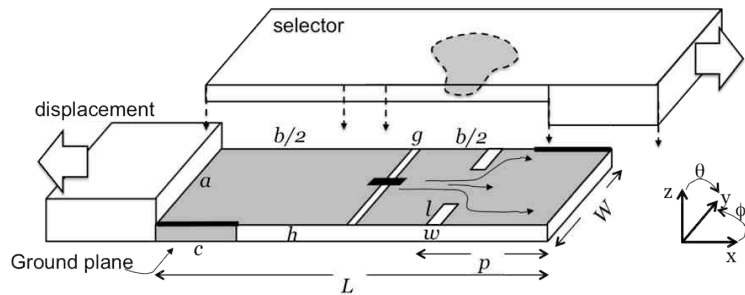


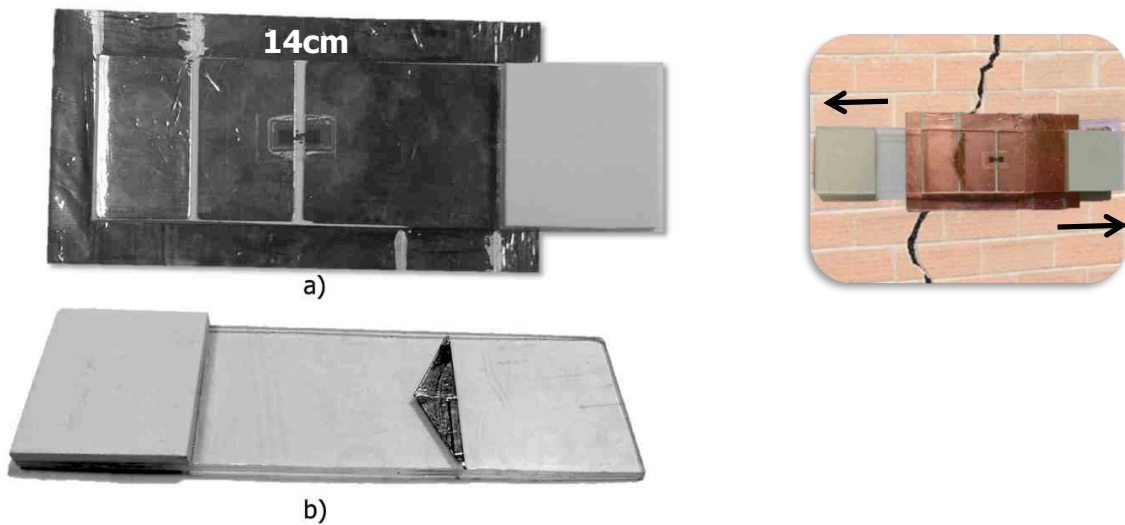
2. RFID Crack-Meter Model

The **mutual shift** of a metallic selector over a **slotted patch** antenna will produce a measurable change of the RF response, corresponding to local displacement

The **sensitivity** and resolution can be fully controlled by means of electromagnetic design

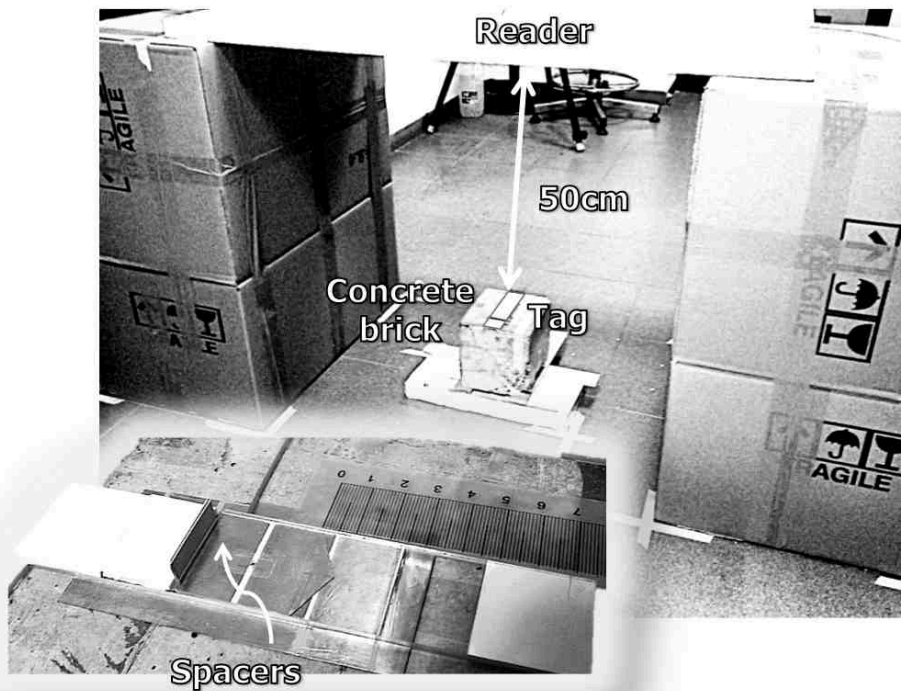


2. RFID Crack-Meter Prototype

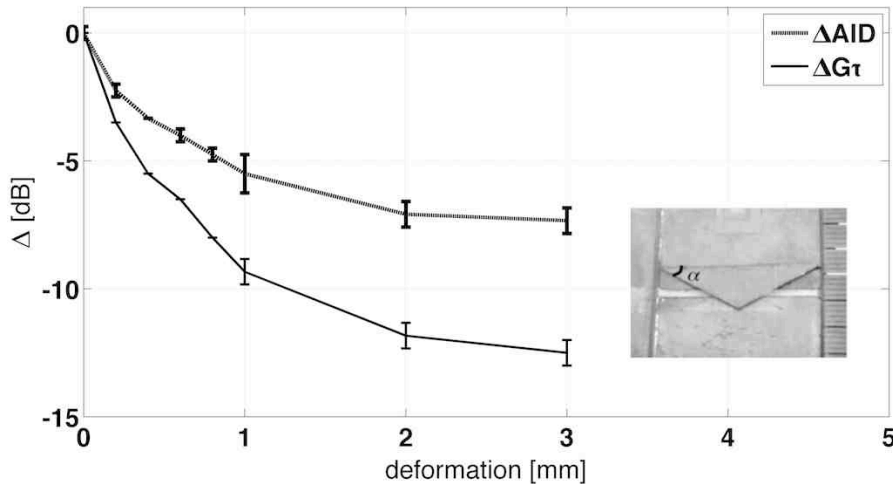


C. Paggi, G. Marrocco, C. Occhiuzzi, “Submillimeter Displacement sensing by passive UHF RFID Antennas”, Submitted IEEE TAP

