



The 11th IEEE International Conference
IEEE RFID-TA 2021
October 6-8, 2021, Delhi, India



SECOND SKIN Project: BioIntegrated Wireless Sensors for the Epidermal Monitoring and Restoring of Sensorial Injuries

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Credits

17 researchers
2 local companies



Prof. Gaetano Marrocco
(Principal investigator)



Prof. Pier Paolo Valentini



Prof. Alberto Bergamini



Carolina Miozzi



Sara Amendola



Cecilia Occhiuzzi



Francesco Amato



Simone Nappi



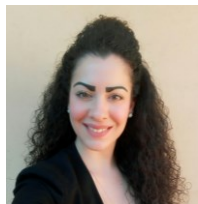
Giulio M. Bianco



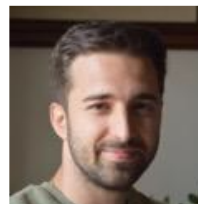
Francesca Camera



Nicola D'uva



Nicoletta Panunzio



Gabriele Diotallevi



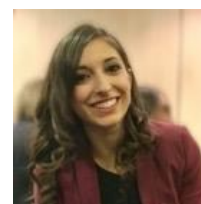
Luca Gargale



Sara Parrella



Cecilia Vivarelli



Giorgia Stendardo





2 years

July 2018 – August 2020

<http://pervasive.ing.uniroma2.it/secondskin.htm>

Outline

Main Technological Innovations And Research Outcomes

- Idea and Goals
- Before SECOND SKIN
- **SECOND SKIN Outcomes**
- Beyond SECOND SKIN:
Multiparametric monitoring
of the human body

