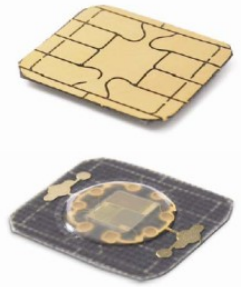
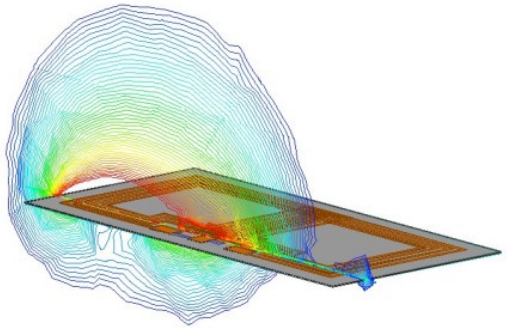
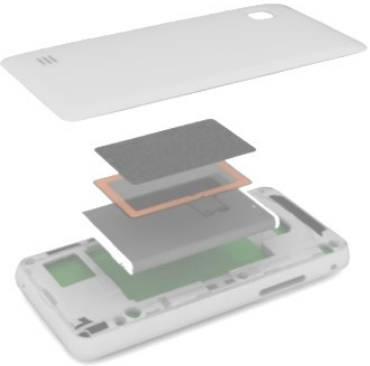
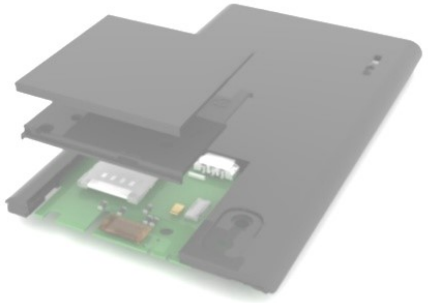




10 UHF Protocols

10th unit in course 451.417, RFID Systems, TU Graz

Benno Flecker
Dipl.-Ing. Dr. Michael Gebhart, MSc

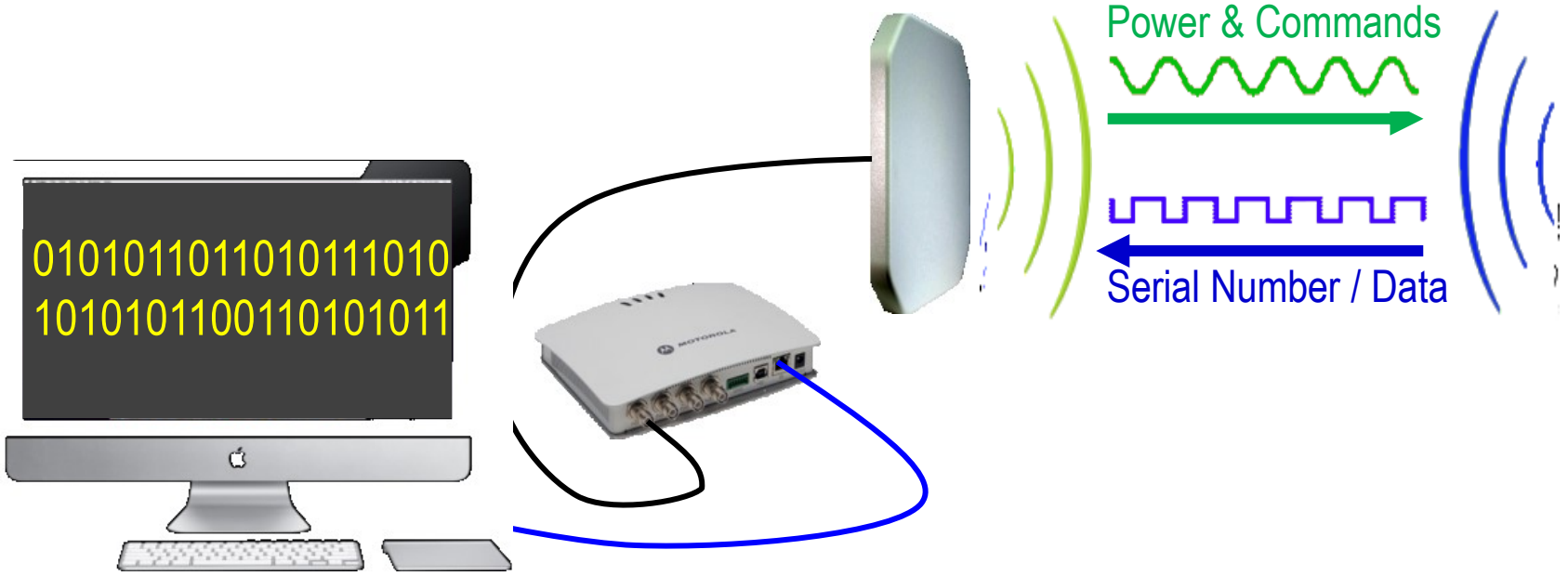
RFID Systems, Graz University of Technology
SS 2023, March 06st

rfid-systems.at
Advancing Technology

RFID System

A traditional passive label (tag) is queried and it responds with it's ID accordingly.
Power and commands are transferred with different frequencies

- UHF [860 – 960MHz]
- HF [13.56MHz]
- LF [125 & 134.2kHz]



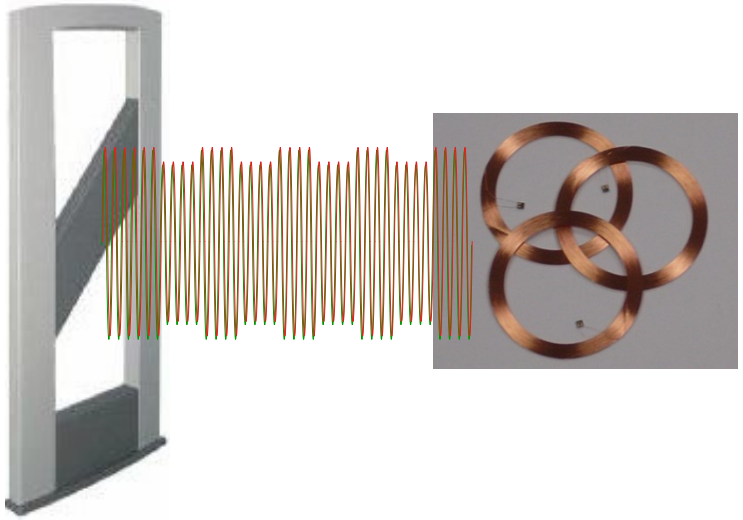
Used RFID technology and its properties

Low frequency (125kHz, 134.2kHz)
- Read Range ~ 1m – one tag each time
- Works well in harsh environment
- Transponder cost ⇧
- System cost ⇩

High frequency (13.56MHz)
- Read Range ~ 1.5m – 40 tags at the same time
- Works well in harsh environment
- Transponder cost (etched Labels, ⇔ Hard tags ⇔)
- System cost ⇔

Ultra high frequency (840-960MHz)
- Very long read ranges of up to 10+m – 1000 tags/sec
- Susceptible to harsh environment
- Transponder cost (etched Labels, ⇩ Hard tags ⇔)
- System cost ⇧

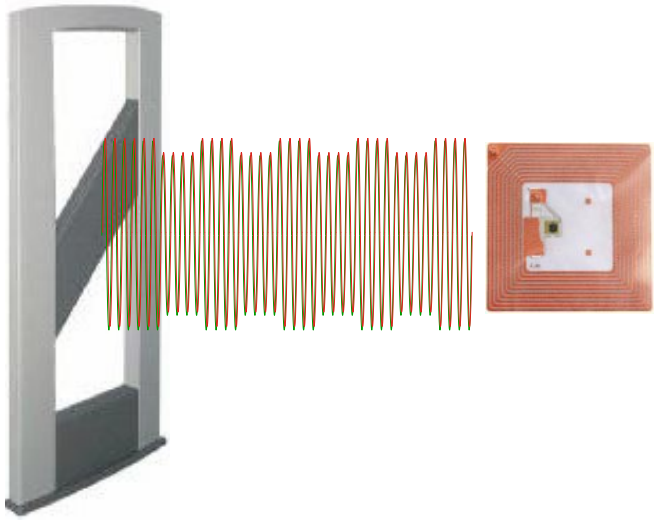
LF Technology



- **Standards:**
  - ISO 11784/85 Animal ID, TTF
  - ISO 14223 RTF & TTF
  - ISO 18000-2 Item Management
- **National Regulations:**
  - Worldwide harmonized

- **Physical concept:**
  - Inductive coupling
- **Operating frequency:**
  - 125/134.2 kHz
- **Antenna:**
  - Coil
- **Operating distance:**
  - Up to 1m
- **Environmental influences:**
  - Weak influence on operating distance
  - Works in metal environment
- **Application:**
  - Animal identification (134.2 kHz)
  - Industrial environment
  - Access Control