2. RFID Crack-Meter Measurements



2. RFID Crack-Meter Measurements



Sensitivity:

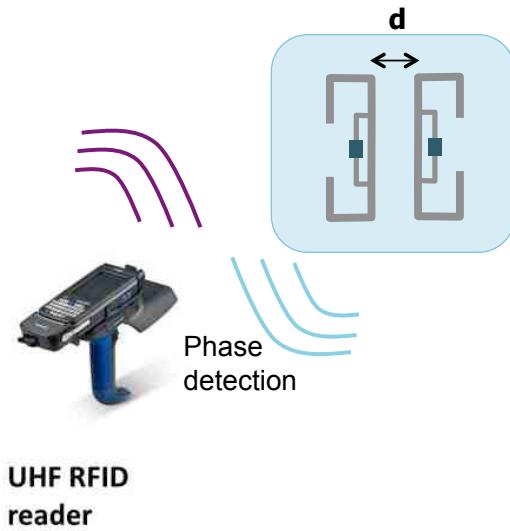
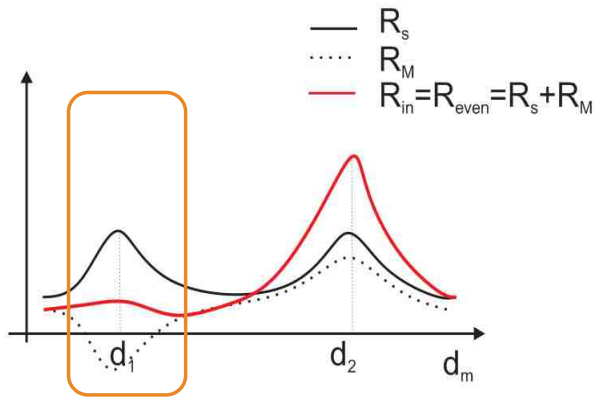
4dB/mm (hand-held reader)
9dB/mm (fixed-reader)

Resolution:

50-100μm (Low-cost COTS reader)
10-20μm (Dedicated COTS reader)

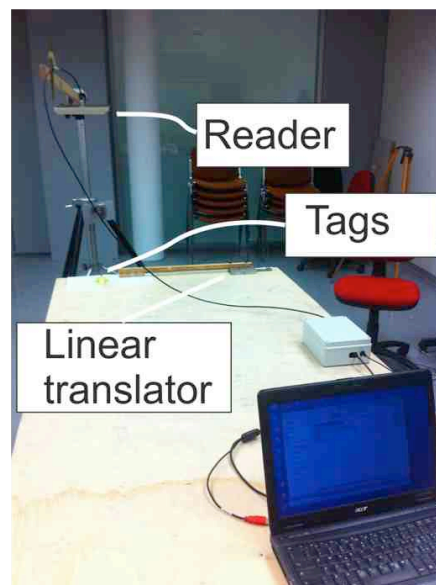
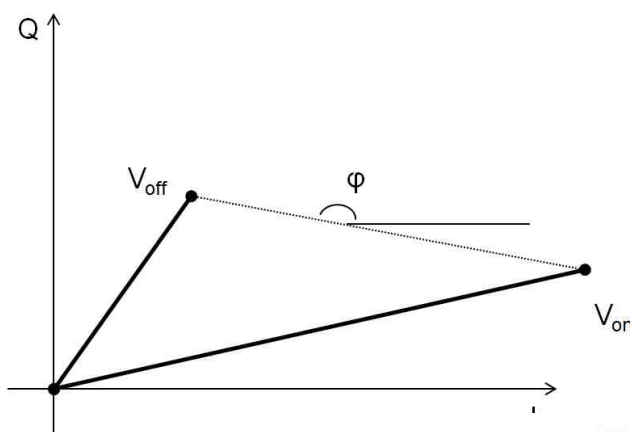
3. Displacement Sensors Phase sensing

Exploiting the change of mutual coupling between two facing RFID tags



S. Caizzone, G. Marrocco, E. Di Giampaolo, "A novel wireless crack sensor exploiting the phase signal of UHF RFID tags", Eucap 2013

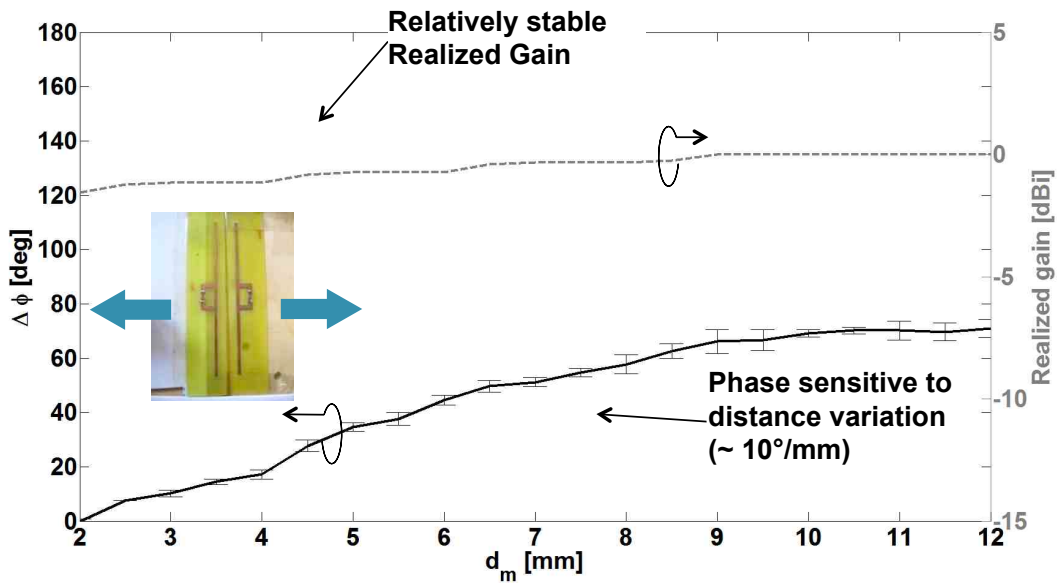
3. Displacement Sensors Phase measurement



$$\varphi_1 = \arg(V_1(OFF) - V_1(ON)) = \arg\left(\frac{1}{Z_S + Z_C}\right) + \varphi_0$$