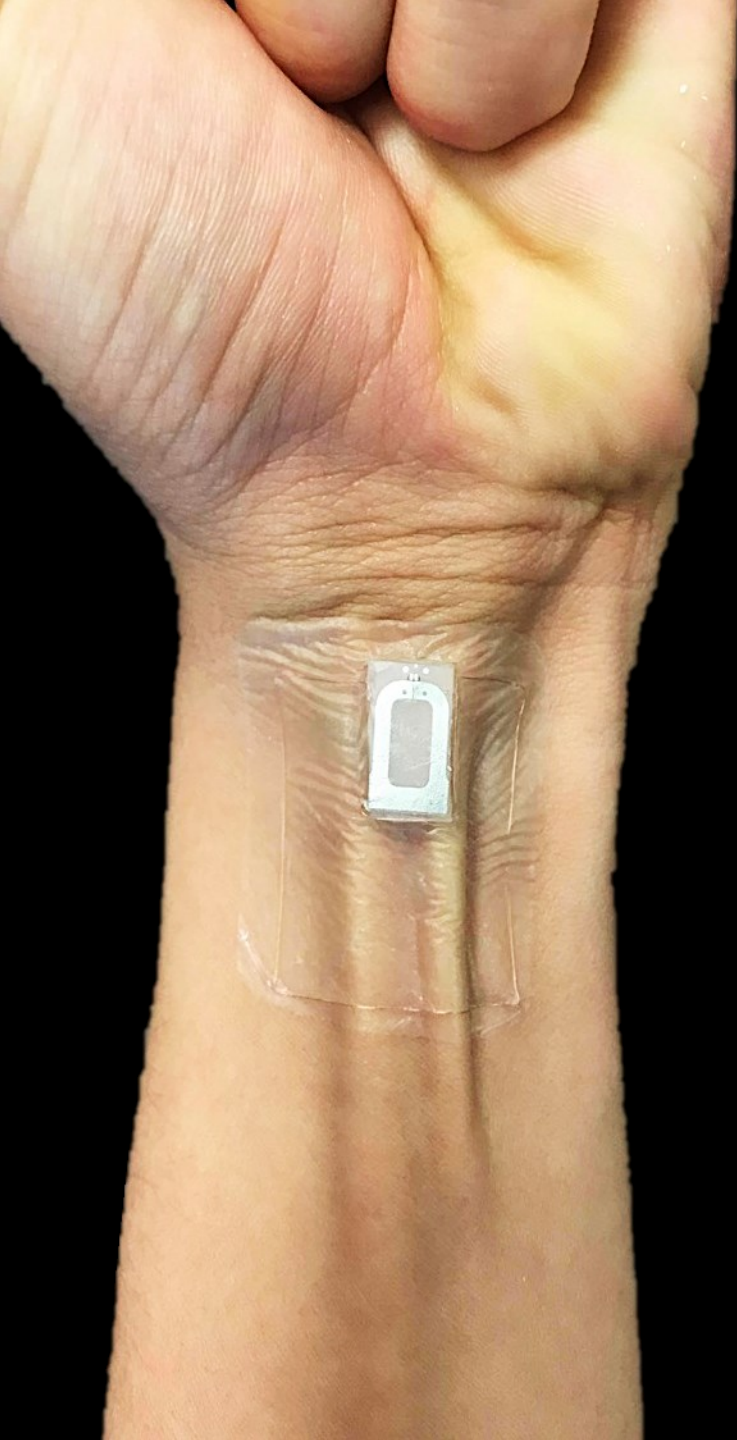
SECOND SKIN

Idea

