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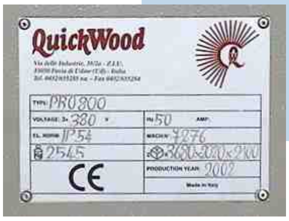
Identification of Objects

From visual to Electromagnetic labeling

Printed Label



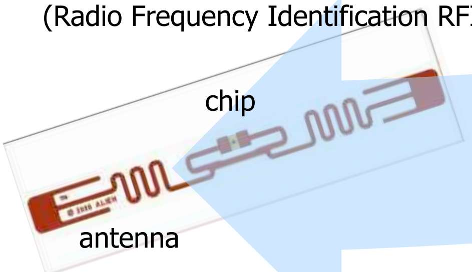
Direct and Visual access to data

Barcode

42000 06200

- Indirect access to data
- Binary coding
- Optical reading by laser scanner
- Reading range: a few cm

Electromagnetic tag
(Radio Frequency Identification RFId)



Electromagentic access to data

Electronic tag (Magnetic & Smart Cards)

- Data reading by electrical contact or magnetic induction
- Battery-less devices
- Binary coding

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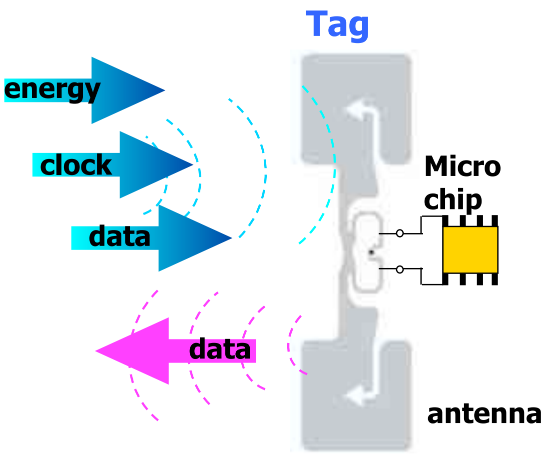
RadioFrequency Identification (RFID)

Reader



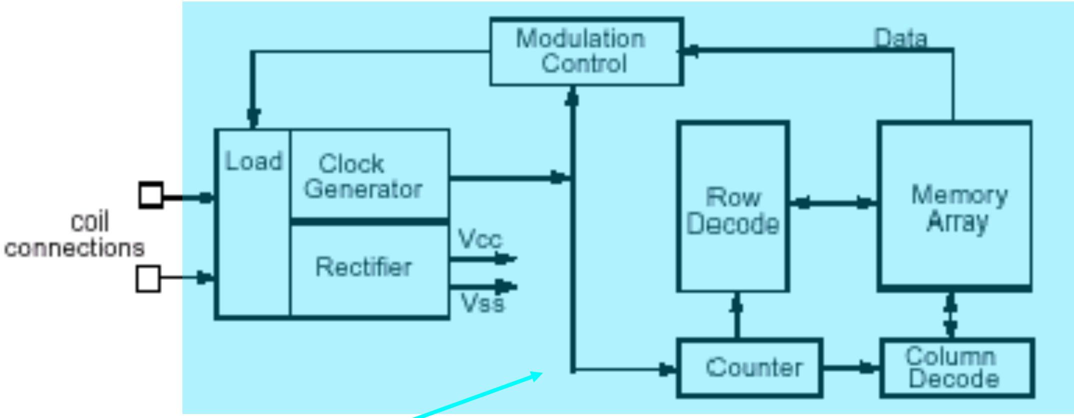
- PASSIVE devices: Tags do not contain a battery; the power is supplied by the reader.
- BACKSCATTERING: Tags reflect the reader's signal right back, modulating the query signal to transmit data.