3. Displacement Sensors

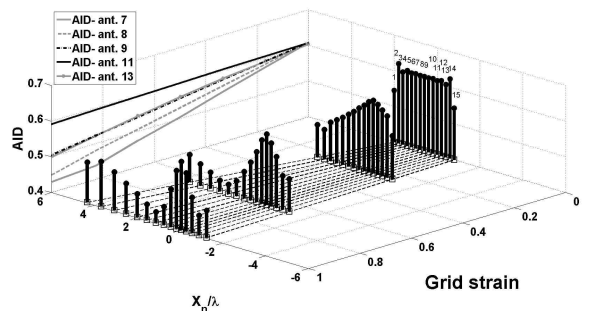
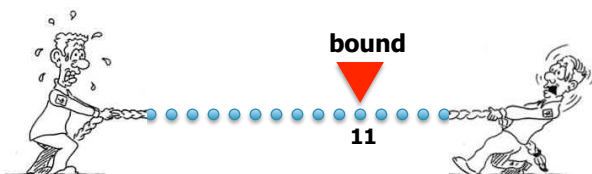
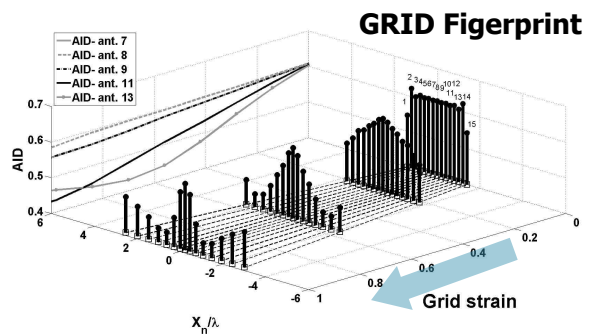
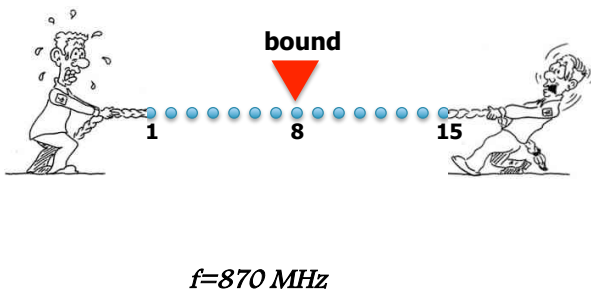
Phase measurement



Measured Sensitivity: 10deg/mm
Read-distance: nearly unaffected by change of mutual-distance

3. Displacement Sensors

Localizing deformations by RFID Grids

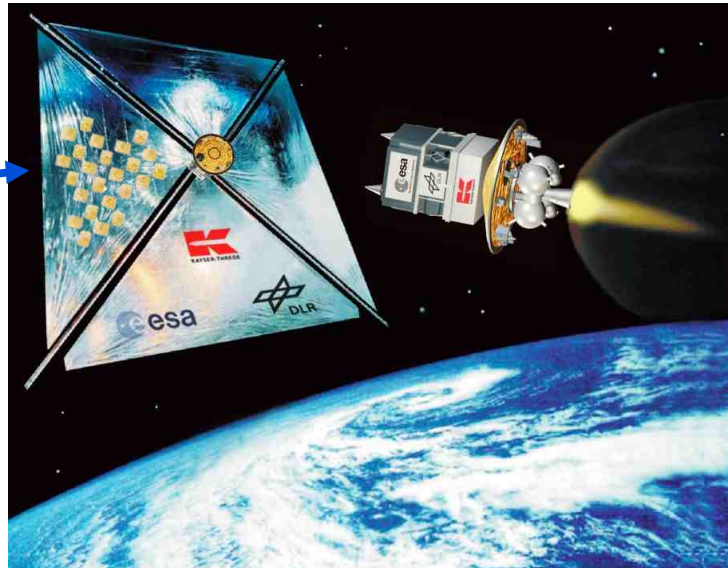
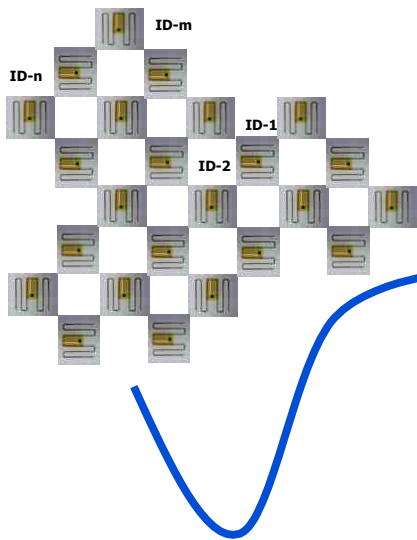


Possibility to recognize the position of a crack



3. Displacement Sensors

Localizing deformations by RFID Grids



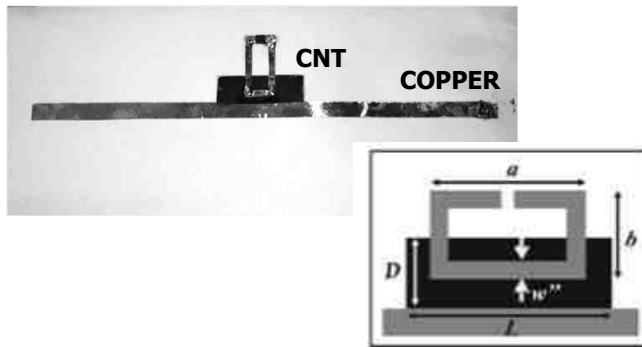
S. Caizzone, G. Marrocco, "RFID-Grids for deformation sensing", 2012 IEEE-RFID, Orlando



Sensing Chemical Species

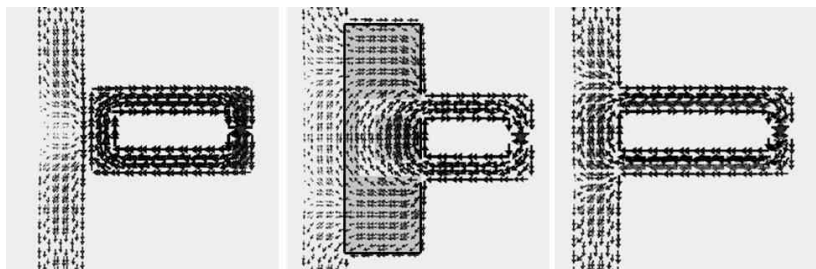
1. RFIDs & Carbon NanoTubes

Ammonia radio-sensor



CNT is a partially conductive material, whose conductivity decreases due to the ammonia absorption.