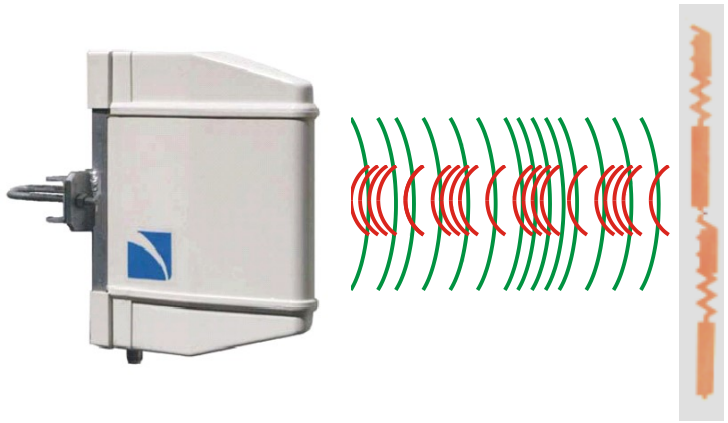
HF Technology



- **Standards:**
  - ISO 15693 Vicinity Card
  - ISO 14443 Proximity Card
  - ISO 18000-3 Item Management
  - HF EPC Gen2 Link
- **National Regulations:**
  - Worldwide harmonized

- **Physical concept:**
  - Inductive coupling
- **Operating frequency:**
  - 13.56 MHz
- **Antenna:**
  - Coil
- **Operating distance:**
  - Vicinity: up to 1.5m
  - Proximity: up to 10cm
- **Environmental influences:**
  - Weak influence on operating distance
  - Works in metal environment
- **Application:**
  - Libraries
  - Public transport
  - Product identification
  - Access control, …

UHF Technology

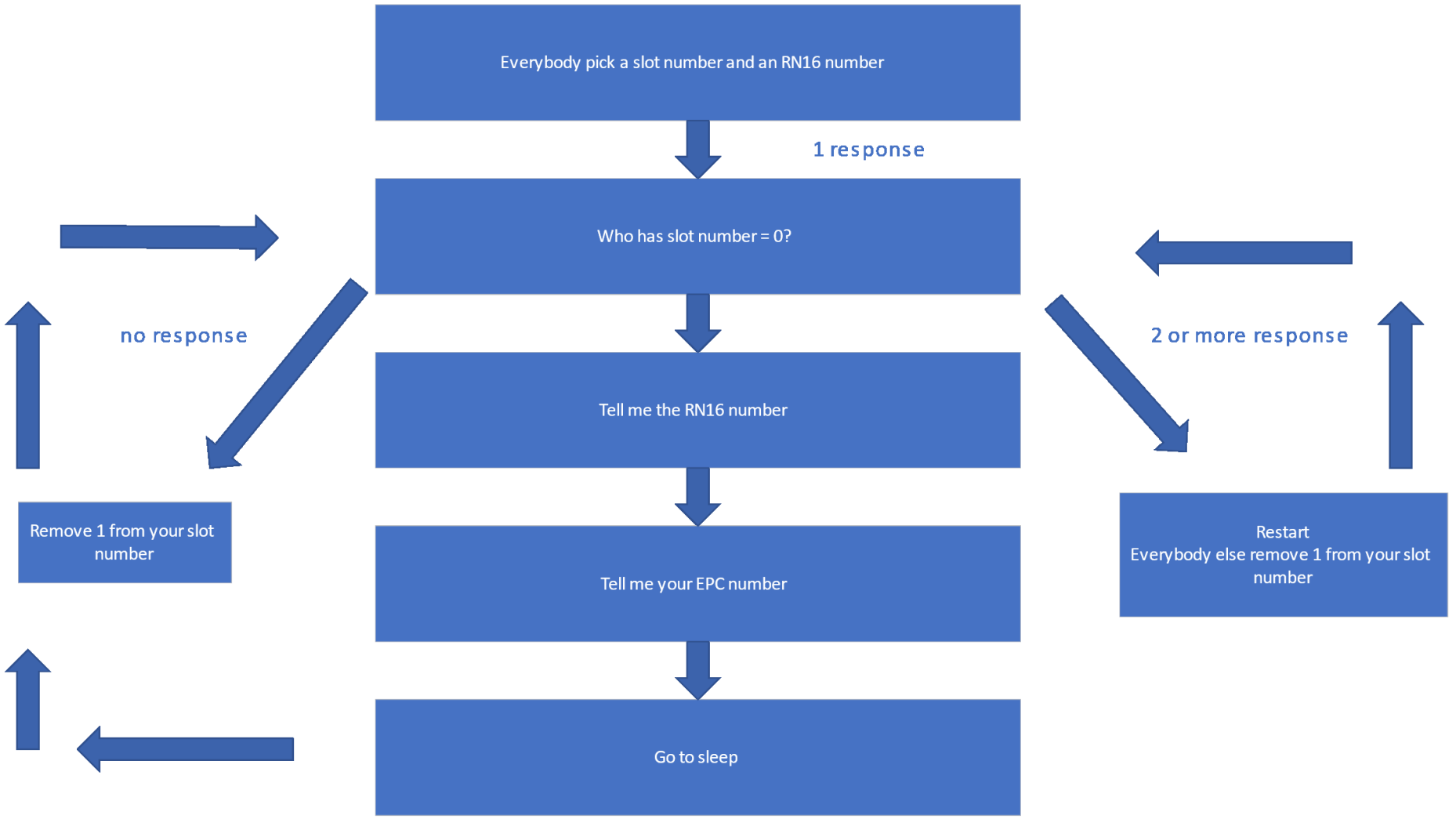


- **Standards**
  - EPC Class I Gen2 V2.1 (Link)
  - ISO 18000-63 Item Management
- **National Regulations:**
  - No worldwide harmonized
- **Physical concept:**
  - EM – wave propagation
- **Operating frequency:**
  - 860 – 960 MHz
- **Antenna:**
  - Dipole and/or loop
- **Operating distance:**
  - Far field: up to 10m
  - Near field: up to 10cm
- **Environmental influences:**
  - Influence on operating distance by reflection and absorption
- **Application:**
  - Pallets and container ID
  - Fashion
  - Retail
  - Electronics

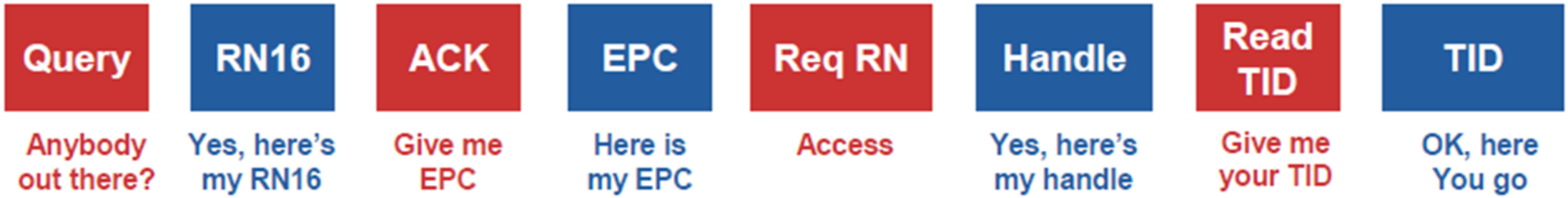
UHF Memory structure

Reserved Memory	• Access and Kill Password
EPC Memory	• EPC Electronic Product Code • Code can be written by user
TID	• TID Tag Identifier (preprogrammed & locked) • IC Manufacturer information, Unique serial number
User Memory	• Manufacturing, quality and product related data storage • User related data storage