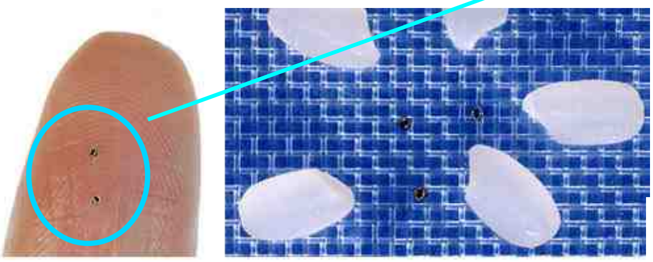
- Back-scattered data modulation

- **Complex impedance matching**

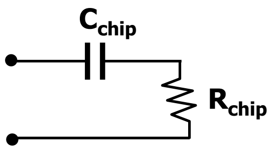
$$Z_A = Z_C^*$$

UHF RFID Microchips





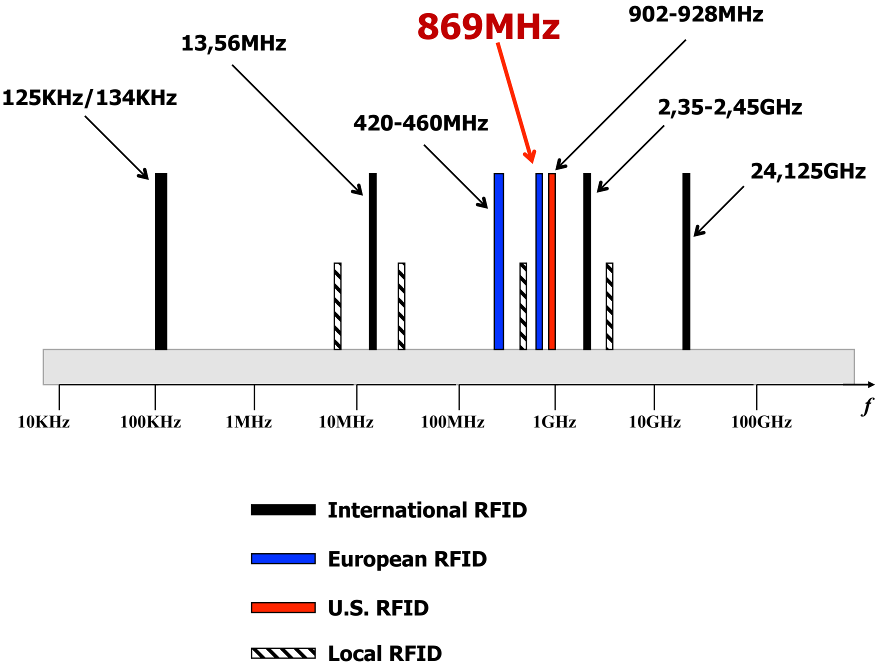
A New RFID with Embedded Antenna μ-Chip



Hitachi μ-chip RFID Technology Compatible with Gamma Sterilization

Tests with MDS Nordion reveal μ-chip can withstand at least 500 kGy gamma ray exposure

Frequency bands



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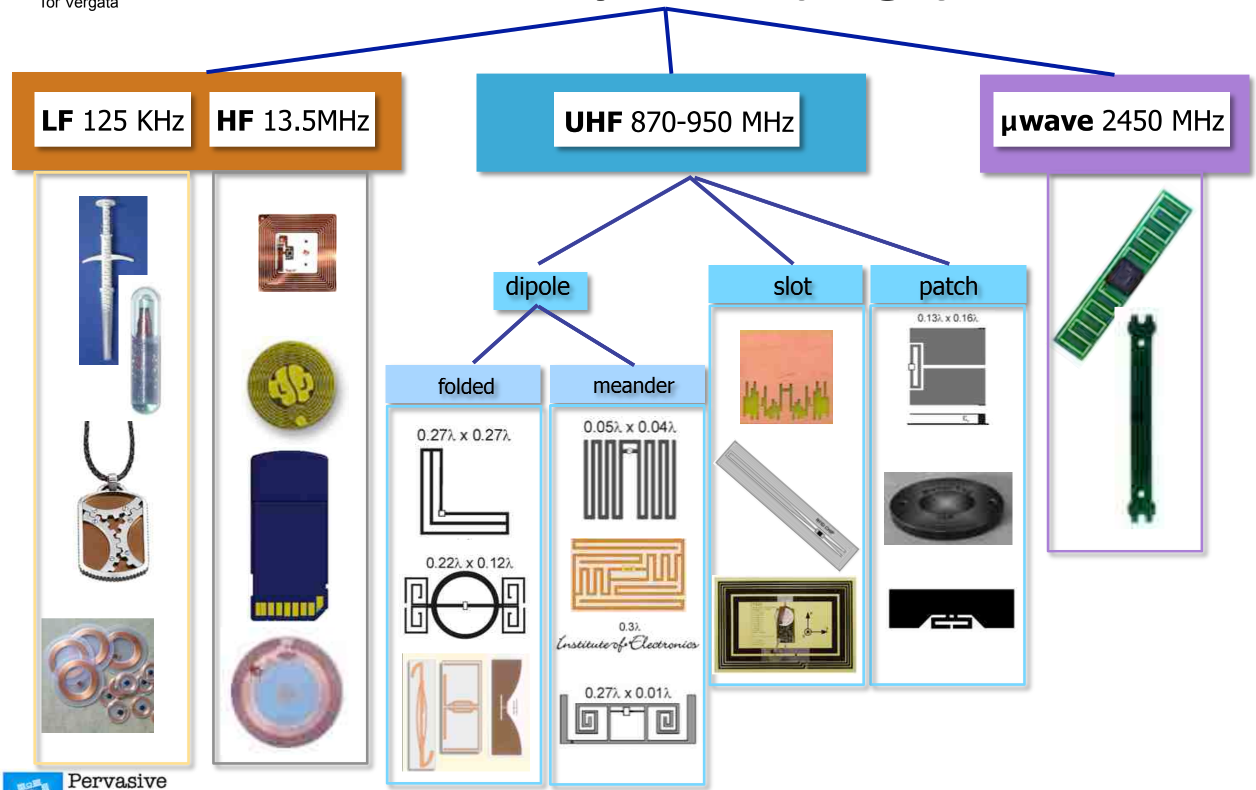
RFID Species (tags)