This **gas** plays as a reducing agent that **injects electrons to the nanotubes** (p-type) reducing the number of holes and hence the conductivity.



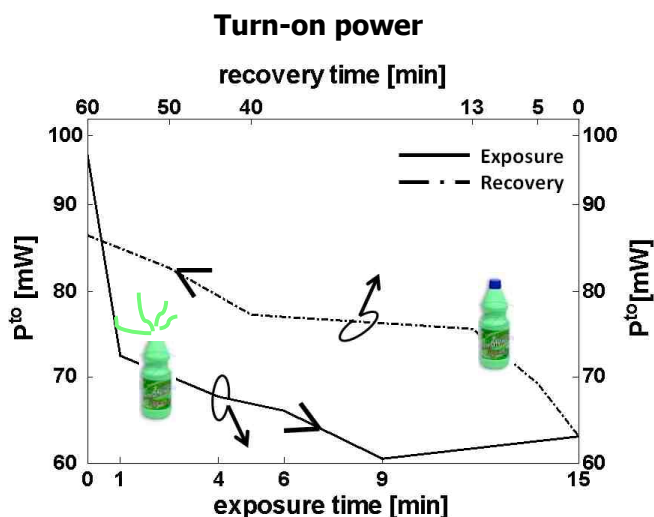
Loop-feed

CNT

T-match

1. RFIDs & Carbon NanoTubes

Ammonia Exposure

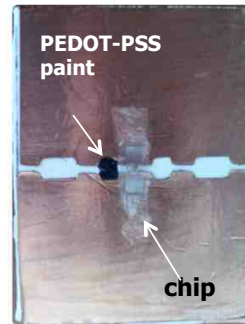
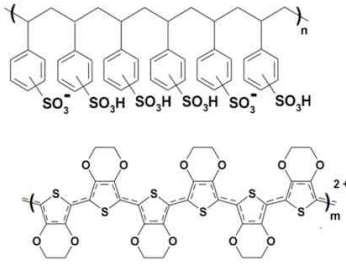


Gas-detection tags for food and environmental monitoring

C. Occhiuzzi, A. Rida, G. Marrocco, M. Tentzeris, "RFID Passive Gas Sensor Integrating Carbon Nanotubes", *IEEE Microwave Theory Tech*, 2011



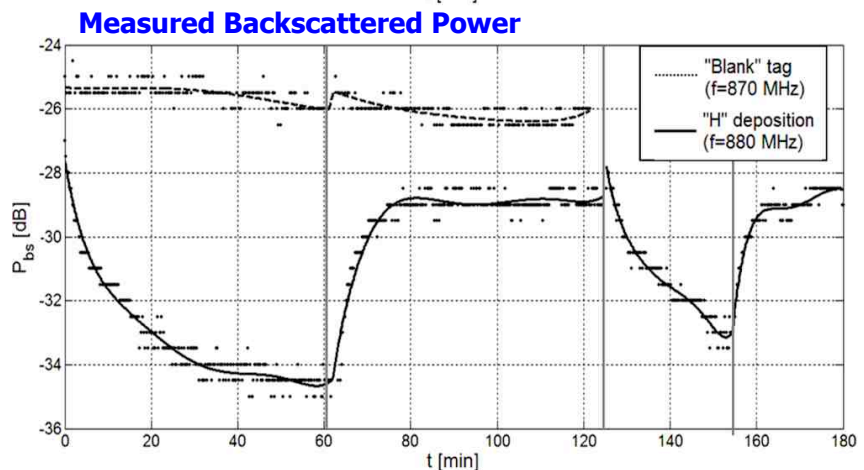
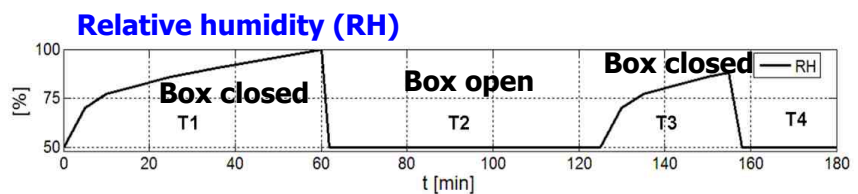
2. Conductive Polymer-doped tag Chemical Receptors for Humidity Sensing