Anti collision algorithm



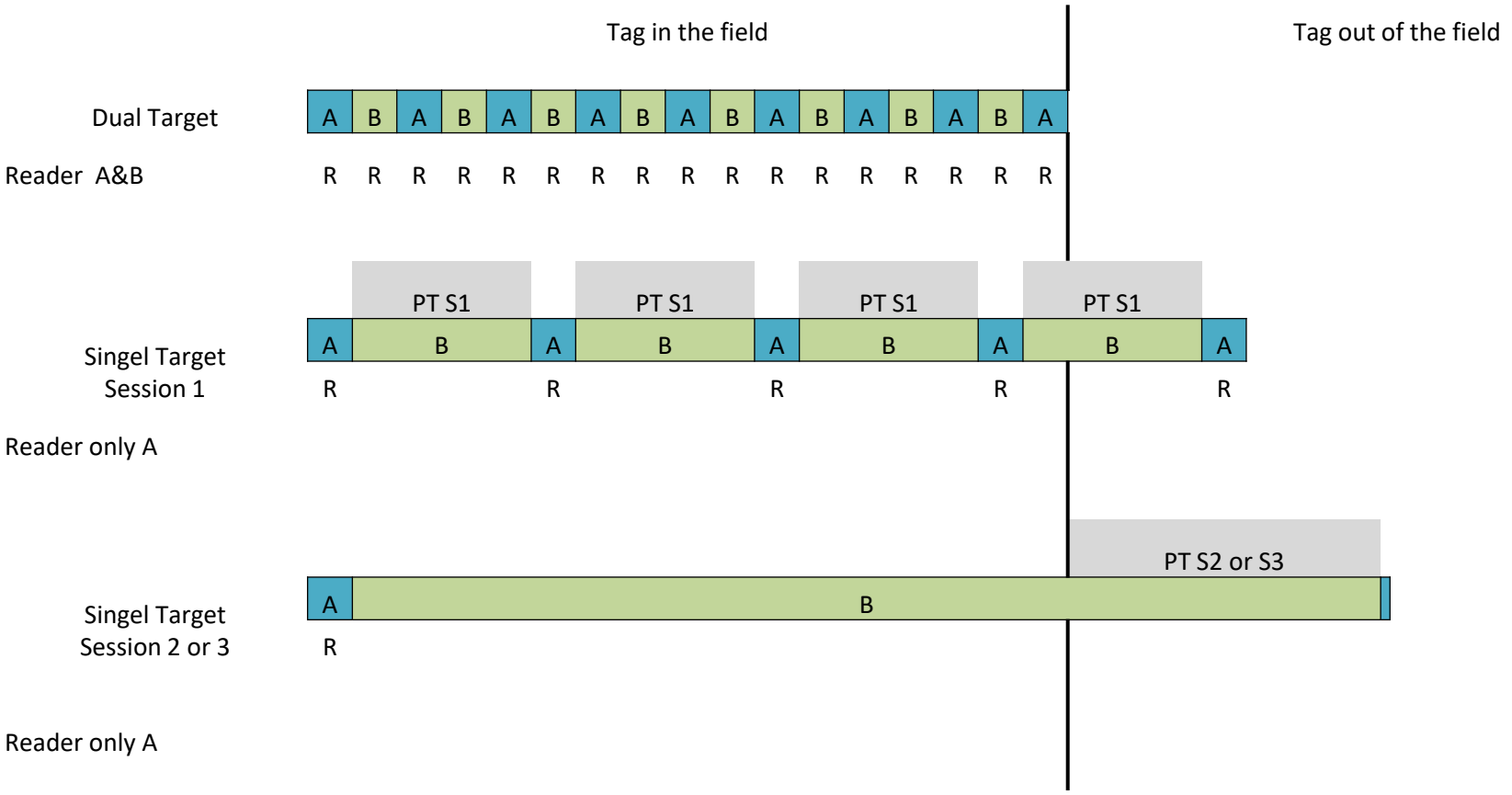
Communication with the tag



Inventory
(1 Communication step)

Command
(e.g. READ TID)

Effect on search mode and sessions



R: READ

PT S1: Persistance Time Session 1

PT S2 or S3: Persistance Time Session 2/ 3

Antenna design inputs

IC
Dimensions, coating
Size
Label Size, Antenna Size
Antenna Substrate
Material; Thickness
Antenna Conductive materials
Material; Thickness; Line width; Gap width; min. corner radius
Performance
Required Frequency Bands; US; EU
Application
Free Air; Cardboard; Plastic; Other material
Stacked tags
Max. no. of tags; Min. distance of tags
Chip Attachment - Direct Attach:
Expected Assembly Capacitance

PEIRP vs. PERP Power

P_{ERP} : Effective radiated power The amount of power that would be necessary at the input terminals of a reference half-wave dipole antenna in order to produce the same maximum field intensity.

P_{EIRP} :Equivalent isotropically radiated power The amount of power that a theoretical isotropic antenna would need to emit to produce the peak power density observed in the direction of maximum antenna gain.

$$P_{ERP} = \frac{P_{EIRP}}{1.64}$$ {10^(dipole gain/10)=1.64 where dipole gain= 2.15dBi}

Gain and Directivity

if the antenna has no electrical losses, then G = D

$$G = \frac{P_{transmitted}}{P_{conducted}} \cdot D$$

Energy Transmission (Reader to TAG)

Transferred power from a reader antenna to the chip

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

$\vartheta_{Matching}$ ... Antenna matching factor ($1 - |\Gamma|^2$)

$\vartheta_{Polarisation}$ ... Polarisation losses

$\vartheta_{Antenna}$ ... efficiency of the label antenna ($P_{radiated}$ / P_{in})

Read Range of an UHF Chip

$$R_{max} = \sqrt{\frac{P_{EIRP} \cdot G_{Label} \cdot \lambda^2}{(4 \cdot \pi)^2 \cdot P_{Chip}} \cdot \vartheta_{Matching} \cdot \vartheta_{Polarisation} \cdot \vartheta_{Antenna}}$$

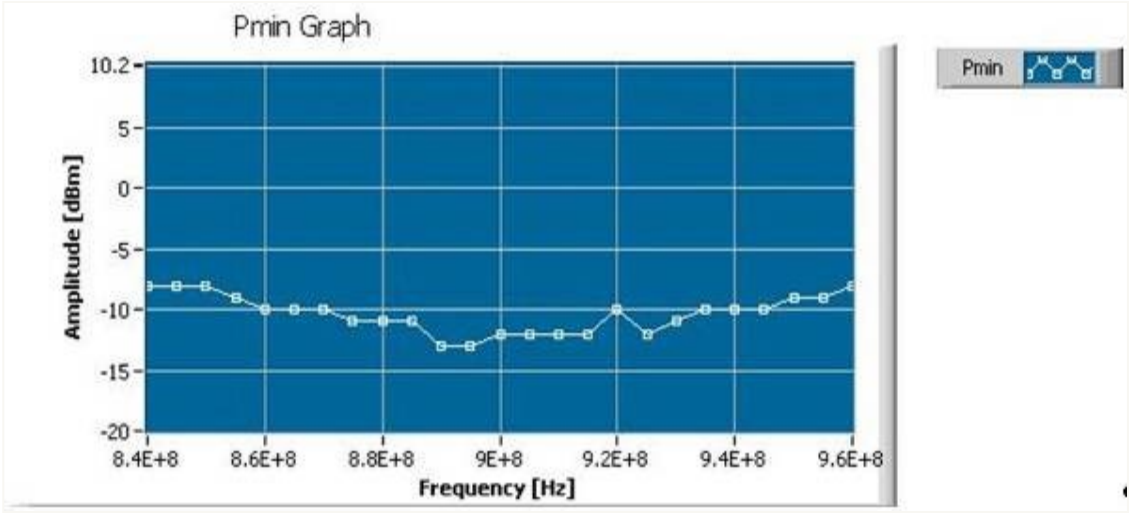
Example I (UHF)
under US regulations:
P_{EIRP} = 4 W; G_{Label} = 1.64; f = 915MHz; P_{CHIP} = 35µW
$\vartheta_{Matching}$ = 0.8; $\vartheta_{Polarisation}$ = 1; $\vartheta_{Antenna}$ = 0.5

$$R_{max} = \sqrt{\frac{4W \cdot 1.64 \cdot (0.33m)^2}{(4 \cdot \pi)^2 \cdot 35 \cdot 10^{-6} W} \cdot 0.8 \cdot 1 \cdot 0.5} = 7.2m$$

Pmin – What can be measured?

The information gained from this measurement method is the minimal required power level at the label for powering the IC.