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UHF RFID readers

Hand-Held reader

Fixed reader

Embedded module

Bluetooth module

Smartphone dongles

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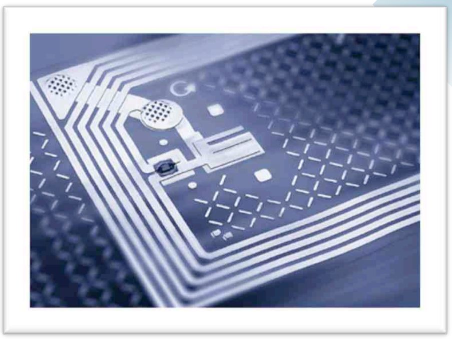
Sensing:

give a "state" to an object



Labeling:

give an ID to an object

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Sensing-Antenna Rationale

The electrical features of a passive RFID transponder placed on a target are closely dependent on the physical properties of the tagged object itself.

$$Z_{in}(\omega,\varepsilon,\mu) = \sqrt{\frac{\mu_r}{\varepsilon_r}} Z_{in}(\sqrt{\mu_r \varepsilon_r}\omega, \varepsilon_0, \mu_0)$$

G.A. Deschamps, 1962

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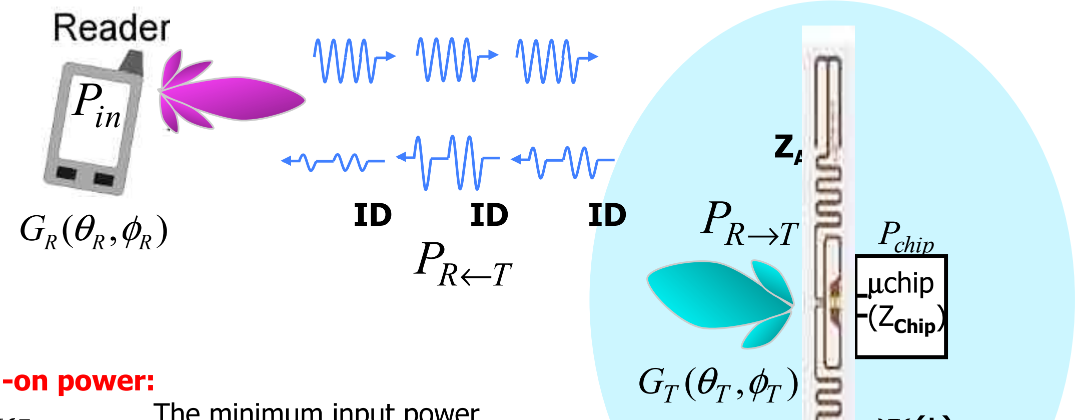
What the Reader may measure

- accessible data



Ψ(t)

1. Turn-on power:

$P_{in}^{to}[\Psi]$ The minimum input power through the reader's antenna, forcing the tag to respond

2. Backscattered power

$P_{R\leftarrow T}[\Psi]$ (RSSI - received signal strength indication)

Object's Feature
- Geometrical
- Chemical
- physical

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The RFID- Sensing Problem

$$P_{in}^{to}(\Psi, d, \theta_{R,T}, \phi_{R,T}, environment)$$
$$P_{R\leftarrow T}(\Psi, d, \theta_{R,T}, \phi_{R,T}, environment)$$

measurement **Reader-tag position**

?

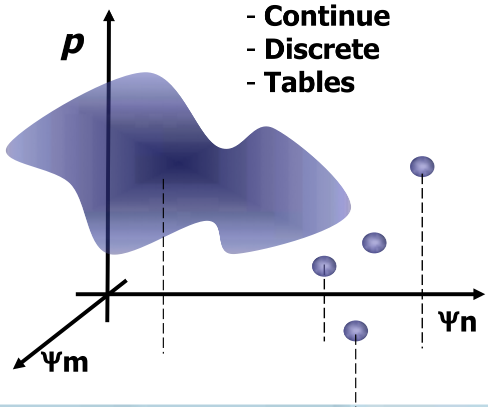
$$\Delta\Psi(t)$$

Unknown

Definition and Shaping of Data Inversion (Calibration) Curves

$$p(P_{R\leftarrow T}, P_{in}^{to}) \leftrightarrow \Psi$$

- **Multidimensional**
- **Continue**
- **Discrete**
- **Tables**



Technology
- Shape Memory Alloys
- Carbon Nanotubes
- Hygroscopic Polymer
- Textile & Elastic Substrates
- Inertial Switches