poly(3,4-ethylenedioxythiophene):poly(styrene-sulfonic acid) – PEDOT:PSS

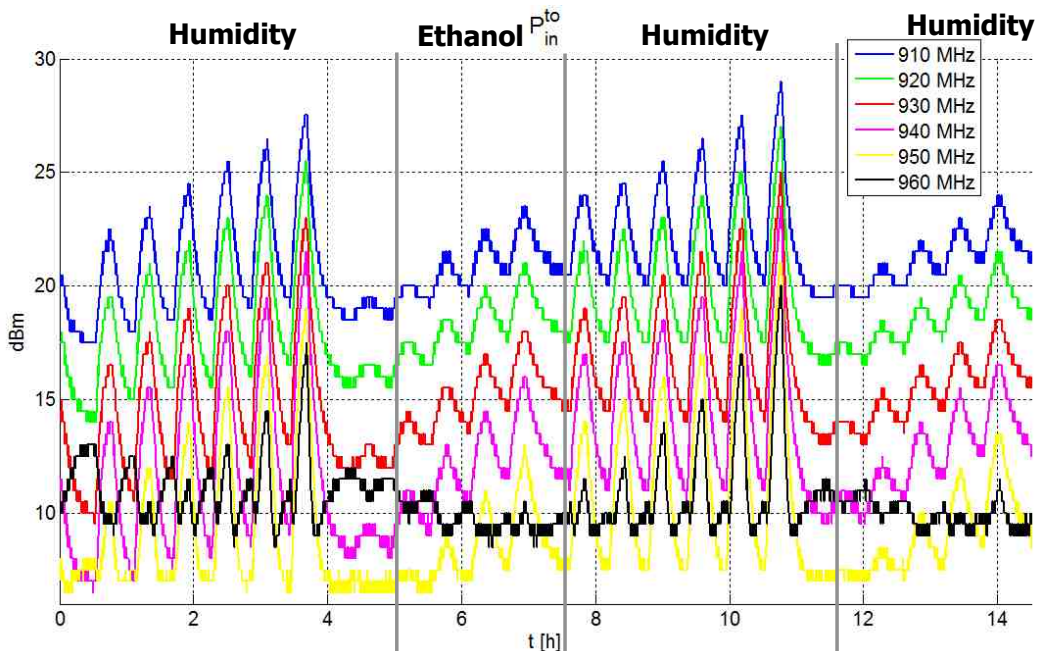
- **Hygroscopic polymer** dispersion which is used to paint the antennas' slots.
- Change of permittivity/conductivity along with vapor absorption
- Possibility of integration into plaster or **bandages to remotely monitor the healing grade of wounds**

2. Conductive Polymer-doped tag Exposure to H₂O vapor



2. Conductive Polymer-doped tag Humidity and Ethanol

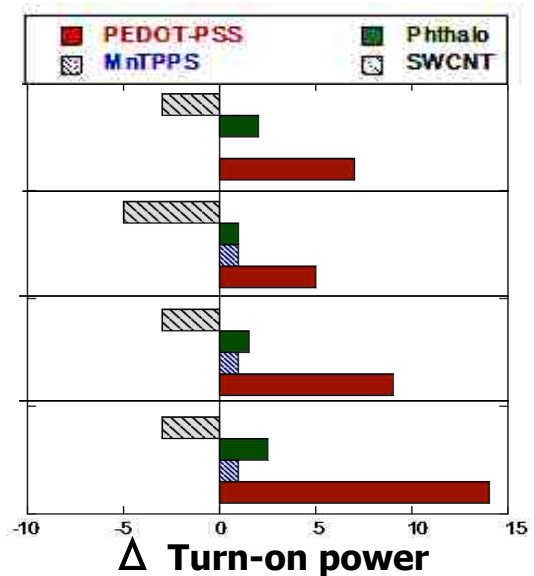
Humidity: 0%-50%-0%-60%-0%-70%-0%-80%-0%-90%-0%-100%
Ethanol: 0%-10%-0%-20%-0%-30%-0%-40%-0%-50%-0%



3. RFID Matrix for Moistures Chemical Lab on tag



Vinegar
Ammonia
Ethanol
Water

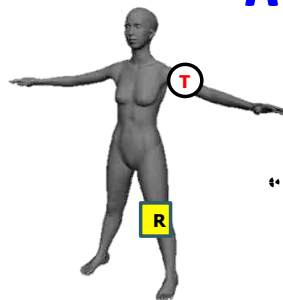


Response Selectivity

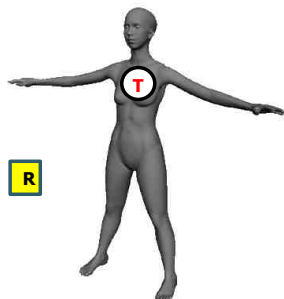
- Pedot:pss
- Single Wall Carbon Nanotubes
- Manganese-Tetraphenylporphyrin
- Phtalocyanine

Sensing Human Behavior

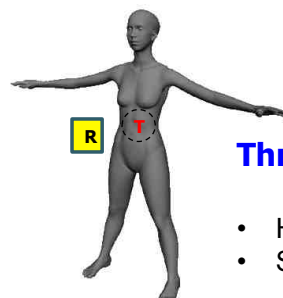
RFID-Bodycentric Systems



- On-Body link:** The reader's antenna over the body
- Activity and shadowing effect
 - Exposure limit

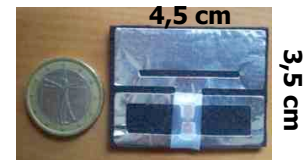
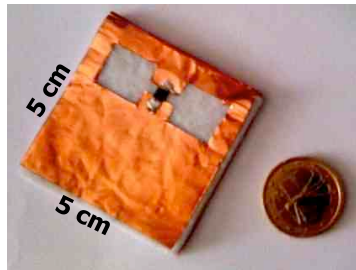
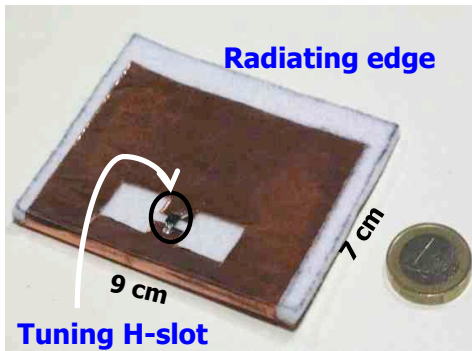


- Off-Body link:** The reader placed far from the body
- Reading range in real scenario
 - Environmental influence
 - Position



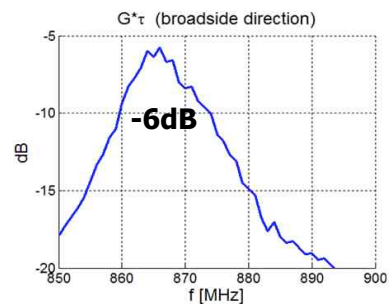
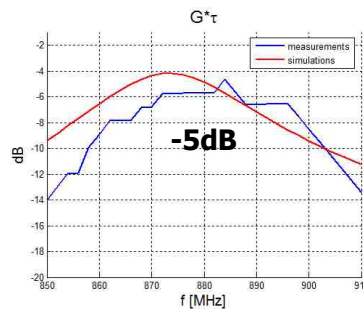
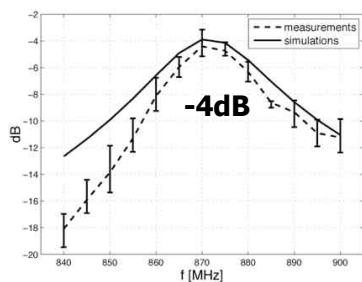
- Through-the-Body link:** The tag is implanted
- High loss
 - Small read ranges