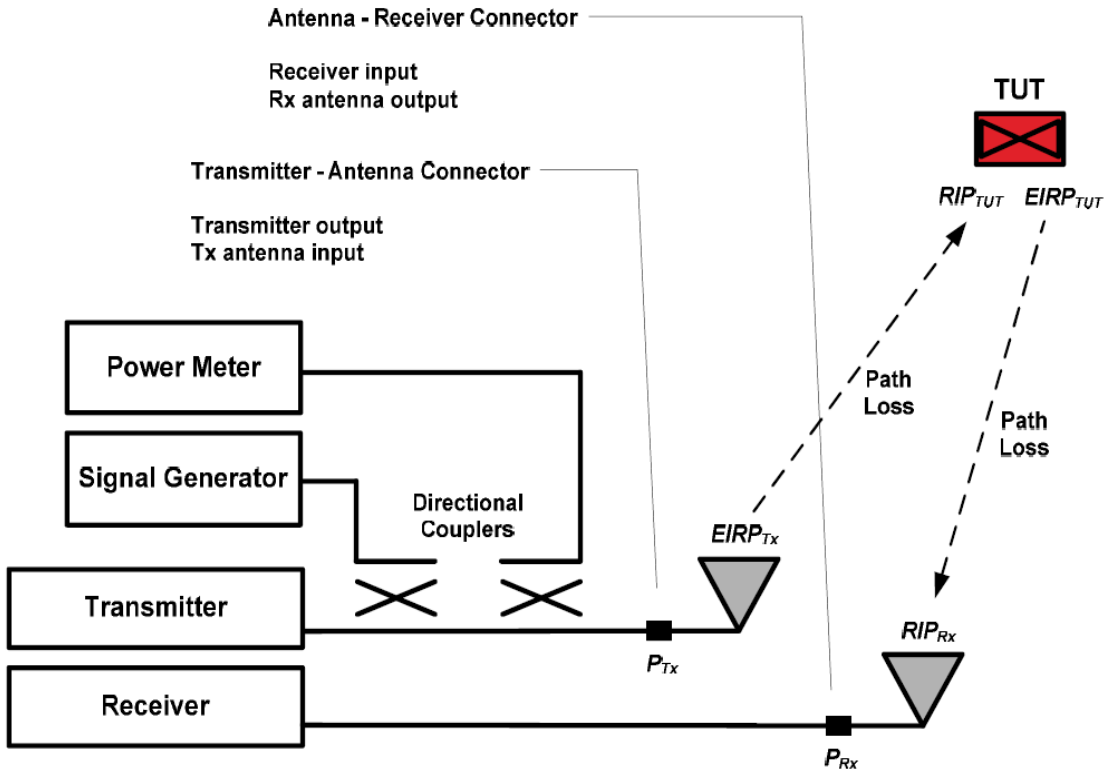
Frequency vs dBm



Gained information:

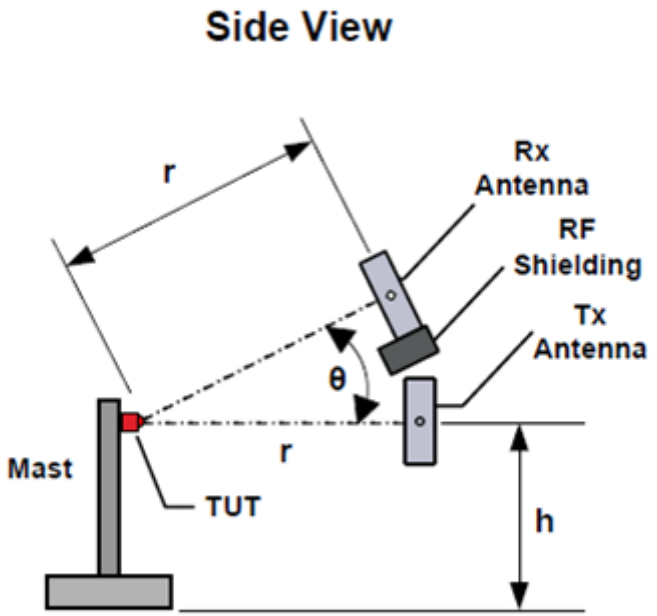
- Label sensitivity
- Label resonance frequency
- Label bandwidth
- Detuning on material
- Production stability

Pmin – Measurement Setup



EPC global document “Tag Performance Parameters and Test Methods Version 1.1.3” Link

Pmin - Anechoic Chamber Setup



Range to tag (r)	1m
Mast height (h)	1m
Tx to Rx angle (θ)	25 deg

Pmin – Available Setup

Test antennas:
2x ETS-Lindgren's Model 3115
https://www.ets-lindgren.com/datasheet/antennas/double-ridged-guide/4002/400203

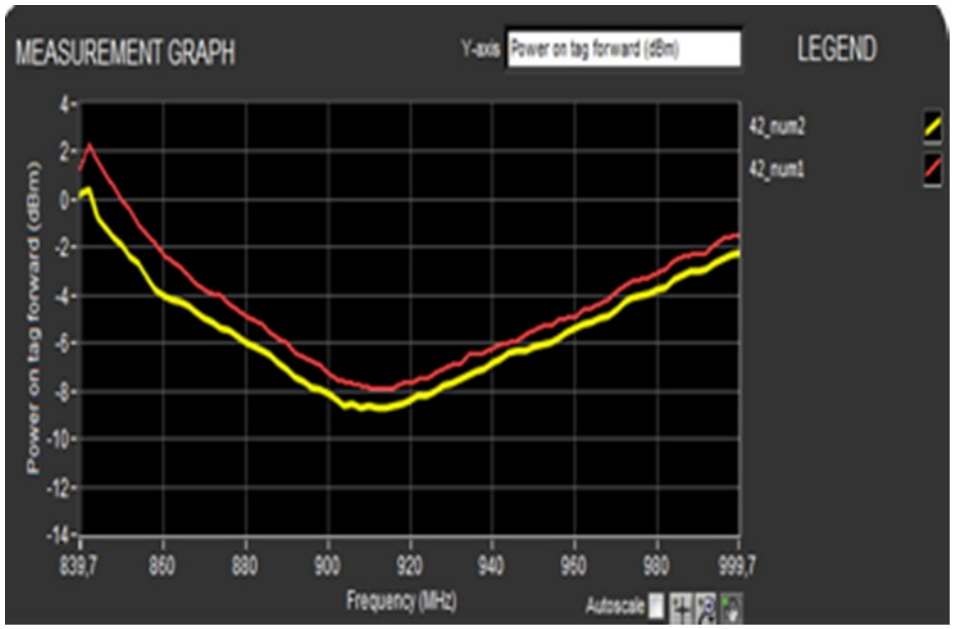
Test reader:
Voyantic Tagformance
https://voyantic.com/lab/tagformance-pro/

Cisc RFID Xplorer
https://www.cisc.at/product/rain-rfid-xplorer/

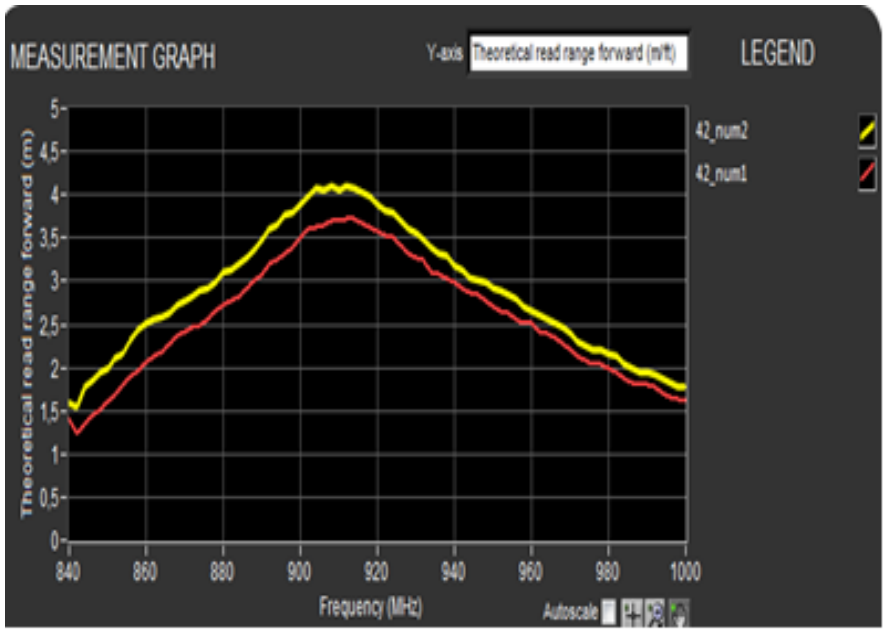
Pmin vs. Read-Range

Read-Range is the inverse of Pmin

$$R = \frac{\lambda}{4\pi}\sqrt{\frac{E_{IRP(W)}}{P_{\min(W)}}}$$



Pmin



Read-Range

Main regulations UHF

	Standard Name	Primary Regions of Operation	Frequency Range	R-->T Technique	Max Radiated Power
FCC	FCC part 15.247	North America	902-928 MHz	FHSS	4W EIRP
ETSI	EN 302208-1 v1.2.1	Europe	865-868 MHz	4 channel plan	2W ERP