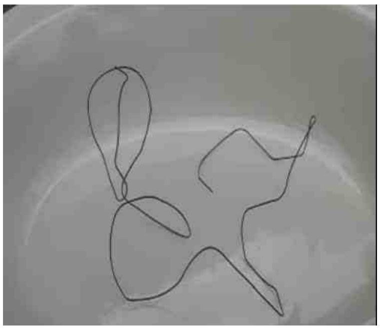
Environment & Things
- Humidity
- Temperature
- Ammonia
- Deformations
- Cracks

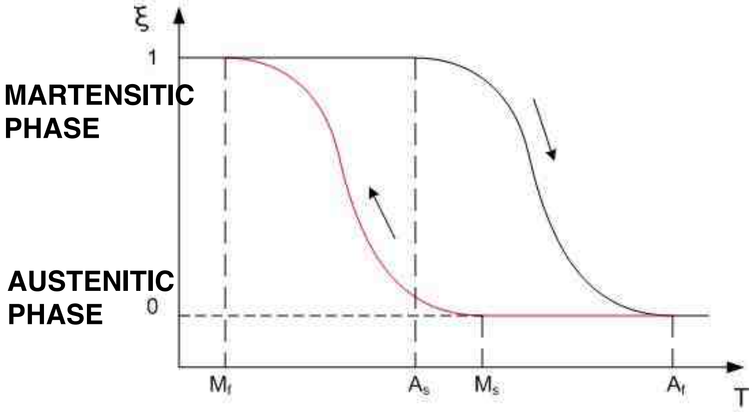
Wearable systems
- Motion
- Breath
- Neuropathologies
- Stress
- Edema
- Stenosis

Sensing Temperature

1. Temperature Thresholds
Shape Memory Alloy

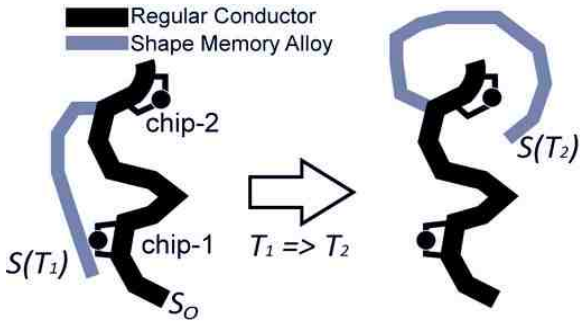
A Shape memory alloy is an alloy that "**remembers**" its original forged shape: after being deformed, it returns to that shape, if it is put in a hot environment





1. Temperature Thresholds
RF-Thermal device

*Antenna which senses the change of the object (or of the environment) through the variation of its **shape***



S_0: parameter-independent Shape

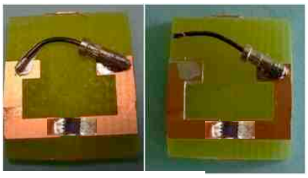
S(T): parameter-dependent Shape

S. Caizzone, C. Occhiuzzi, G. Marrocco, "**Temperature Sensing by Multi-Chip RFID Antenna Integrating Shape-Memory Alloys**", *IEEE Trans. Antennas. Propagat.*, 2011

