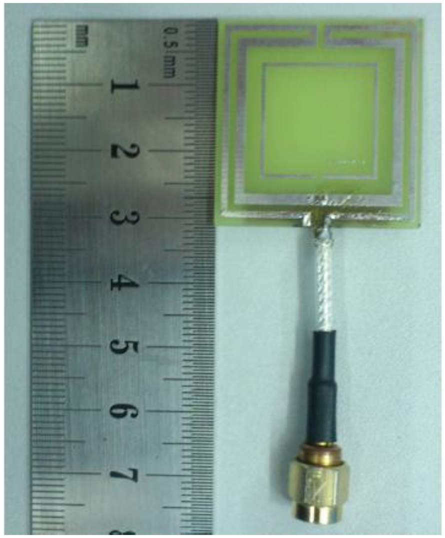
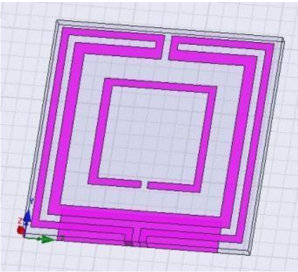
UHF RFID As Near Field Application

Near Field vs. Far Field

- Reduce the power of the reader. [Reader Side]
- Shorter range tag. [Tag Side]
- Use near field UHF RFID antenna.





Cheaper, lower power UHF RFID should be designed and this should push the market toward new trend to replace the NFC.

http://www.hindawi.com/journals/ijap/2013/961042/

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Garment Management

ThingMagic - Disney Case Study

Tracking $100 million worth of costumes (3 million garments) at parks and on cruise ships

RFID-based garment management solution used at 25 costume storage areas and 40 issue counters; Processing 23,000 costumes check-outs daily

Benefits:

- Inventory counting times reduced from 180 labor hours to two labor hours
- Increased inventory accuracy to nearly 100 percent

ROI:

Cost savings of more than $1 million and ROI in less than a year

ThingMagic Vega

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Ford Motor Company

ThingMagic In-Vehicle Readers for Ford's 2009 F- & E-Series trucks and vans, 2010 TransitConnect

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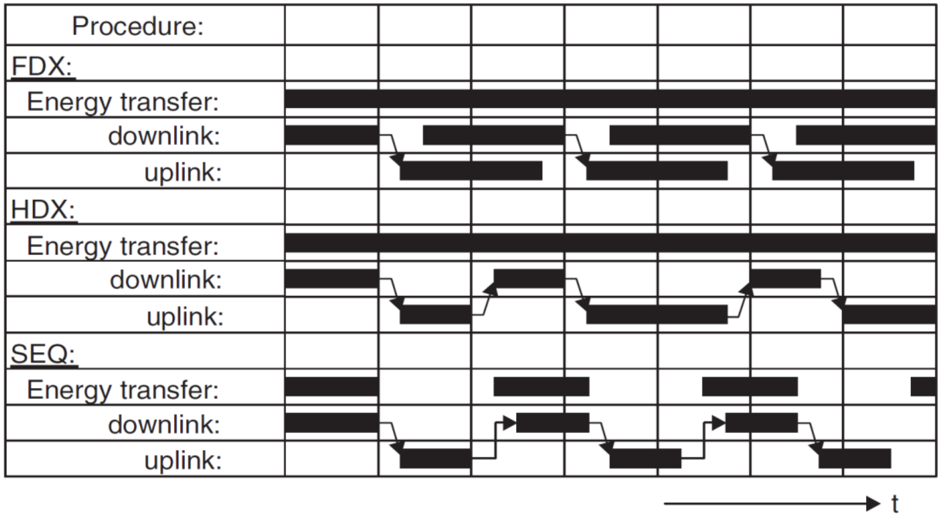
Modes of Operations

Full-Duplex (FDX): the data transfer from the tag to the reader takes place at the same time as the data transfer from the reader to the tag.

Half-Duplex (HDX): the data transfer from the tag to the reader alternates with data transfer from the reader to the tag.

Sequential (SEQ): the transfer of energy from the transponder to the reader takes place for a limited period of time only.



FDX: tag transmit at different frequency from reader.

HDX & FDX: Reader transmit energy all the time.

Reader to Tag (Downlink), Tag to Reader (Uplink).

Klaus Finkenzeller "RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication", Edition 3, Wiley 2010.

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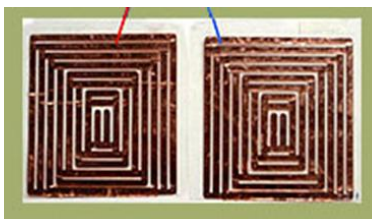
Transponder Formats

Chip vs. Chipless Tags: Some tags has Application-specific integrated circuit (ASIC) chip to store tag data, while others tags are chipless.

Active vs. Passive Tags: Active tags have there own power source (battery), while passive tags are energized by the reader (battery-less).