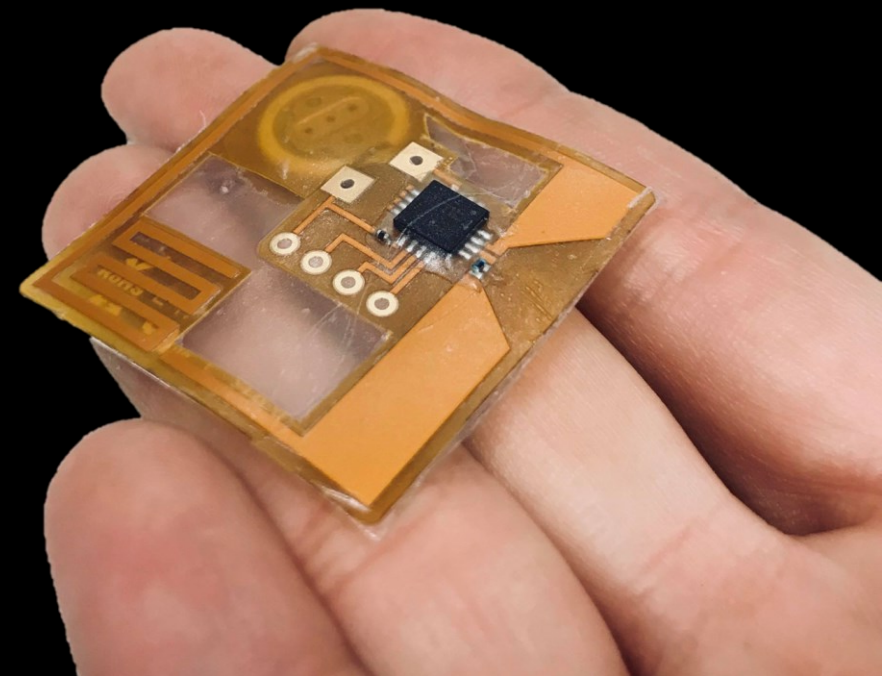
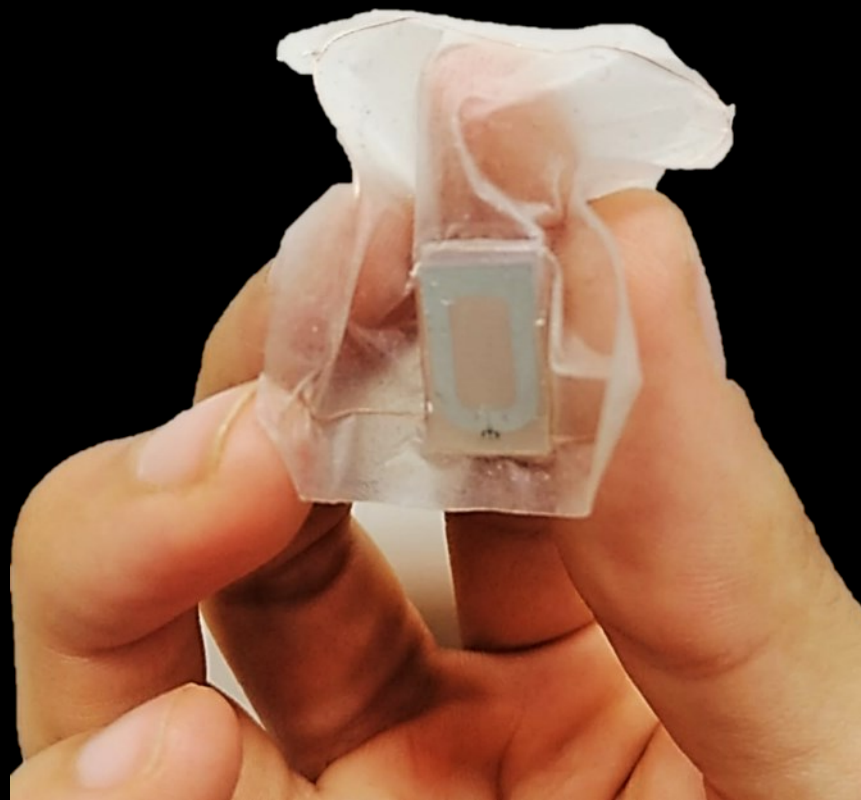