Local regulations in RFID

Germany	865.6 - 867.6	2 W ERP	ETSI
India	865 - 867	4 W ERP	
United States	902 - 928	4 W EIRP	FHSS
Russian Federation	866.0 - 867.6	100 mW ERP	ETSI
	866 - 868	500 mW ERP	
	866.0 - 867.6	2 W ERP	
	915 - 921	4 W ERP	
Singapore	866 - 869	0.5 W ERP	
	920 - 925	2 W ERP	
Japan	916.7 - 920.9	4 W EIRP	Either LBT free or LBT Licence required
	916.7 - 923.5	0.5 W EIRP	LBT
China	920.5 - 924.5	2 W ERP	FHSS
Korea	917 - 920.8	4 W EIRP	FHSS or LBT
	917 - 923.5	200 mW EIRP	FHSS or LBT
Taiwan	922 - 928	1 W ERP	FHSS, Indoor
	922 - 928	0.5 W ERP	FHSS, Outdoor
Future EU ongoing	916.1 - 918.9	4 W ERP	EU 2018/1538

UHF Frequency Regulations (GS1) Link

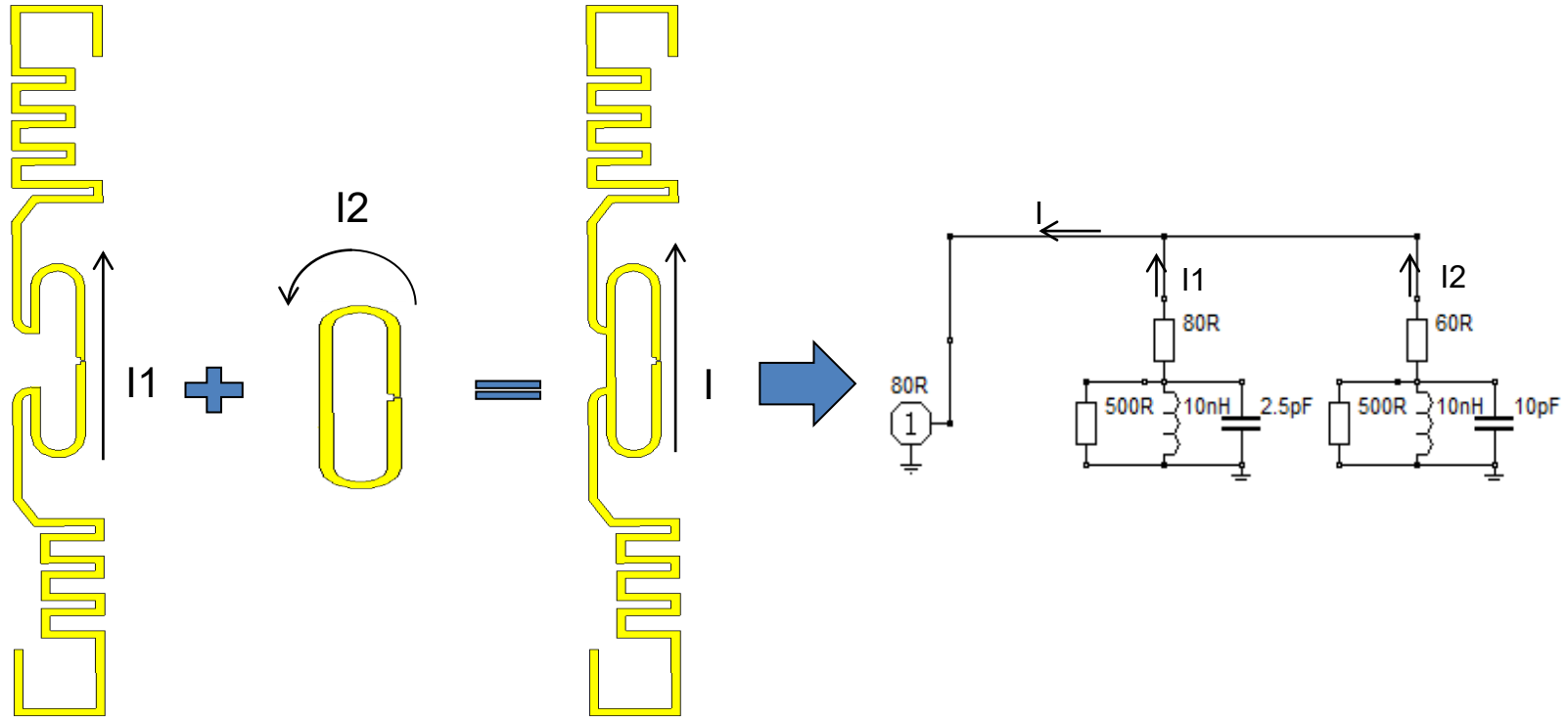
Simulations tools

CST STUDIO SUITE Link
CST is a company of Dassault Systems since October 2016

ANSYS HFSS http://www.ansys.com
2600 ANSYS Drive, Canonsburg, PA 15317, USA

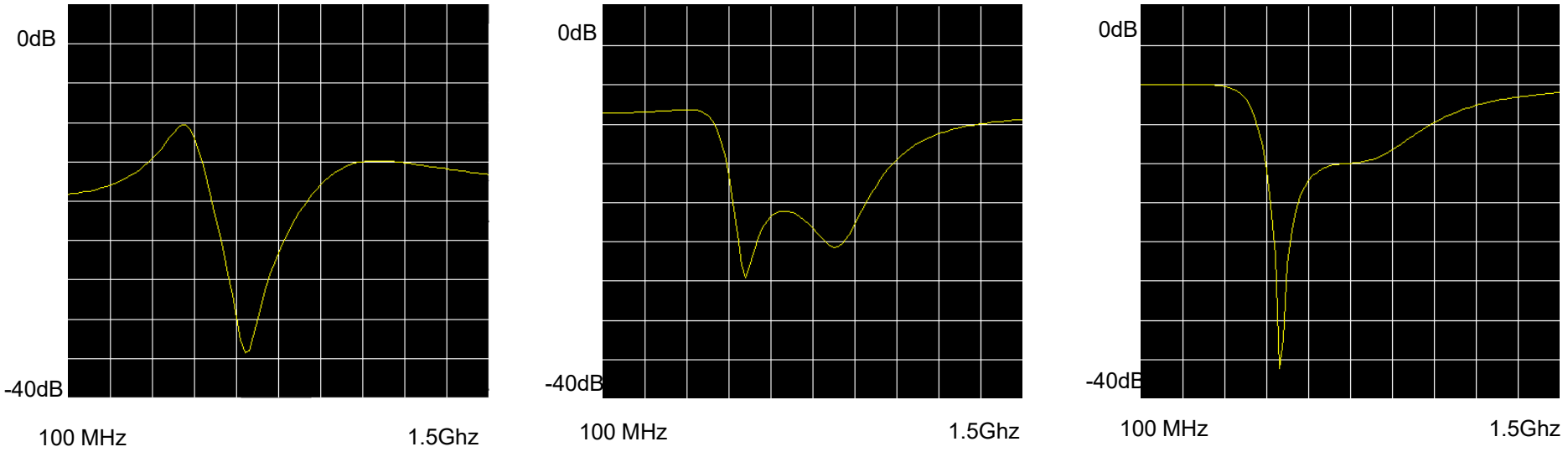
Stagger Tuning

- Idea- Two resonant circuits coupled optimally to achieve a broadband response
- Most commonly implemented as shown below – a loop coupled to a dipole