Semi-passive tags: these tags have a power source (battery) which are only activated when the tags is in the field of a reader.



Chipless Tags

Chip Tag

Active Tag

Passive Tag

Semi-Passive Tag

https://www.google.com/Images

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Frequency, Range and Coupling

Frequ[illegible]ncy of Ope[illegible]io[illegible]	Range	Co[illegible]ing
LF ([illegible]	[illegible]m	[illegible]
HF ([illegible]	[illegible]m	[illegible]
UHF (8[illegible])	> 1 m	[illegible]Vave (B[illegible]ca[illegible]ng)
UHF (2.4 GHz)	> 1 m	Ele[illegible]romag[illegible]etic Wave
Microwave (> 3GHz)	> [illegible]	Electromagnetic Wave

Environment Effect

Power Transfer Efficiency

Processing Capabilities

Short Ra[illegible] RFID

L[illegible]g Range RFID

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Gen2 Protocol Commands

Table 6.18 – Commands

Command	Code	Length (bits)	Mandatory?	Protection
QueryRep	00	4	Yes	Unique command length
ACK	01	18	Yes	Unique command length
Query	1000	22	Yes	Unique command length and a CRC-5
QueryAdjust	1001	9	Yes	Unique command length
Select	1010	> 44	Yes	CRC-16
Reserved for future use	1011	–	–	–
NAK	11000000	8	Yes	Unique command length
Req_RN	11000001	40	Yes	CRC-16
Read	11000010	> 57	Yes	CRC-16
Write	11000011	> 58	Yes	CRC-16
Kill	11000100	59	Yes	CRC-16
Lock	11000101	60	Yes	CRC-16
Access	11000110	56	No	CRC-16
BlockWrite	11000111	> 57	No	CRC-16
BlockErase	11001000	> 57	No	CRC-16
BlockPermalock	11001001	> 66	No	CRC-16
Reserved for future use	11001010 … 11011111	–	–	–
Reserved for custom commands	11100000 00000000 … 11100000 11111111	–	–	Manufacturer specified
Reserved for proprietary commands	11100001 00000000 … 11100001 11111111	–	–	Manufacturer specified
Reserved for future use	11100010 00000000 … 11101111 11111111	–	–	–

Types of Commands:
-Mandatory
-Optional
-Custom Commands

Custom commands are commands allowed by the GEN2 protocol standard to be used by the Tag manufacturers to implement some specific functionalities.

Shall not duplicate the functionality of any mandatory or optional command.

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http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

Gen2 Protocol Commands Format

Query Command

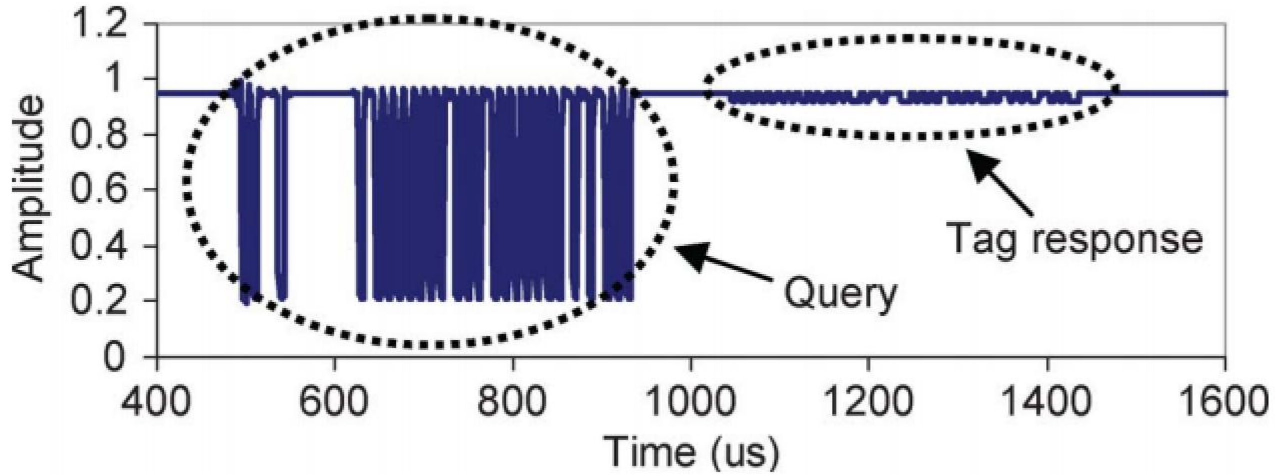
Table 6.21 – *Query* command

	Command	DR	M	TRext	Sel	Session	Target	Q	CRC-5
# of bits	4	1	2	1	2	2	1	4	5
description	1000	0: DR=8 1: DR=64/3	00: M=1 01: M=2 10: M=4 11: M=8	0: No pilot tone 1: Use pilot tone	00: All 01: All 10: ~SL 11: SL	00: S0 01: S1 10: S2 11: S3	0: *A* 1: *B*	0–15	