1. Temperature Thresholds

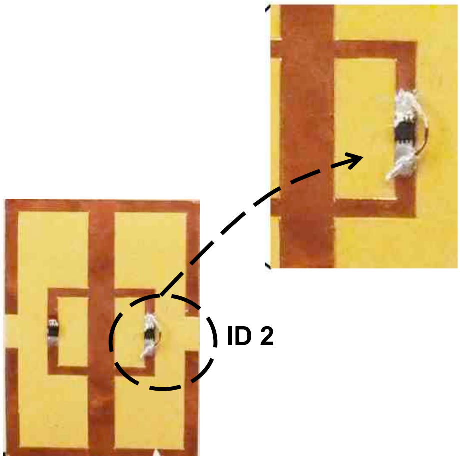
Temperature-controlled Modulation

Short c. **Open .c.**

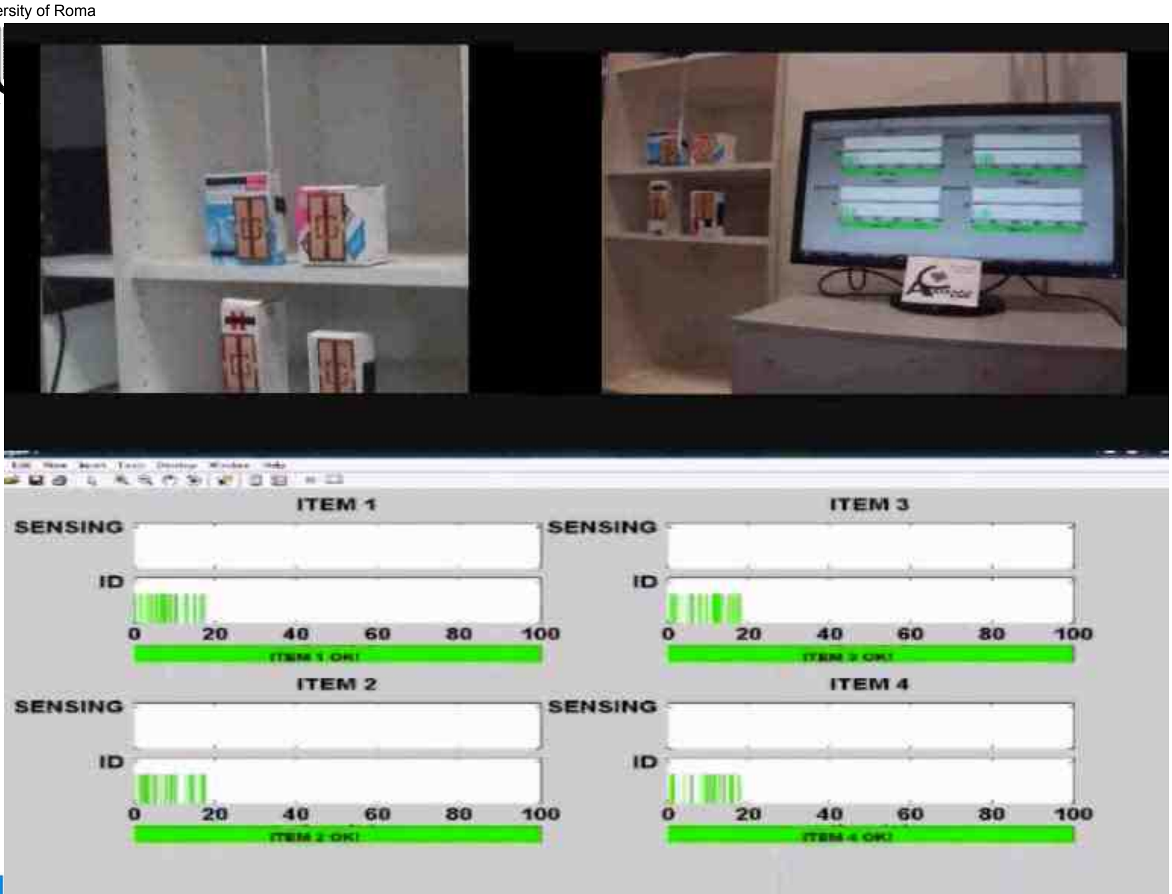


T<Ta → ID.1

T>Ta → ID.1 + ID.2

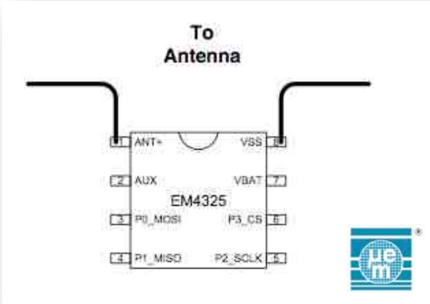


When T>Ta the sensor reacts changing **permanently** its state.



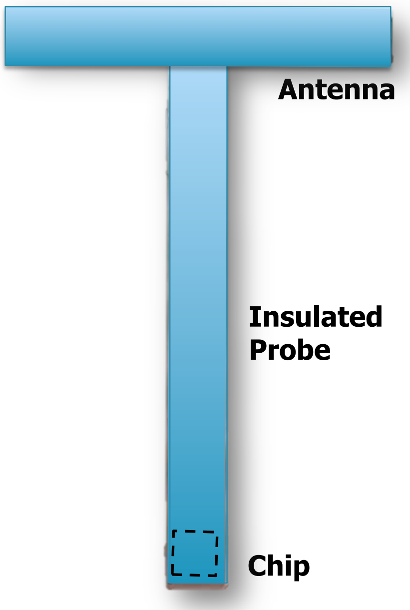
2. Absolute Temperature Logger

- On-chip **integrated** temperature measurement
- Reduced power sensitivity w.r.t. *conventional* microchips
- Price: €.1
- Battery-less and Battery-assisted mode (extended read-range)
- Temperature Range: -40°C - +85°C