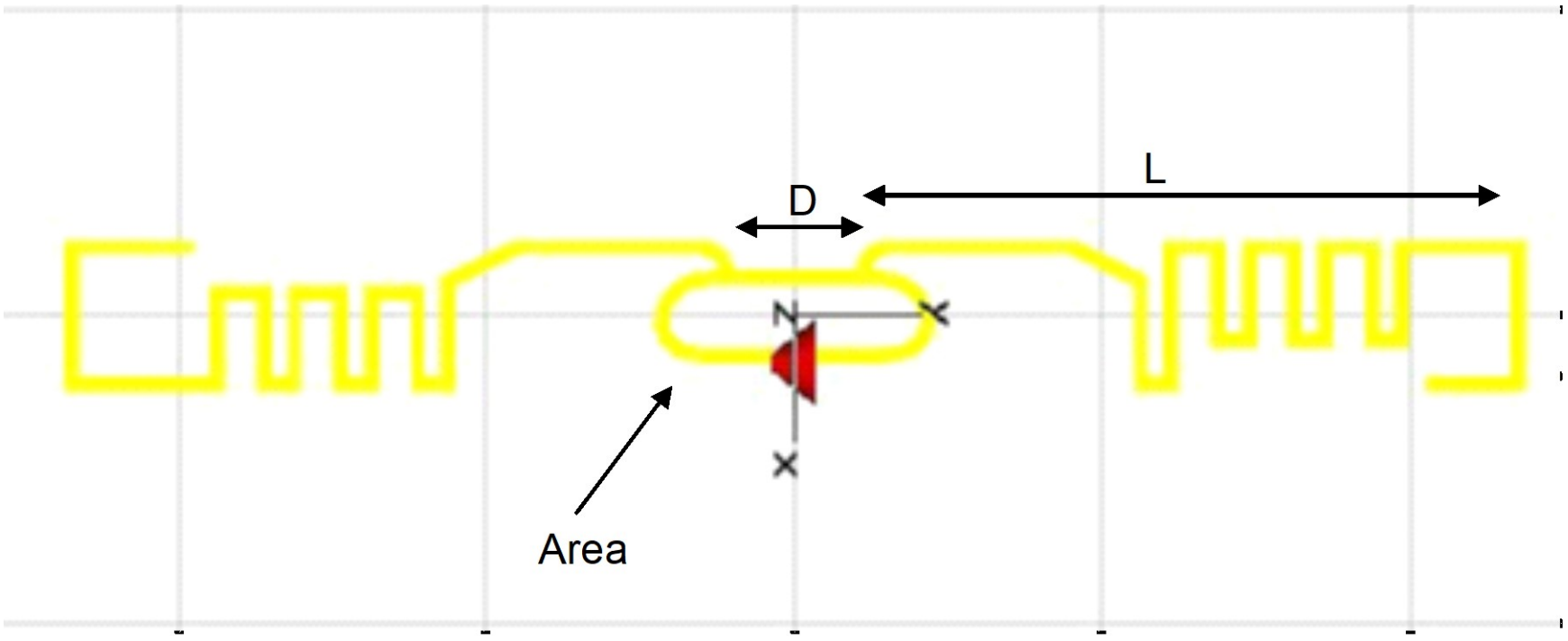
Effect of coupling on stagger tuning

|S11| vs. Frequency

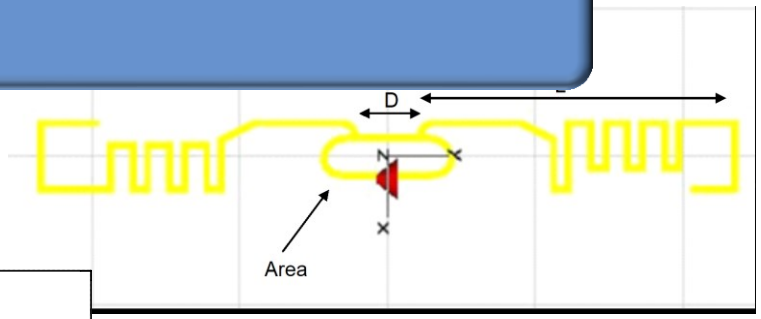


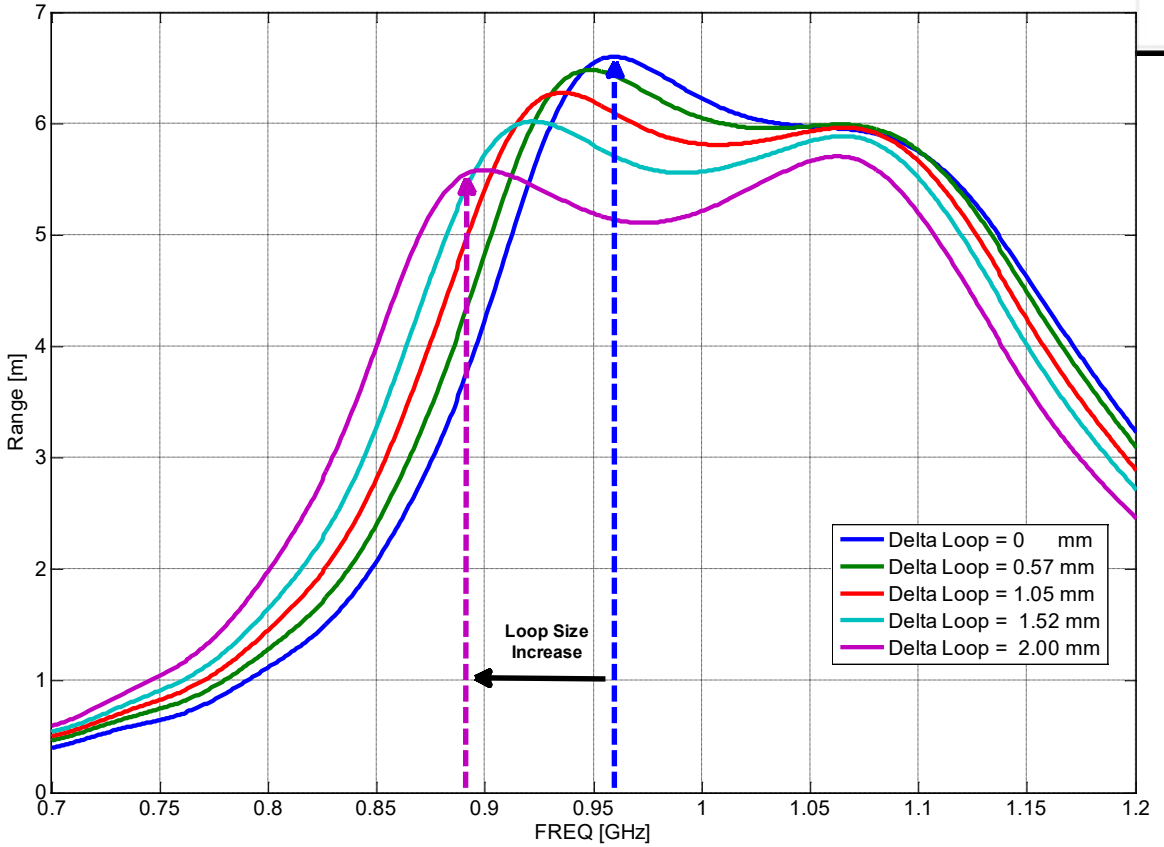
Increasing coupling

Dipol antenna design

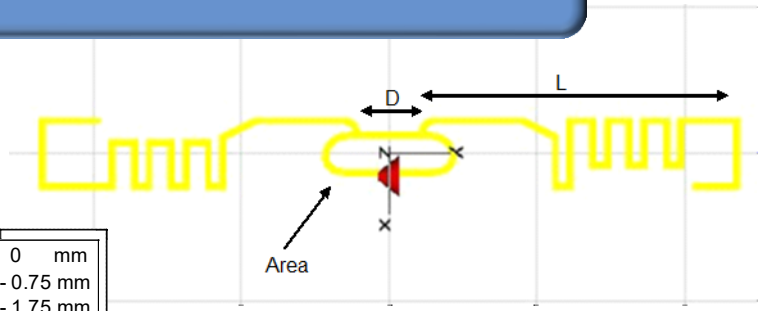


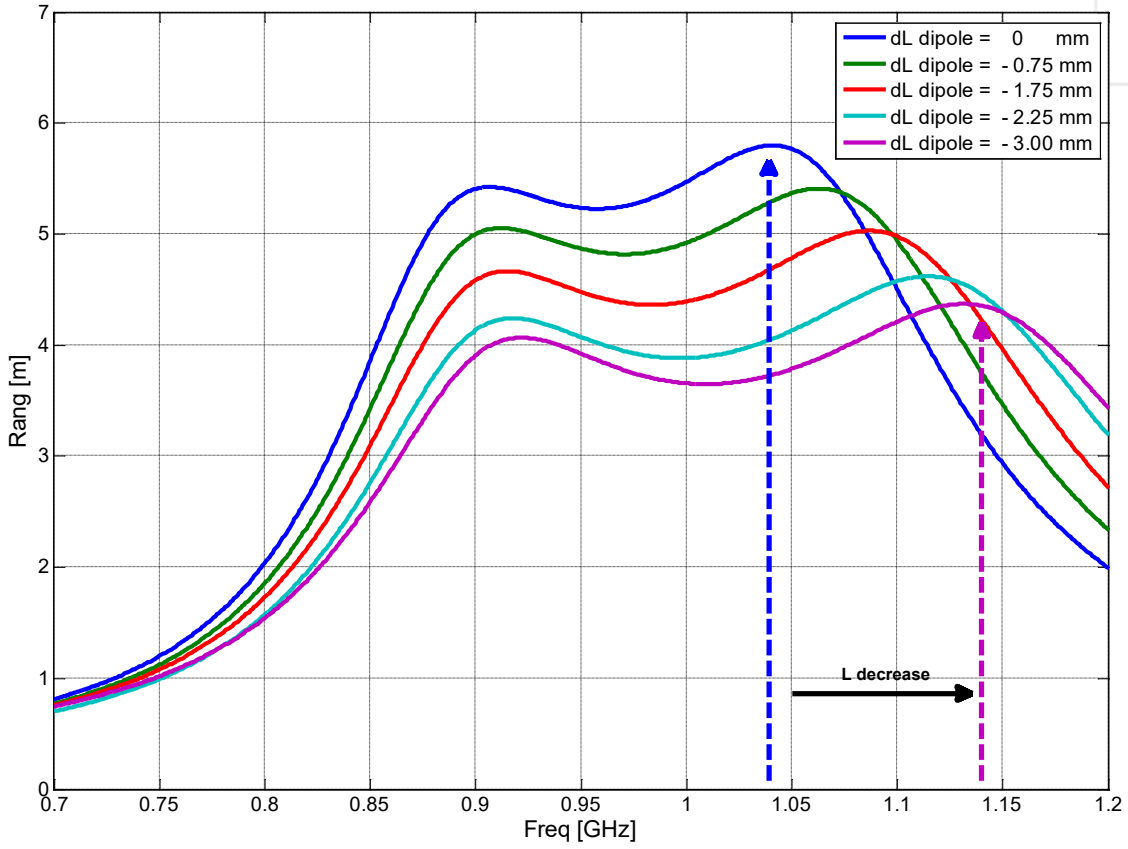
Change loop size



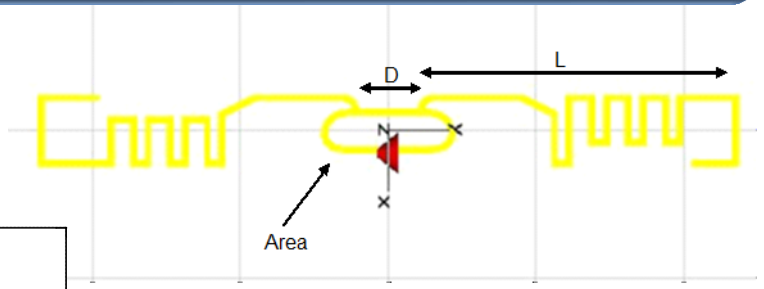


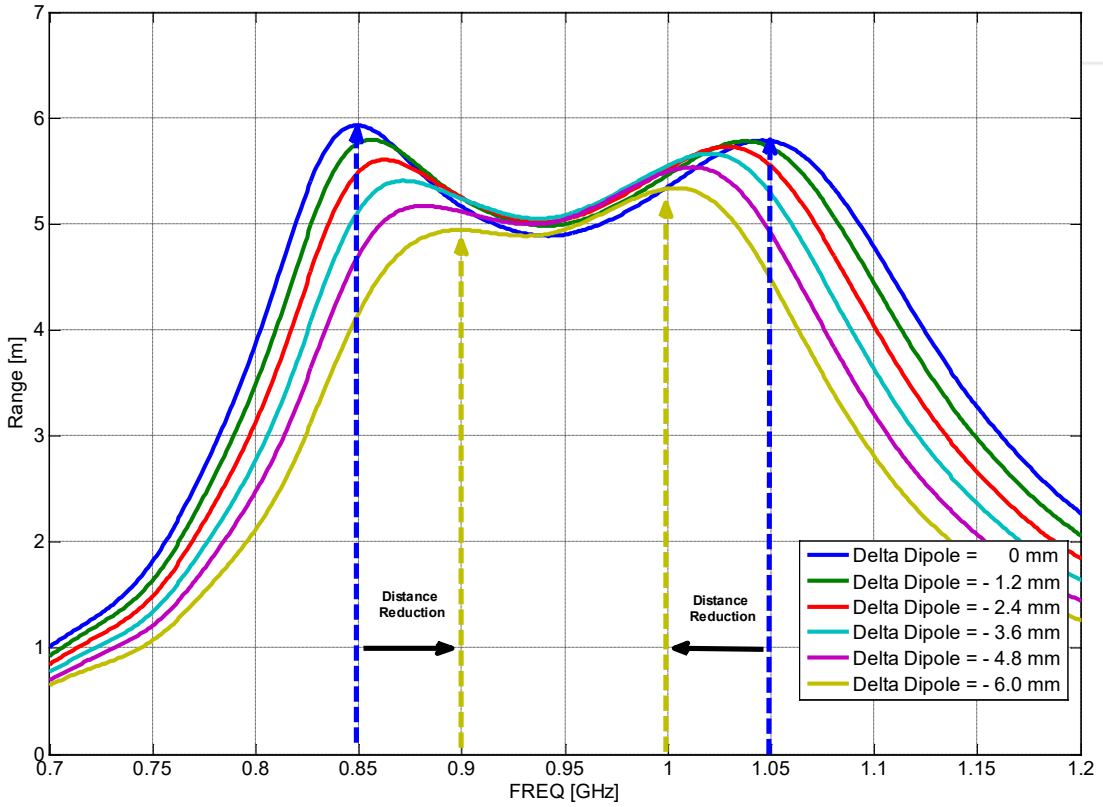
Change dipole length



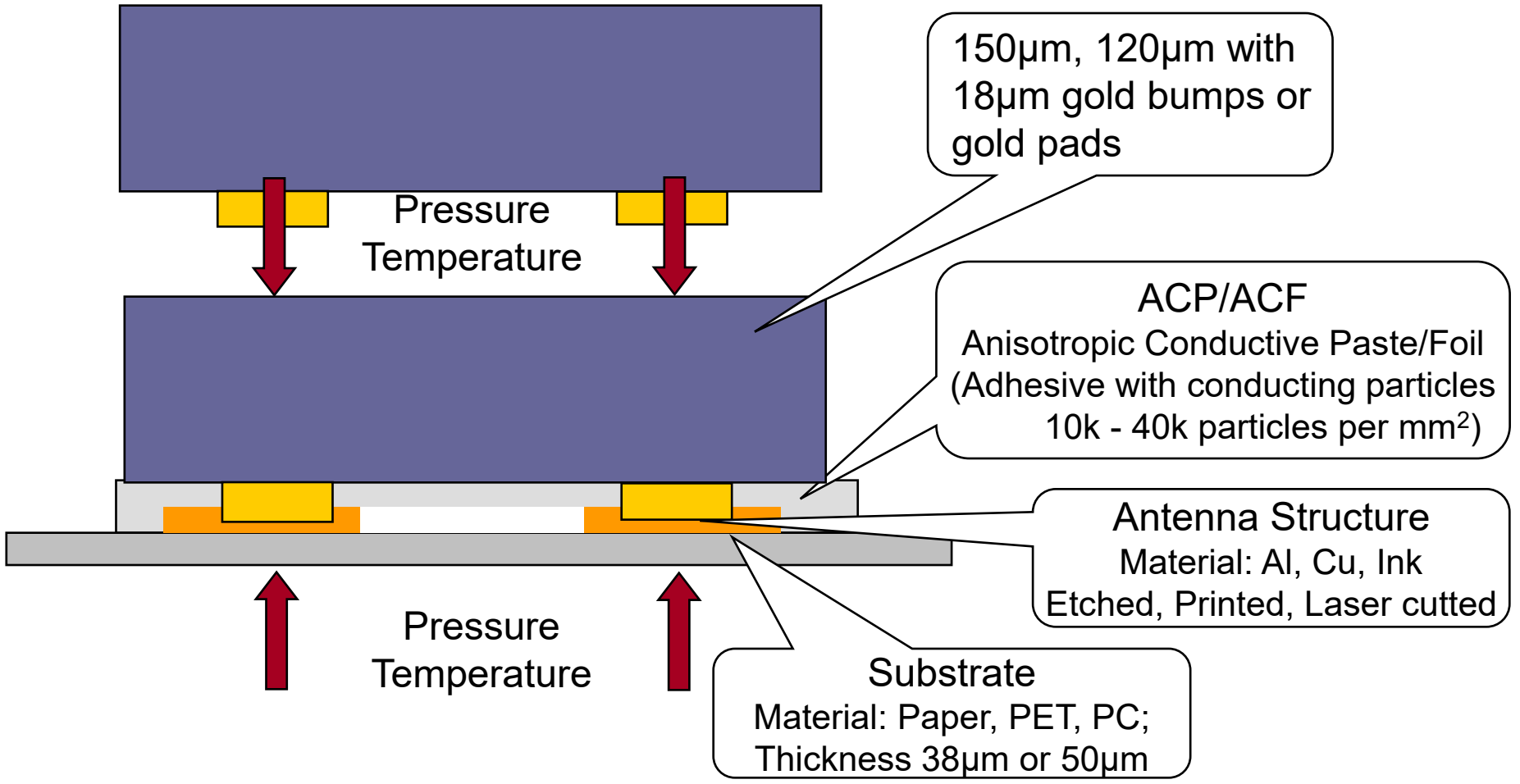


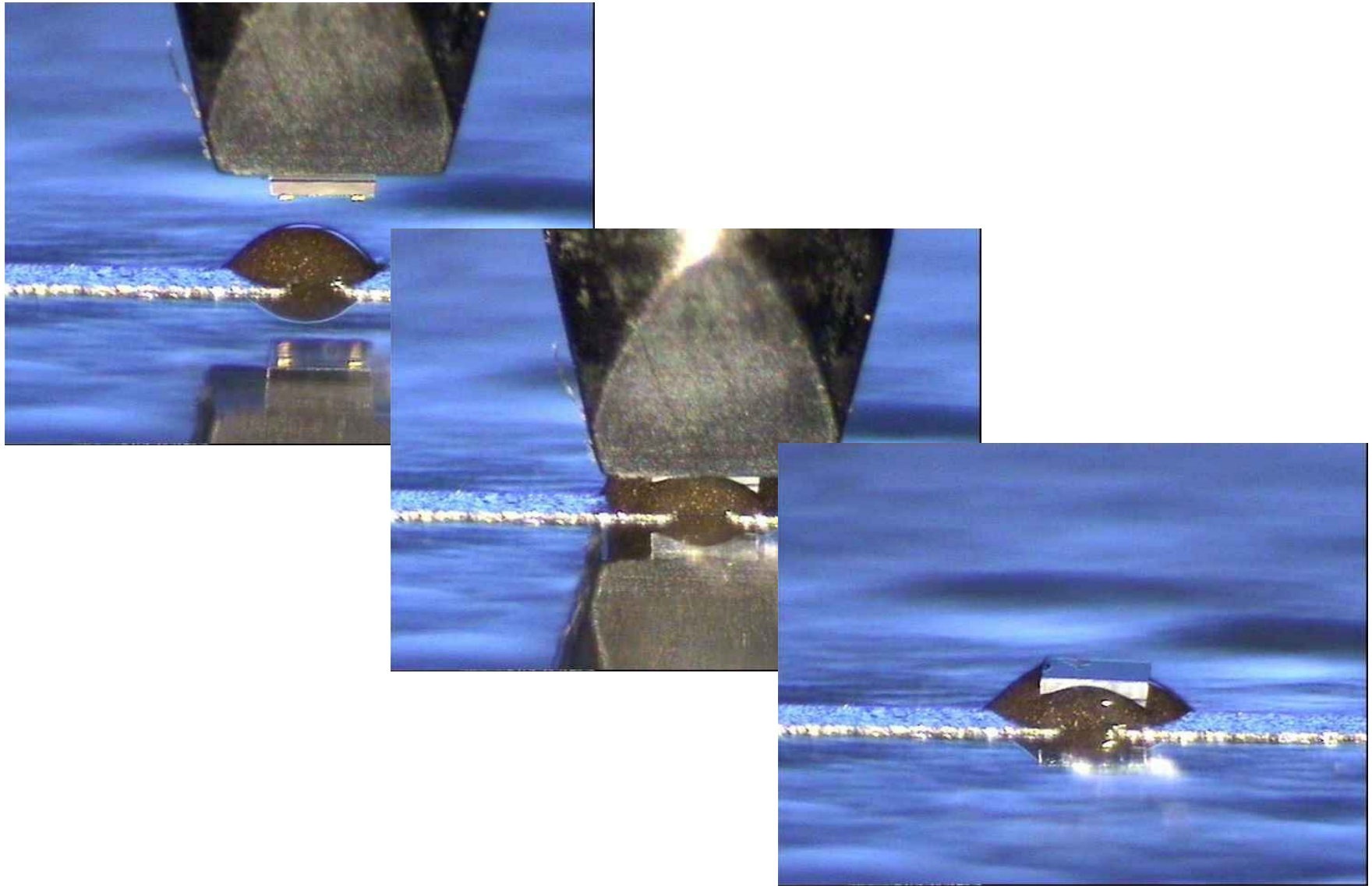
Change connection dipole loop





Direct Chip attach





Thank you for your Audience!

Please feel free to ask questions...

Questions for self-evaluation

Provide an overview about the RFID frequencies.

Explain the standards for UHF

References (LF - Low Frequency)

- ISO 11784:1996 Radio frequency identification of animals — Code structure

  (Published Stage: 90.92 (Confirmed 2021))

  Corrigenda / Amendments ISO 11784:1996/Amd 1:2004; ISO 11784:1996/Amd 2:2010
- ISO 11785:1996 Radio frequency identification of animals — Technical concept

  (Published Stage: 90.93 (Confirmed 2022))

  Corrigenda / Amendments ISO 11785:1996/Cor 1:2008
- ISO 14223-1:2011 Radiofrequency identification of animals — Advanced transponders — Part 1: Air interface

  (Published Stage: 90.93 (Confirmed 2022))
- ISO 14223-2:2010 Radiofrequency identification of animals — Advanced transponders — Part 2: Code and command structure

  (Published Stage: 90.93 (Confirmed 2021))
- ISO 14223-3:2018 Radiofrequency identification of animals — Advanced transponders — Part 3: Applications

  (Published Stage: 90.93 (Confirmed 2023))