Table 6.22 – Tag reply to a *Query* command

	Response
# of bits	16
description	RN16

Command:
1000000100100000011100



DR = 8 (BLF 44.44 kHz)
Tag backscatter encoding: FM0
Pilot tone: on

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf
P. V. Nikitin, and K. V. S. Rao, "LabVIEW-Based UHF RFID Tag Test and Measurement System", IEEE Trans. on Industrial Electronics, Vol. 56, No. 7, pp. 2374 – 2381, Jul. 2009

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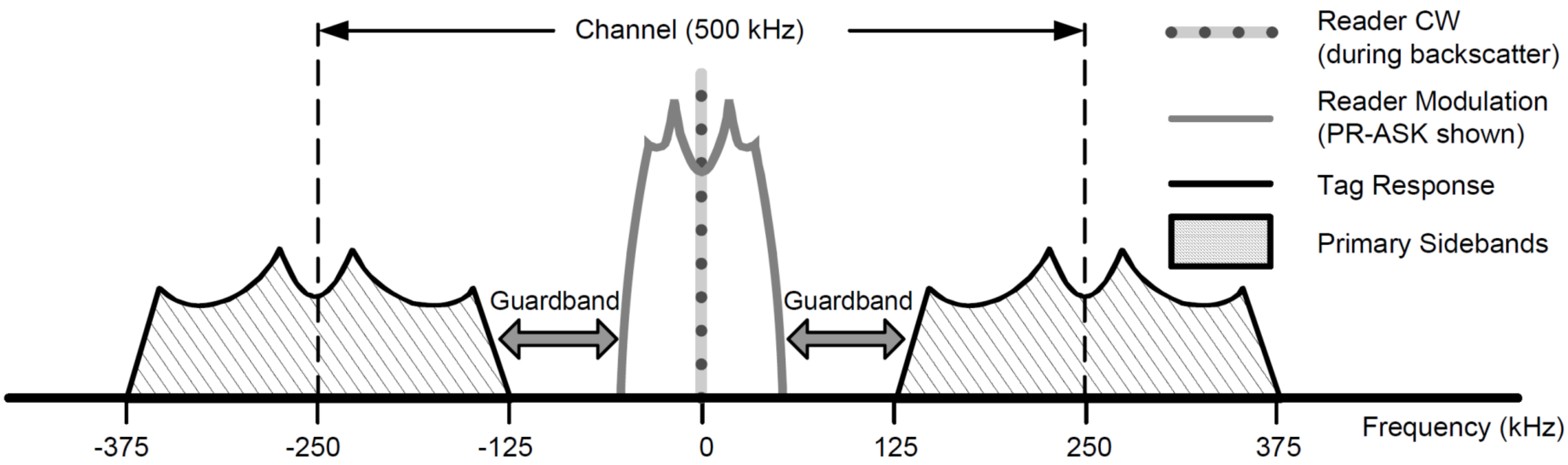
Gen2 Protocol Frequency Domain Signal

Frequency Domain Signal



- Reader transmissions using PR-ASK modulation with Tari = 25 µs, and 62.5 kbps Tag data.
- Backscatter on a 250 kHz subcarrier (BLF = 250 kHz; M = 4).

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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Gen2 Protocol Link Timing