Wearable textile RFID Tags



Felt substrate

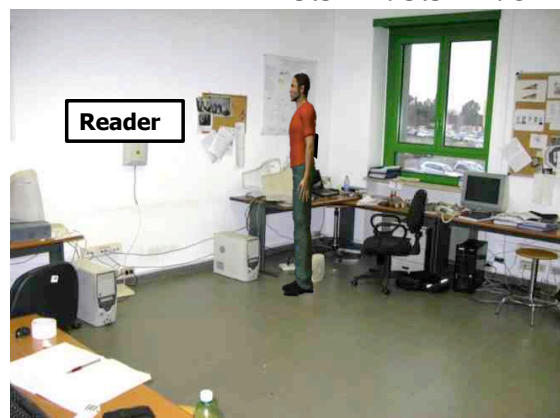
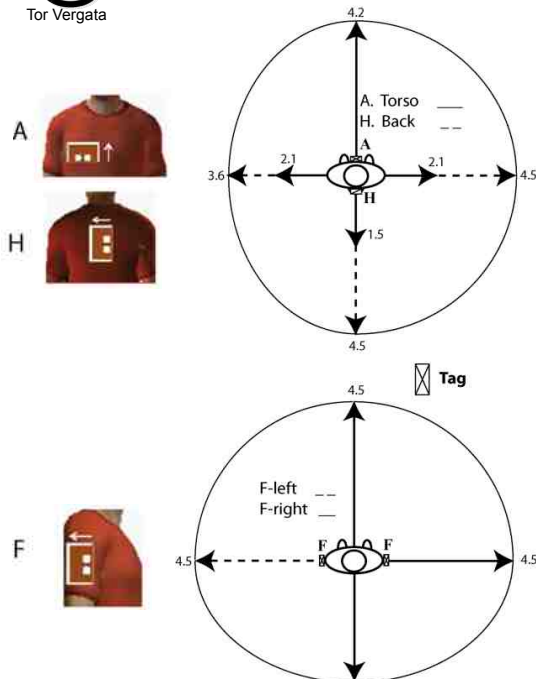
EPDM (Ethylene-Propylene Diene Monomer)



Observation: Normal incidence

Off-body RFID link - Real scenario

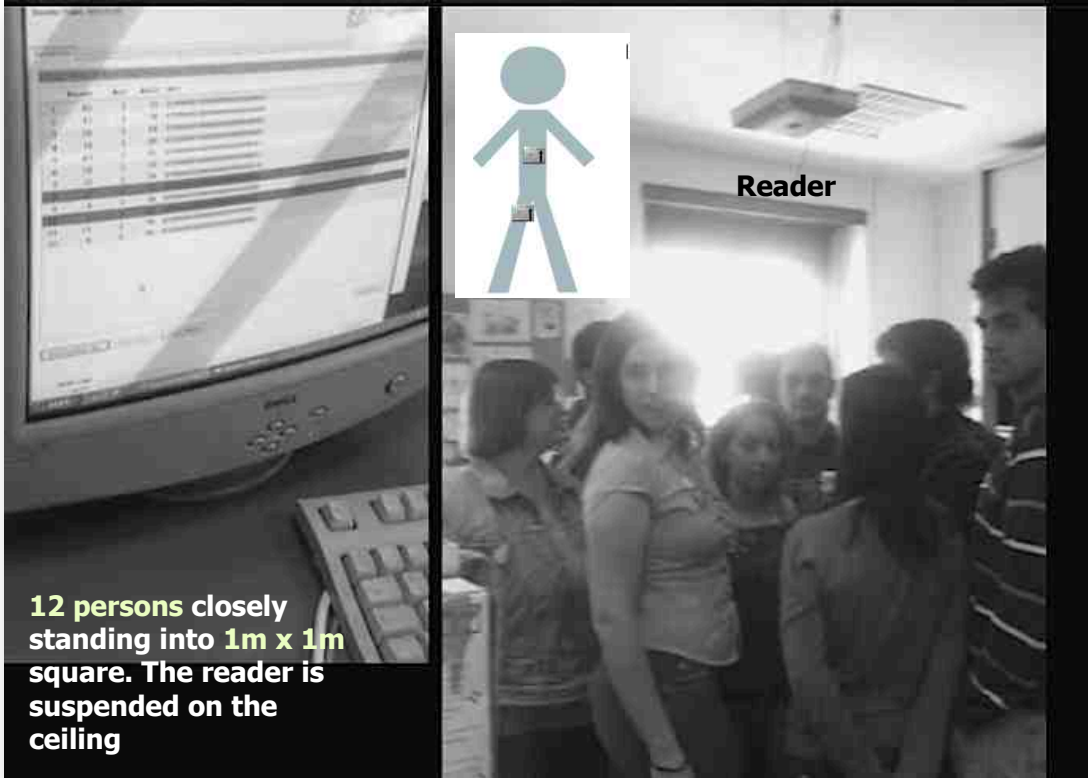
5.5m x 5.5m x 3m



- Two tags properly placed enable a robust monitoring in a 4x3 m room
- **Chip Sensitivity -15dBm**
- No shadowing effects during normal activity