- ISO/IEC 18000-2:2009 Information technology — Radio frequency identification for item management — Part 2: Parameters for air interface communications below 135 kHz

  (Published Stage: 90.93 (Confirmed 2022))

References (HF - High Frequency)

ISO/IEC 15693-1:2018 Cards and security devices for personal identification — Contactless vicinity objects — Part 1: Physical characteristics

(Published Stage: 90.20)

ISO/IEC 15693-2:2019 Cards and security devices for personal identification — Contactless vicinity objects — Part 2: Air interface and initialization

(Published Stage: 60.60)

ISO/IEC 15693-3:2019 Cards and security devices for personal identification — Contactless vicinity objects — Part 3: Anticollision and transmission protocol

(Published Stage: 60.60)

ISO/IEC 18000-3:2010 Information technology — Radio frequency identification for item management — Part 3: Parameters for air interface communications at 13,56 MHz

(Published Stage: 90.93 (Confirmed 2022))

Radio-Frequency Identity Protocols EPC Class-1 HF RFID Air Interface Protocol V2.0.3 Link

Overview of UHF frequency allocations (860 to 960 MHz) for RAIN RFID - 10 November 2022 Link

References (HF - High Frequency)

ISO/IEC 14443-1:2018 Cards and security devices for personal identification — Contactless proximity objects — Part 1: Physical characteristics

(Published Stage: 60.60)

ISO/IEC 14443-2:2020 Cards and security devices for personal identification — Contactless proximity objects — Part 2: Radio frequency power and signal interface

(Published Stage: 60.60)

Corrigenda / Amendments: ISO/IEC 14443-2:2020/Amd 1:2021; ISO/IEC 14443-2:2020/Cor 1:2021; ISO/IEC 14443-2:2020/Cor 2:2023

ISO/IEC 14443-3:2018 Cards and security devices for personal identification — Contactless proximity objects — Part 3: Initialization and anticollision