Gen2 Protocol Specifies the Link Timing

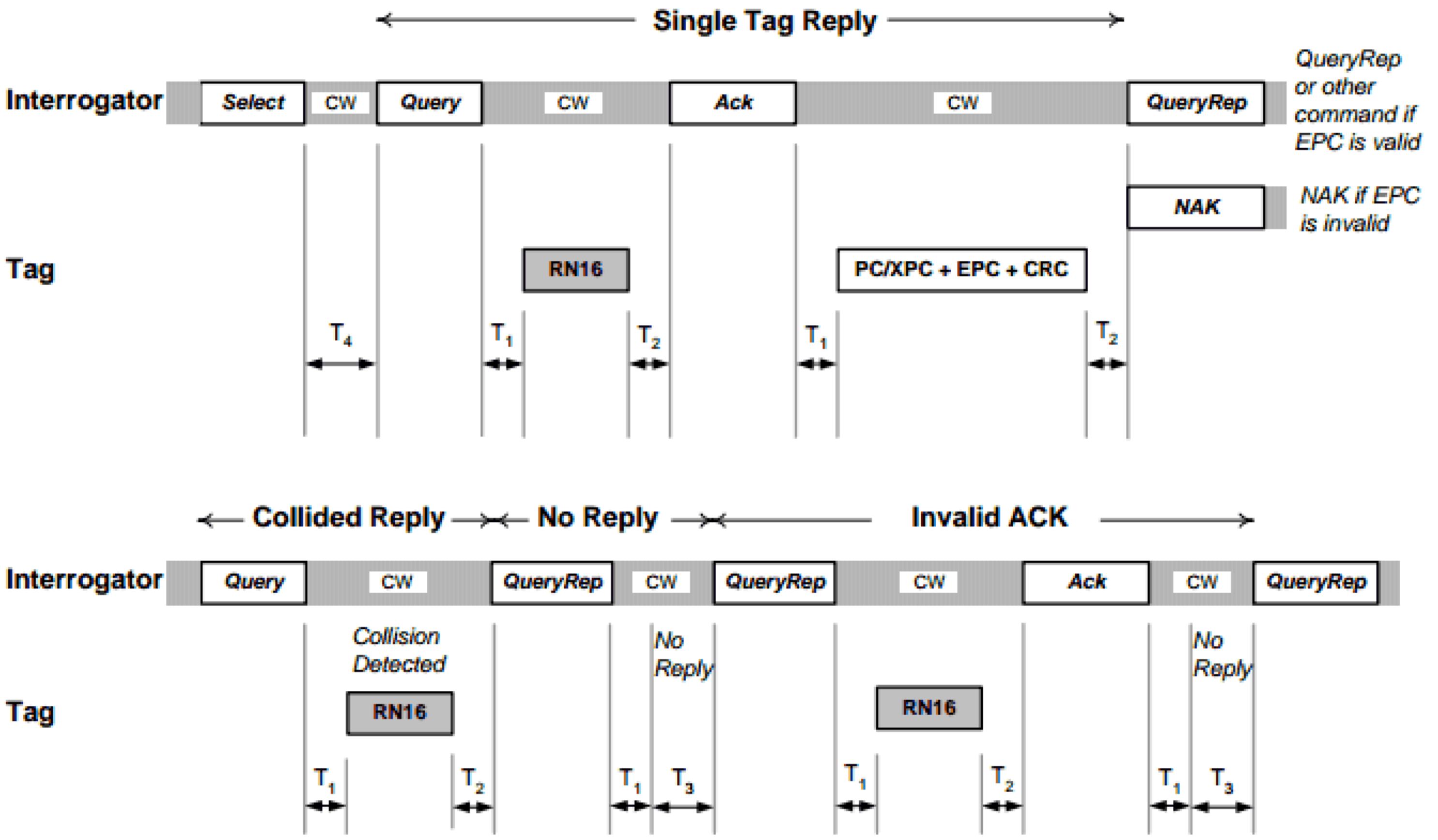

Figure 6.16 – Link timing

http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

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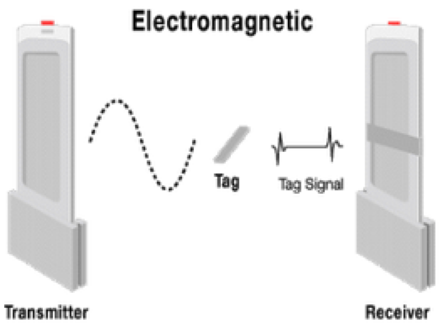
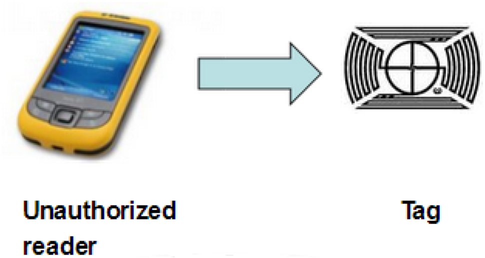
Custom Commands



A tag might have to respond fast to set an alarm



Tag Data should be invisible to unauthorized reader

Data Should be loaded to tag as fast as possible.

NXP

-Read Protect
- EAS Alarm

Impinj®

-QT
Read/Write

ALIEN®

-Load Image
-Block Read Lock

Hitachi Chemical
Working On Wonders

EM MICROELECTRONIC

And More ..