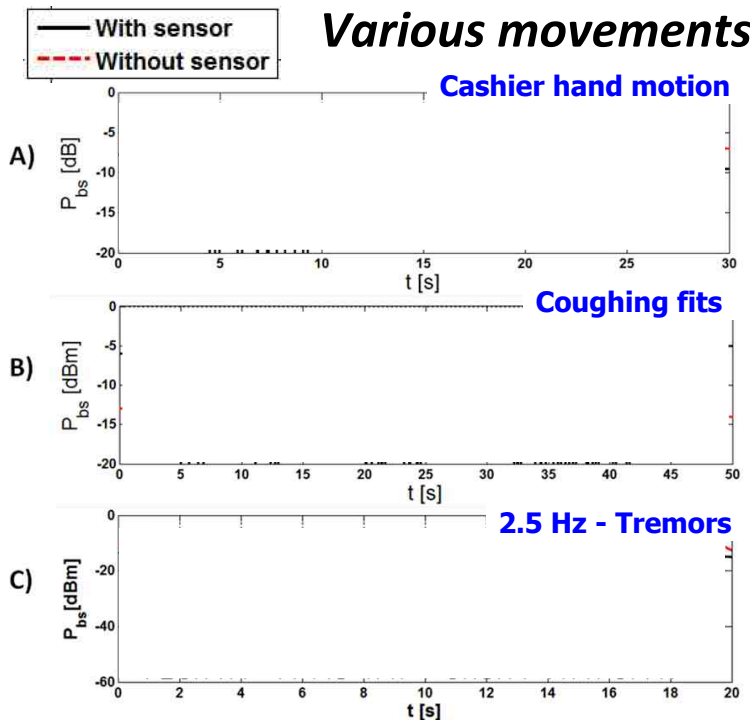
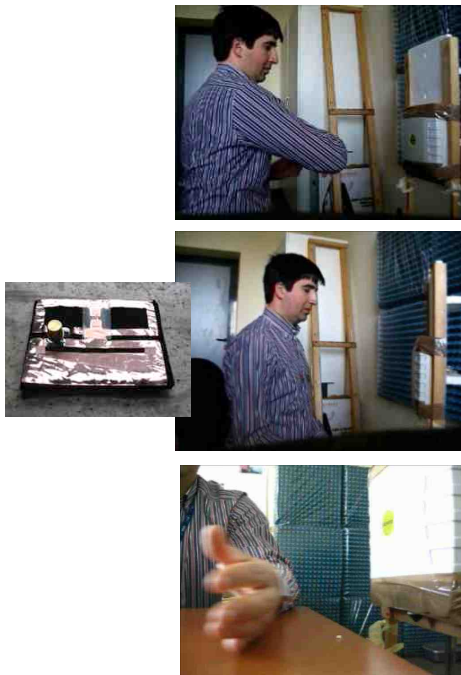
S. Manzari, C. Occhiuzzi, G. Marrocco, "Feasibility of Bodycentric Passive RFID Systems by Using Textile Tags" to appear on IEEE Antennas Propagat. Magazine Aug. 2012

On-body RFID link

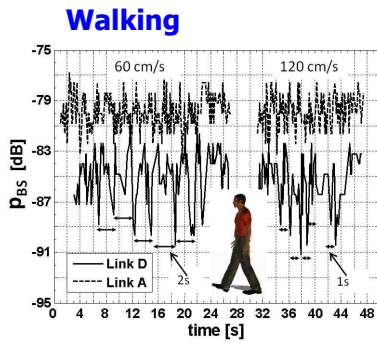
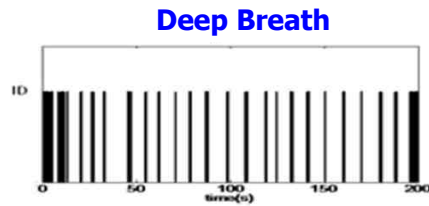


Omni-directional Motion Sensing

Various movements



Detection and classification of body motion



**Application of
Machine Learning
algorithms**

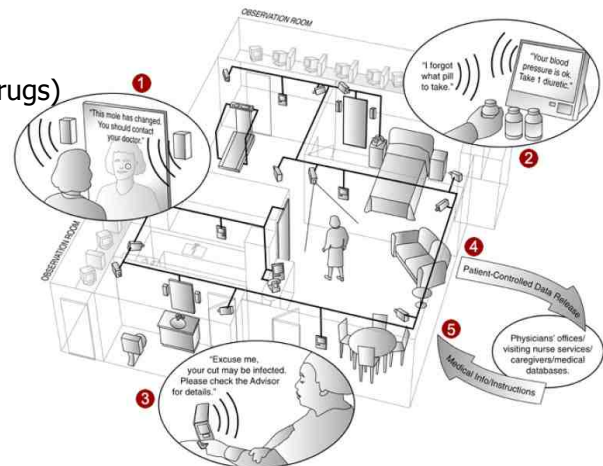
Automatic classification of motor sequences



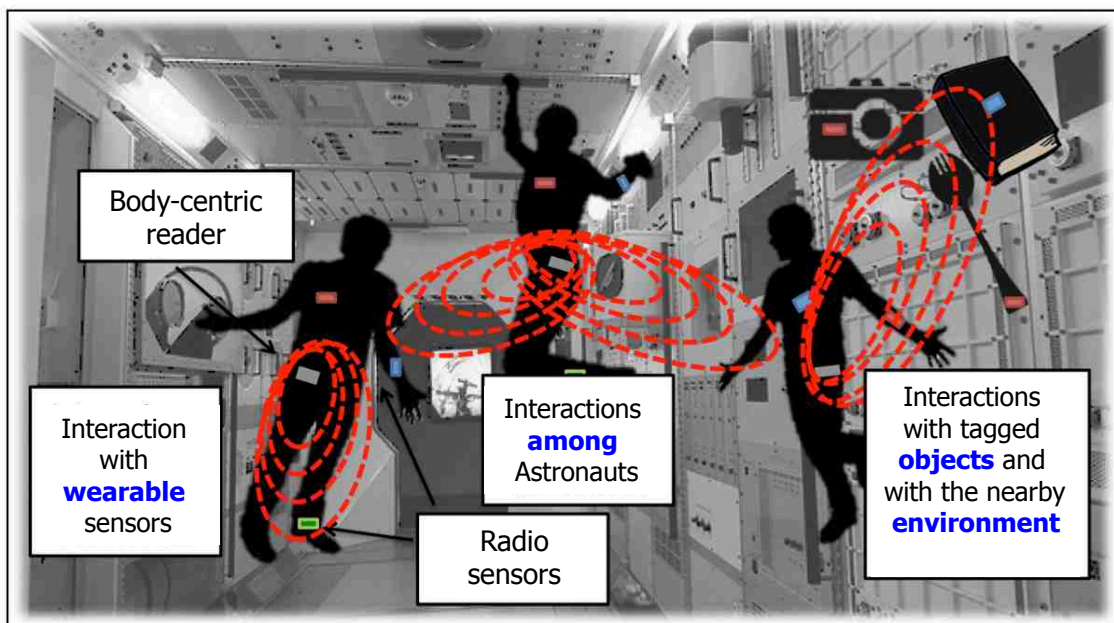
Some Possible Applications

1. Pervasive Healthcare

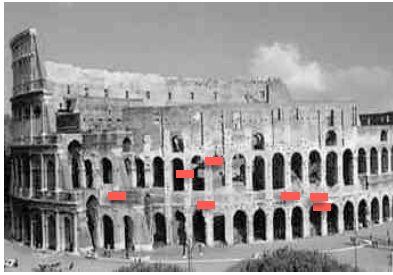
- Ambient Intelligence systems**
- Body sensors**
- motion
 - ECG
 - Evolution of pathologies
- Smart Objects**
- Localization
 - Quality (food, drugs)
- Smart House**
- temperature
 - Gas
 - Structural safety
 - localization systems