(Published Stage: 60.60)

Corrigenda / Amendments: ISO/IEC 14443-3:2018/Amd 1:2021; ISO/IEC 14443-3:2018/Amd 2:2020; ISO/IEC 14443-3:2018/AWI Amd 3

ISO/IEC 14443-4:2018 Cards and security devices for personal identification — Contactless proximity objects — Part 4: Transmission protocol

(Published Stage: 60.60)

Corrigenda / Amendments: ISO/IEC 14443-4:2018/Amd 1:2021; ISO/IEC 14443-4:2018/Amd 2:2020; ISO/IEC 14443-4:2018/AWI Amd 3

References (UHF – Ultra High Frequency)

ISO/IEC 18000-63:2021 Information technology — Radio frequency identification for item management — Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C

(Published Stage: 90.92)

ISO 14223-1:2011 Radiofrequency identification of animals — Advanced transponders — Part 1: Air interface

(Published Stage: 90.93 (Confirmed 2022))

EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID Standard

Release 2.1, Ratified, Jul 2018, Link

Tag Performance Parameters and Test Methods Version 1.1.3 Link

ETSI EN 302 208-1 V2.1.1 (2015-02) Link

RAIN RFID https://rainrfid.org/

HW Links (some examples)

Labels:
Avery Dennison (http://rfid.averydennison.com/)
Confidex (http://www.confidex.net/)

Reader:
Impinj (https://www.impinj.com/)
Kathrein RFID (Link)
Caen (https://www.caenrfid.com/en/)

Measurement Equipment:
Voyantic Tagformance https://voyantic.com/lab/tagformance-pro/
Cisc RFID Xplorer https://www.cisc.at/product/rain-rfid-xplorer/

Simulation tools:
CST STUDIO SUITE Link
ANSYS HFSS http://www.ansys.com

Arbitrations

RFID	Radio Frequency Identification
UHF	Ultra High Frequency
HF	High Frequency
LF	Low Frequency
RTF	Reader Talks First
TTF	Tag Talks First
EPC	Electronic Product Code
TID	Tag Identifier