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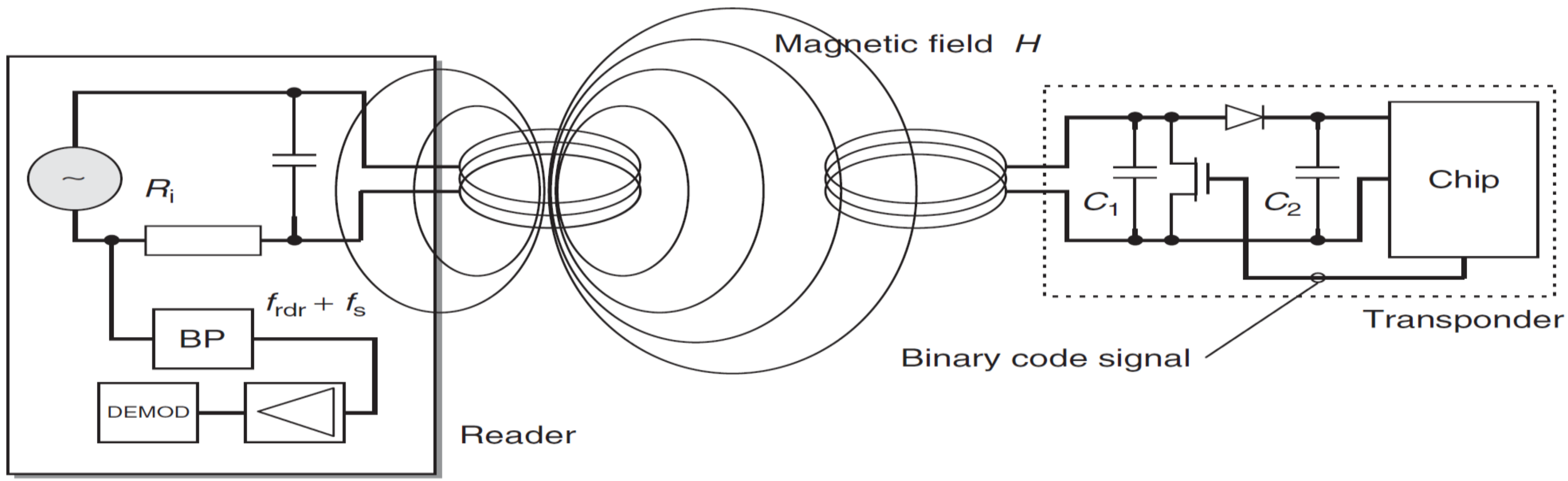
http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

Inductive Coupling Operation Overview



1. Reader's antenna coil generates a strong, high-frequency electromagnetic field that is magnetically coupled with the tag antenna coil.

2. The coupled reactive near-field energy is used by the tag to power up the Chip

3. The tag modulate back the single through load modulation.

Klaus Finkenzeller "RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication", Edition 3, Wiley 2010.

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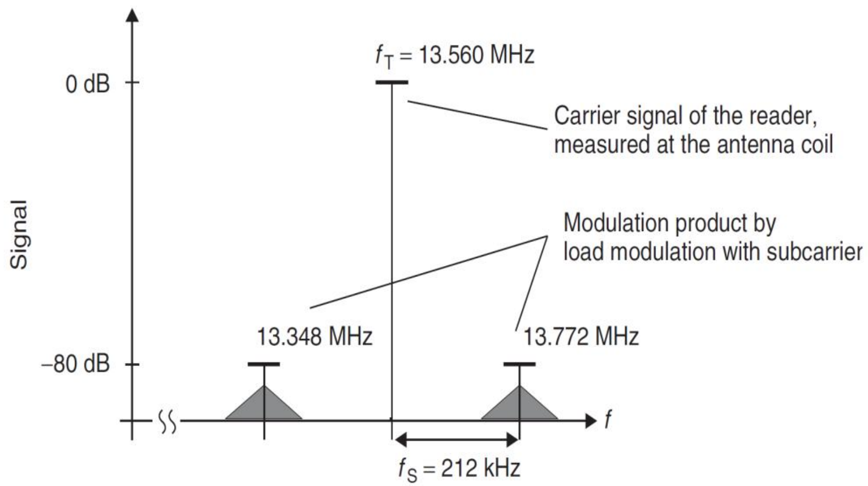
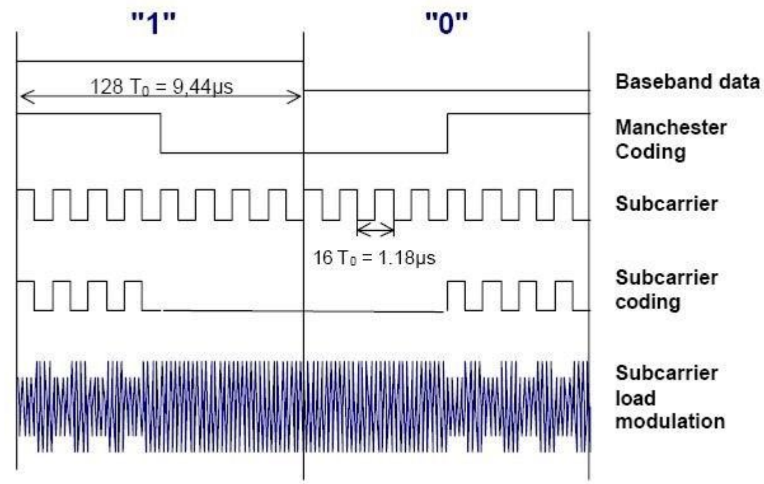
Load Modulation with Subcarrier



Frequency Domain Signal



Time Domain Signal

Tag signal <<< the reader signal

Load resistor in the transponder is switched on and off at a very high elementary frequency f_S

Using BPF the tag signal can be easily separated, usually f_S varies based on the protocol.