2. Human relationship in Extreme Spaces

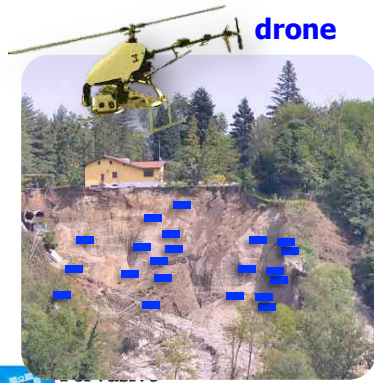


3. Structural Health Monitoring

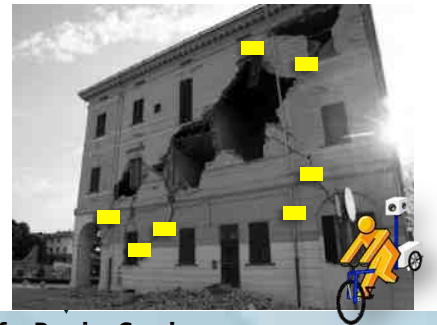


Passive systems to monitor crack, humidity and temperature in concrete walls, pillars and any other structure that need a continuous, distributed and low-cost monitoring of its "health".

- HISTORICAL BUILDINGS
- CIVIL HOUSES
- POST DISASTER ASSESSMENT
- GEOLOGIC INSTABILITY
- CONSTRUCTION MONITORING



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Università di Roma Tor Vergata

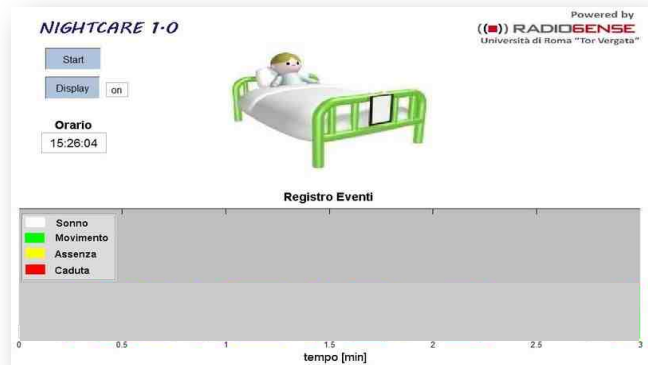


Gaetano Marrocco – **RFID Technology for Passive Sensing**

An Example of RFID Sensing System

NightCare System

Ambient Intelligence system able to monitor the parameters of sleep quality and to identify anomalous events and **prompt for remote or local assistance**



The system analyzes the interactions of the person with the surrounding environment (bed, carpets, ..) by using our wearable Tags

→ [Video](#)

Many thanks !!

Gaetano Marrocco
marrocco@disp.uniroma2.it



Pervasive
Electromagnetics Lab
Università di Roma Tor Vergata

http://dl.dropbox.com/u/4358070/alab_web/Alab_people_marrocco.htm

- S. Manzari, C. Occhiuzzi, G. Marrocco, « **Feasibility of Body-centric Systems by Using passive textile RFID tags** », *IEEE Antennas and Propagation Magazine*, Vol.54, N.9, pp 2851-2858, 2012
- S. Manzari, C. Occhiuzzi, S. Nawale, A. Catini, C. Di Natale, and G. Marrocco, "**Humidity Sensing by Polymer-loaded UHF RFID Antennas**", *IEEE Sensors Journal*, Vol.12, N.9, pp. 2851-2858, 2012
- G. Marrocco, S. Caizzone, "**Electromagnetic Models for Passive Tag to Tag Communications**", *IEEE Trans. Antennas and Propagat.* Vol.60, N.11, pp. 5381-5389, 2012
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- C. Occhiuzzi, A. Rida, G. Marrocco, M. Tentzeris, "**RFID Passive Gas Sensor Integrating Carbon Nanotubes**", *IEEE Microwave Theory Tech.* , Vol.59, N.10 part 2,, pp. 2674-2684, 2011
- S. Caizzone, G. Marrocco, "**RFID Grids: Part II - Experimentations**", *IEEE Trans. Antennas and Propagat.* Vol. 59, N.8, pp. 2896-2904, Aug. 2011
- S. Caizzone, C. Occhiuzzi, G. Marrocco, "**Multi-chip RFID Antenna Integrating Shape Memory Alloys for Detection of Thermal Thresholds**", *IEEE Trans. Antennas and Propagat.* Vol.59, N.7, pp. 2488-2494, Jul, 2011
- G. Marrocco, "**Pervasive Electromagnetics: sensing paradigms by passive RFID Technology**", *IEEE Wireless Communications*, Invited Paper, Vol.17, N.6, pp.10-17, Dec. 2010, 2010
- E. Di Giampaolo, F. Forni, G. Marrocco, "**RFID-Network Planning by Particle Swarm Optimization**", *Aces Journal*, Vol.25, N.3, pp. 263-272, March 2010
- C. Occhiuzzi, G. Marrocco, "**The RFID Technology for Neuroscience: feasibility of Limbs' Monitoring in Sleep Diseases**". *IEEE Trans. Information Technology in Biomedicine*, Vol.14, N.1, pp. 37-43, Jan. 2010.
- G. Marrocco, "**The Art of UHF RFID Antenna Design: Impedance Matching and Size-reduction Techniques**", *IEEE Antennas and Propagation Magazine*, Vol.50, N.1, pp.66-79, Feb. 2008.