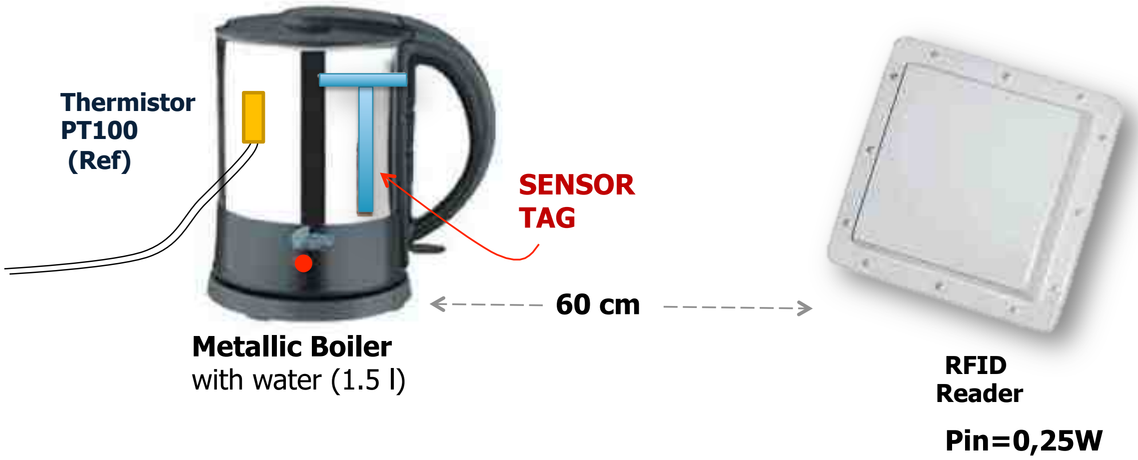
2. Absolute Temperature Logger

Example of implantable tag



2. Absolute Temperature Logger

Experiments



- The thermistor is directly attached over the boiler
- Sensor tag includes a Forex insulator

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2. Absolute Temperature Logger

Experiments

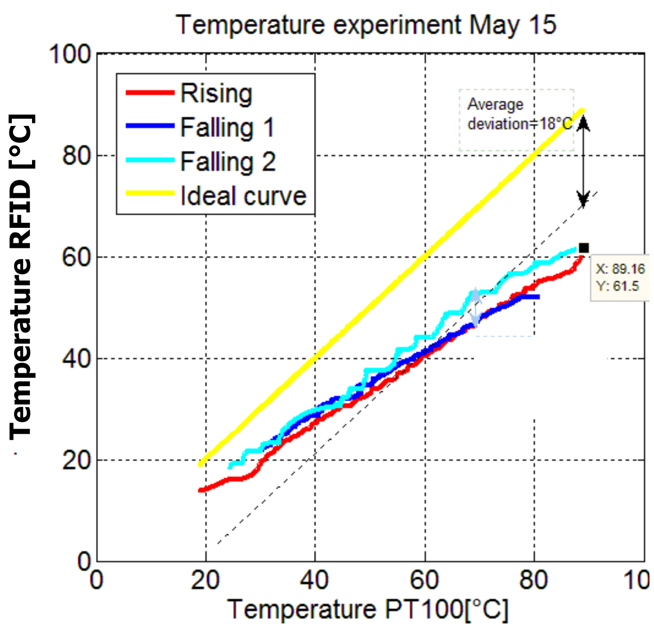
Range: [20 , 94]°C
FSO: [0, 64]°C
Resolution RFID: 0.36°C