http://www.gorferay.com/energy-transmission/

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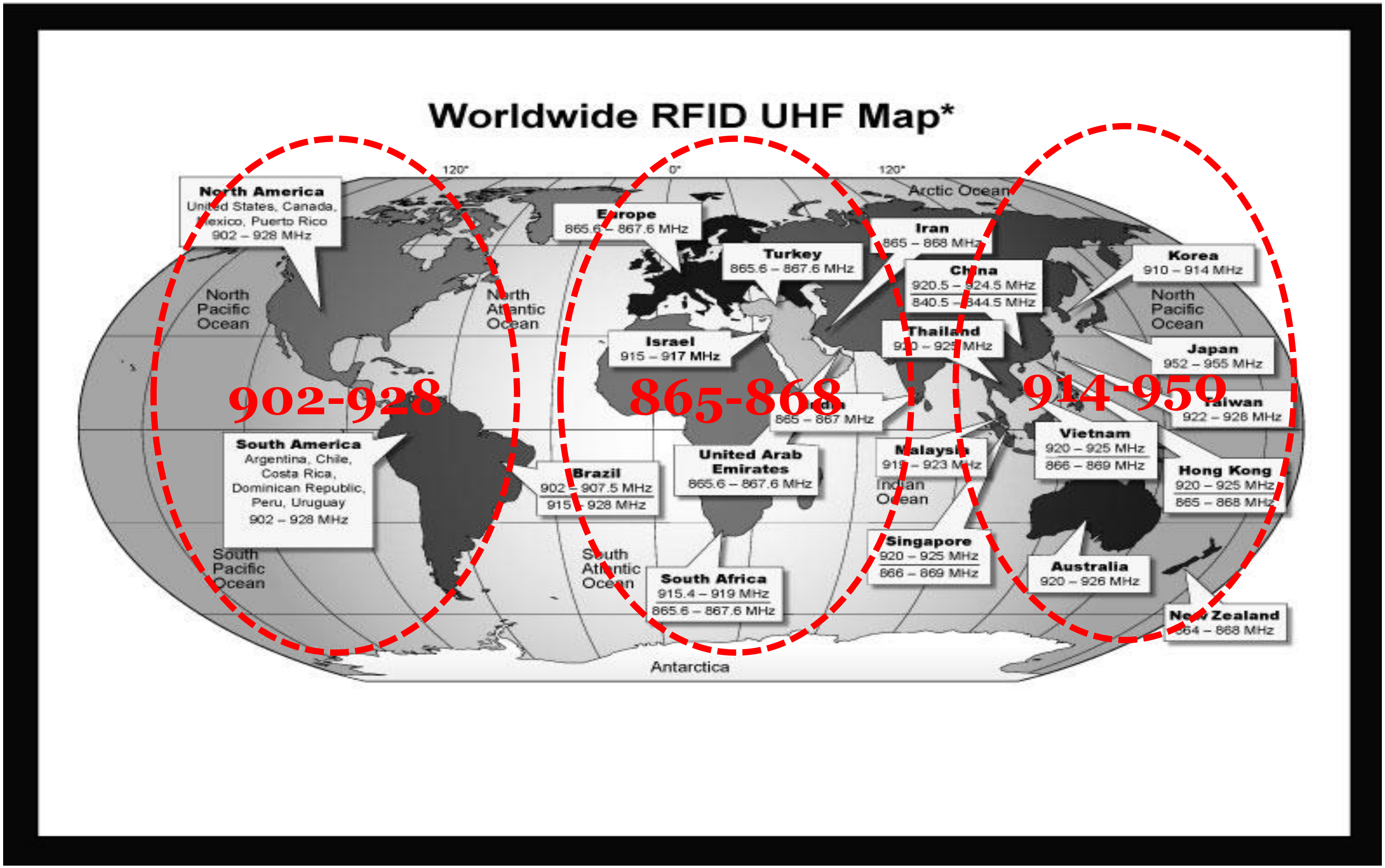
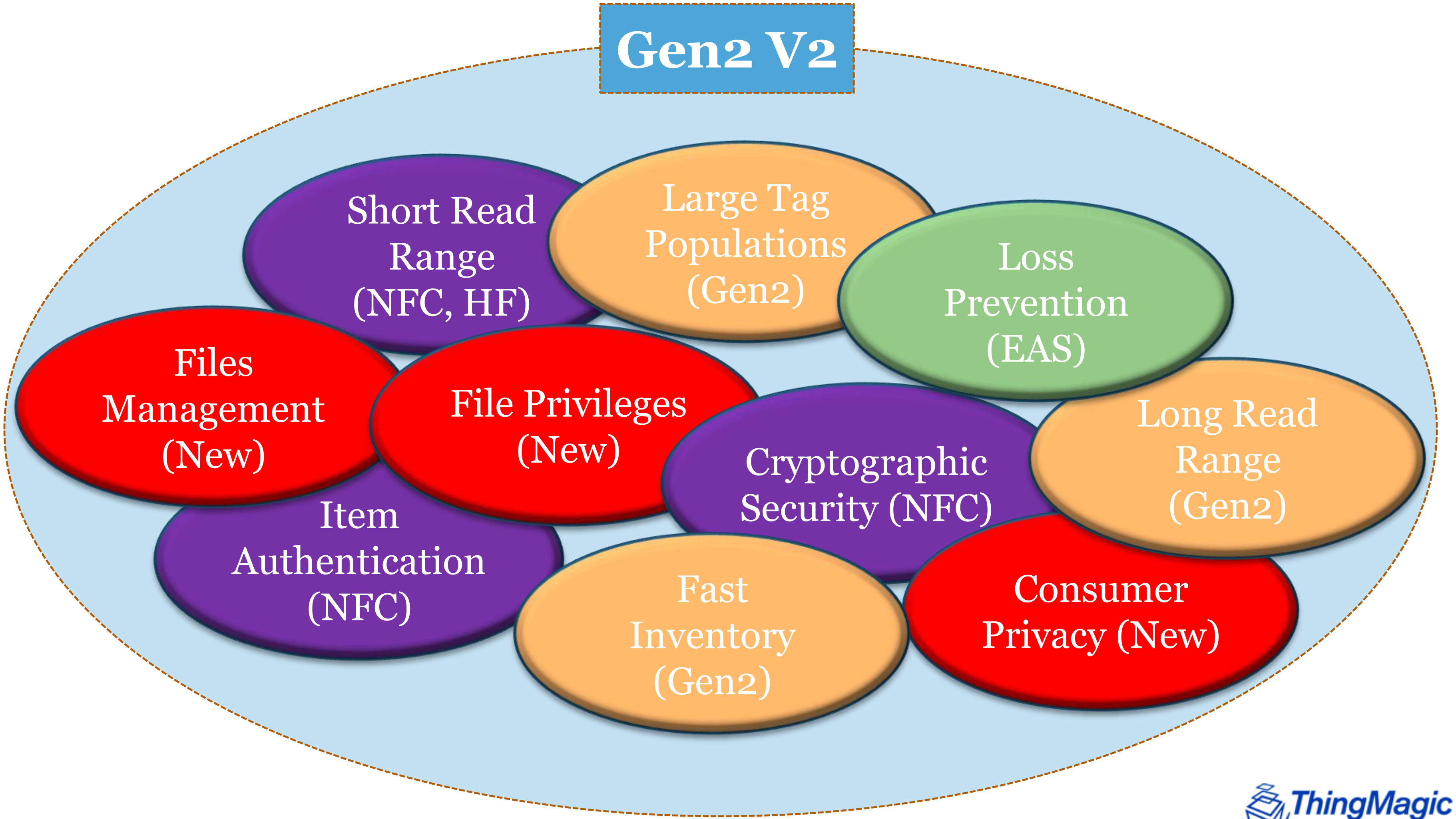
UHF RFID Frequencies