Linear response

Stable response

Calibration is required because of the presence of the insulator

$$T=0.7T_{TAG}-0.2$$



2. Absolute Temperature Logger

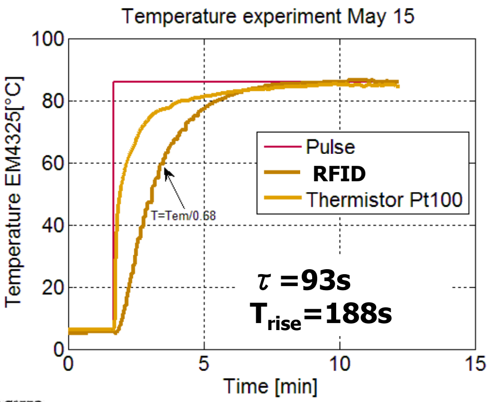
Step Response

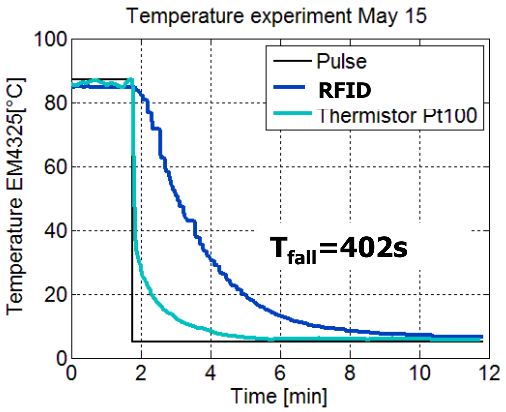
$t_0 < t < t_1$

RISE T

$t_1 < t < t_2$

FALL T

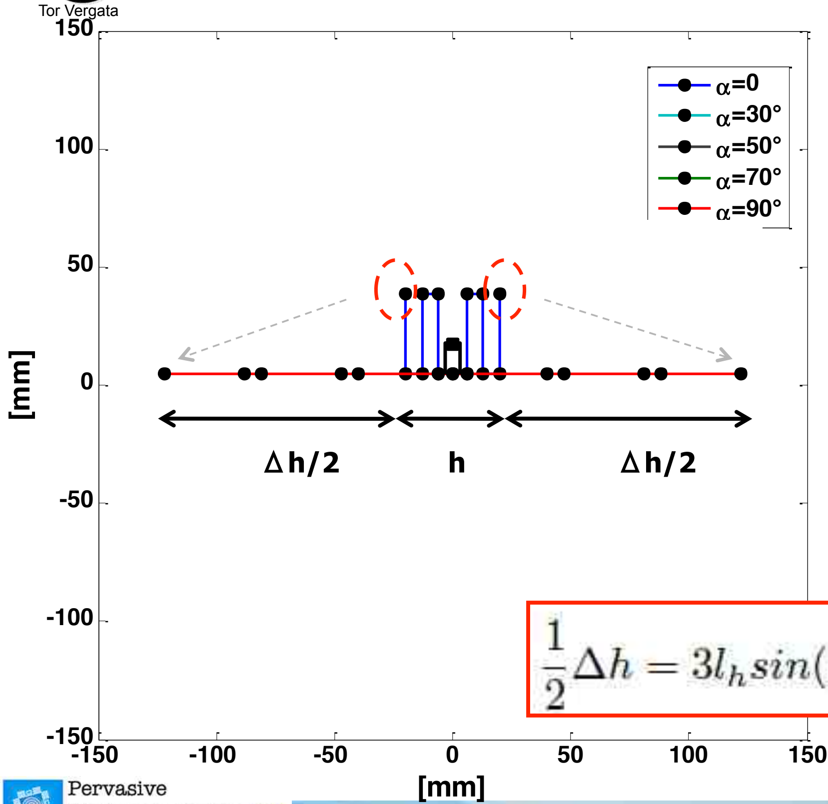




Sensing Deformations

1. RFID Strain-Gauge

Mechanical model



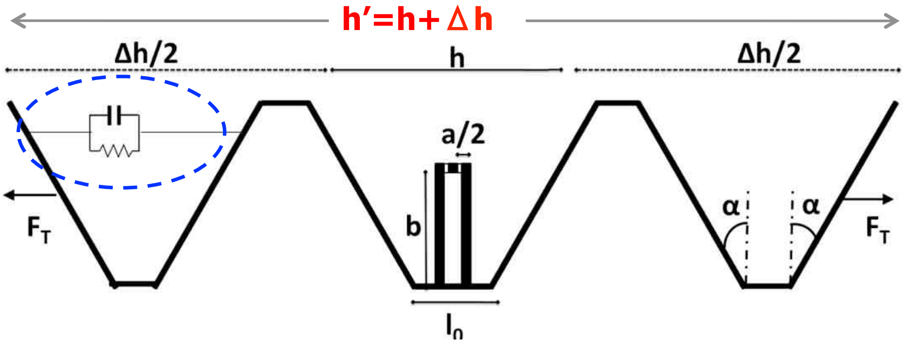
Hypothesis: inextensible wires (rigid structure)

- the external forces act only at the joints,
- rotation of the folding elements
- translation (horizontal and vertical) of the moving nodes of the structure

$$\frac{1}{2}\Delta h = 3l_h sin(\alpha) + 4r_s[1 - cos(\alpha)]$$

1. RFID Strain-Gauge

RF model



The antenna's **shape factor** changes as well as the **distributed loading**, and hence both the input impedance and the antenna gain will be accordingly modified.

Strain

ΔZin **ΔG**

C. Occhiuzzi, C. Paggi, G. Marrocco, "**Passive Strain-Sensor based on Meander-line Antennas**", *IEEE Trans. Antennas and Propagat. 2011*

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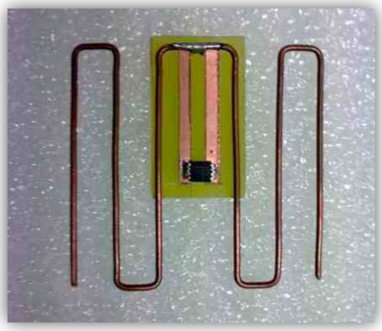
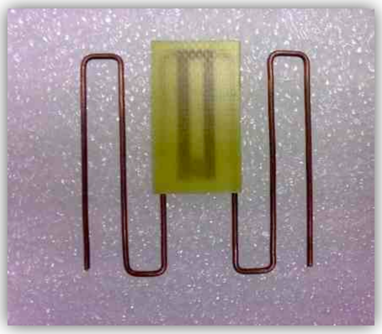
1. RFID Strain-Gauge