https://www.google.com/Images

Gen2 V2 Protocol

What is new in V2 compared to V1



http://www.rfidjournal.net/masterPresentations/rfid_hightech2012/np/diorio_1100_oct11.pdf

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RFID Regulations

- Each country has its own organization that regulates the use of communication systems.
- This organization regulates the frequency band to be used and the maximum allowed power, spectrum mask, etc.
- Moreover, it regulates the unintentional radiations level outside the assigned bands to reduce the interference.

http://en.wikipedia.org/wiki/List_of_telecommunications_regulatory_bodies

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UHF RFID Regulation Specifications

- As an example let's see the ETSI EN 302 208-1 V1.4.1

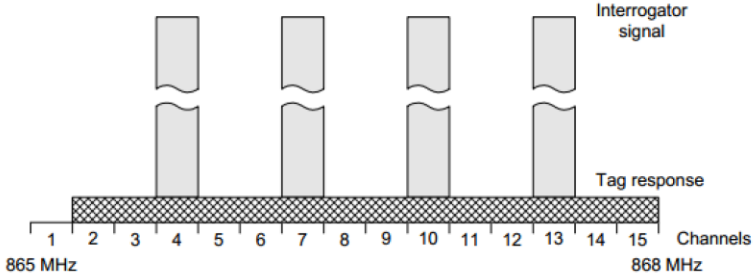
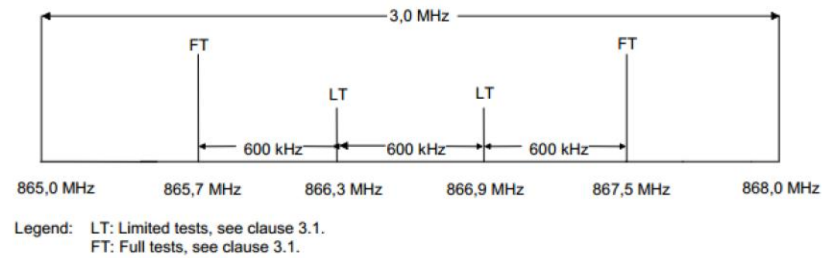
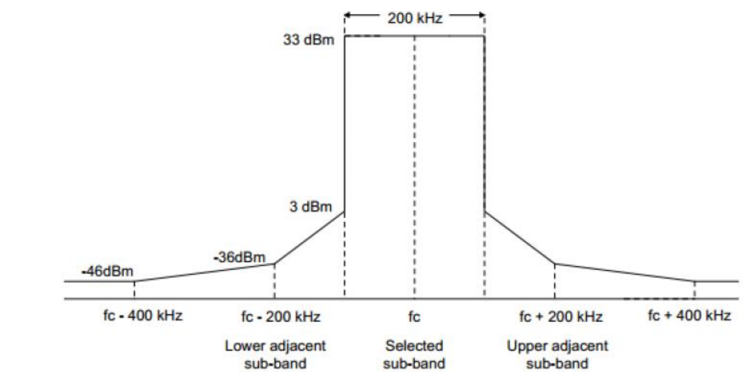


Figure 1: Diagram of channel plan



Legend: LT: Limited tests, see clause 3.1.
FT: Full tests, see clause 3.1.

Figure 2: Tests on a single sample for equipment within the band 865,0 MHz to 868,0 MHz



NOTE: Where fc is the centre frequency of the carrier transmitted by the interrogator.

Figure 3: Spectrum mask for modulated signals

Table 4: Spurious emission limits in e.r.p.

State	47 MHz to 74 MHz 87,5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other frequencies below 1 000 MHz	Frequencies above 1 000 MHz
Operating	4 nW (-54 dBm)	250 nW (-36 dBm)	1 µW (-30 dBm)
Standby	2 nW (-57 dBm)	2 nW (-57 dBm)	20 nW (-47 dBm)

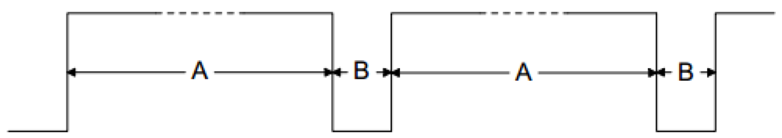


Figure 5: Repeated transmissions on the same channel

A <= 4 s; B >=100 ms.

Max. T_x Power = 2 W
Extreme Conditions

Also Specify Receiver Parameters

http://www.etsi.org/deliver/etsi_en/302200_302299/30220801/01.04.01_60/en_30220801v010401p.pdf

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UHF RFID Protocols

- Most of the communication systems parameters are defined by different communication protocols.
- These communication protocols define the physical layer parameters such as: modulation, encoding, data rates, signaling, timing, etc. for both the reader and the tag.
- These protocols facilities the standardization of UHF RFID products from different manufacturers.

https://www.google.com/Images

EPC Class-1 Generation-2 v 1.2.0

Reader-to-Tag (R->T) Communication

- Modulation: DSB-ASK, SSB-ASK, or PR-ASK
- Data Encoding: PIE
- R=>T RF envelope, Power-up & down waveform.
- Transmit mask
- Preamble and Frame-sync
- Collision Handling

Tag-to-Reader (T->R) Communication

- Modulation: ASK and /or PSK
- Data Encoding: FM0 and Miller
- Tari 6.25µs to 25µs
- Backscattering Link Frequency (BLF) 40 to 640 kHz
- Memory Banks

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http://www.gs1.org/gsmp/kc/epcglobal/uhfc1g2/uhfc1g2_1_2_0-standard-20080511.pdf

Low Level Reader Protocol (LLRP)

Ratified by EPCGlobal in April 2007

Protocol that is intended to standardize the network interface of the RFID readers.

It is designed as a standard in order for developers to have a common programmatic interface to RFID readers from different manufacturers.

http://www.gs1.org/gsmp/kc/epcglobal/llrp/llrp_1_0-presentation-20070716.pdf
http://www.gs1.org/gsmp/kc/epcglobal/llrp/llrp_1_1-standard-20101013.pdf

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UHF RFID Reader Features

Here is a list of important feature of UHF RFID Readers

- **Sensitivity**
- **Protocol Compliance**
- **Regulation Compliance**
- **Read Rate**
- **Collision Detection**
- **Adaptation with Tag Population**
- **Power Consumption**
- **Durability**
- **Configurability**

And More

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UHF RFID Tag Features

Here is a list of important feature of UHF RFID Tags

- **Threshold Power**
- **Orientation Sensitivity**
- **Protocol Compliance**
- **Security Measures**
- **User Memory Storage**
- **Custom Commands**
- **Material Mounting**
- **Passive or Battery Assisted**
- **Sensors**

And More

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