Prototype

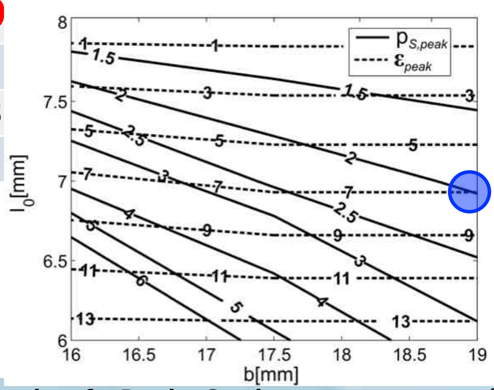




T-match section is printed over a 15x25x0.96 mm FR4 substrate

Parameter	Value [mm]
l_0	7
l_v	7
a	4
b	19
h	36
r_s	0.5
l_h	36

emphasize small deformations



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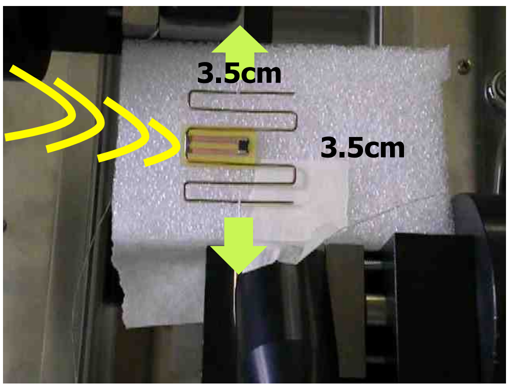
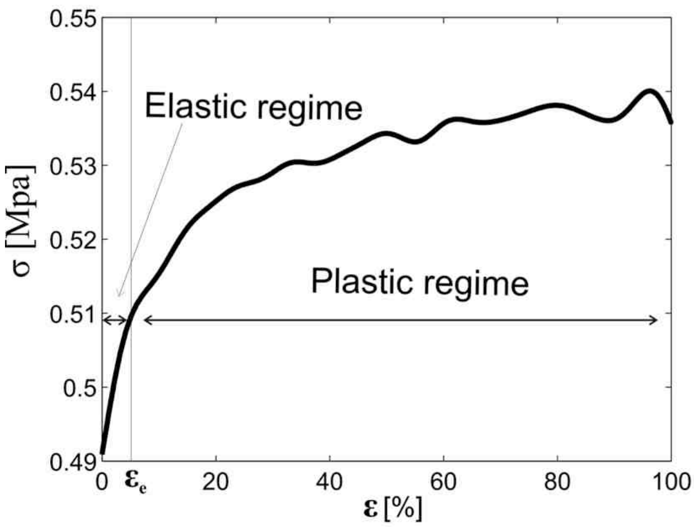
1. RFID Strain-Gauge

Experiments

Prototype subjected to controlled **0-3 Newton axial tractive** force for a period of 80s

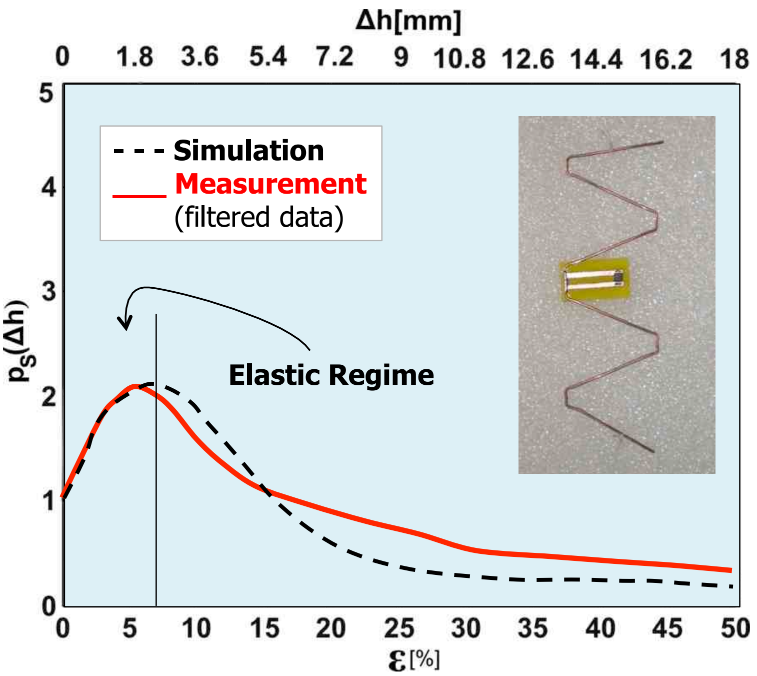




Strain

1. RFID Strain-Gauge

Measurements



ε_{max}=7% s=20%

Δp_s=10%

ε =0.7%
Δh=**250μm** @870MHz
Δh=85μm @2450MHz

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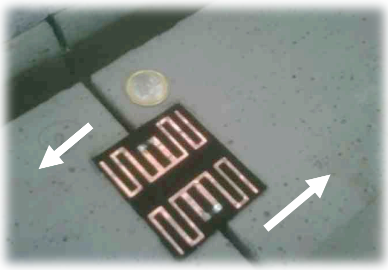
1. RFID Strain-Gauge

Stress over Pillar



Planar MLA over elastic substrate