SECOND SKIN Technology

UHF RFID Epidermal Electronics

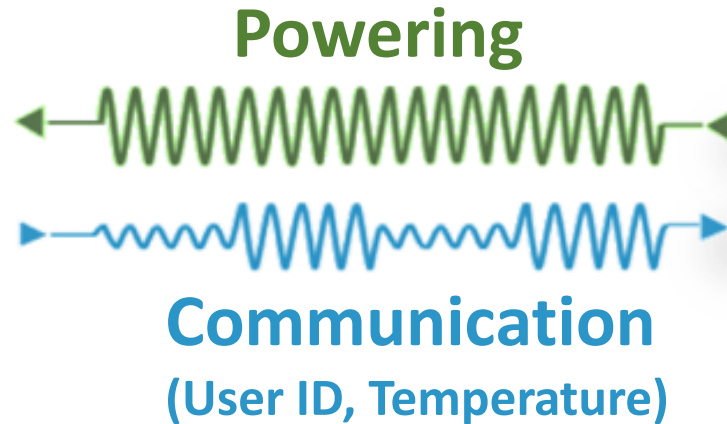


- Temperature
- Breath anomalies
- Electrophysiology
- pH
- Sweat



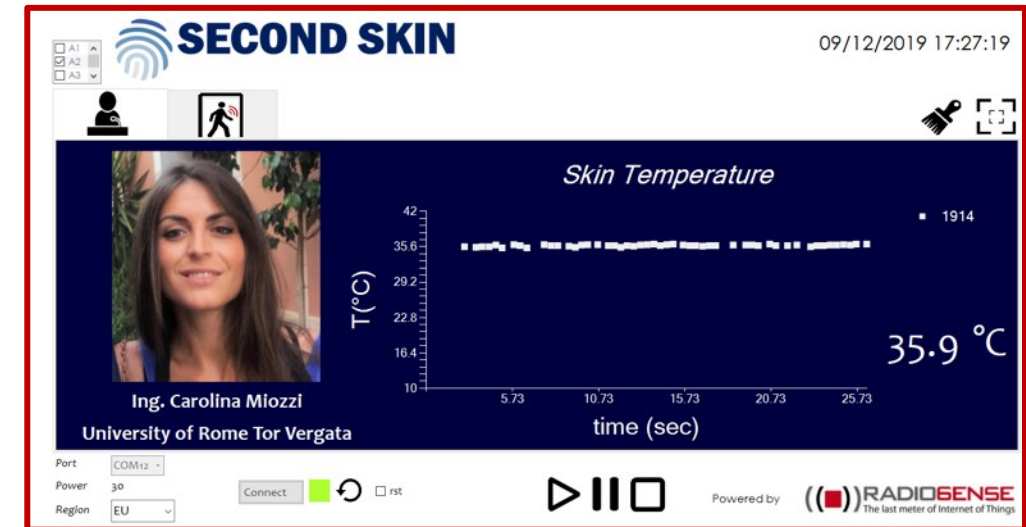
SECOND SKIN Platform

Wireless
epidermal sensor



RFID backscattering communication

- Battery-less
- Remote reading (up to 1 m)
- Low cost
- Unique identification of the user + temperature data detection



Data processing and real-time visualization
interface



Before SECOND SKIN

and Goals



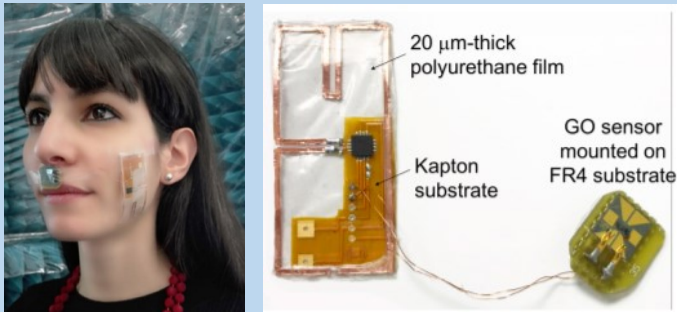
On-the-Body (on-skin) RF Communication

- Skin temperature measurements



Amendola 2016
10.1109/JSEN.2016.2594582

- Breath monitoring



Caccami 2018
10.1109/JSEN.2018.2867208

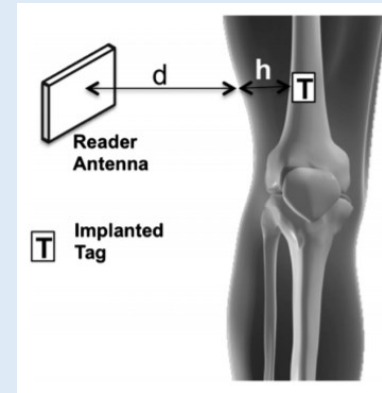
- Regeneration of sensory functionalities



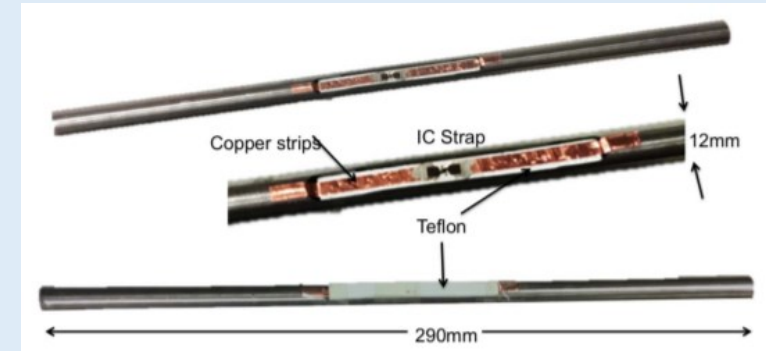
Di Cecco 2017
10.1109/RFID.2017.7945587

Background Know-How

Through-the-Body RF Communication



Lodato 2014
10.1109/TAP.2014.2345586



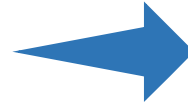
Lodato 2016
10.1109/JSEN.2015.2503887

RFID technology feasible
on skin and inside the body !

Before SECOND SKIN

Open Challenges

- New materials
- New fabrication techniques
- Immunity to human body variability
- Reproducibility of the data collected
- Expand the monitored physiological parameters



SECOND SKIN

Goals

- Variety of epidermal antennas, robust w.r.t. individual variability
- Eco-friendly and low-cost designing and manufacturing techniques
- Algorithms for real-time data conditioning and processing



SECOND SKIN

Research Outcomes



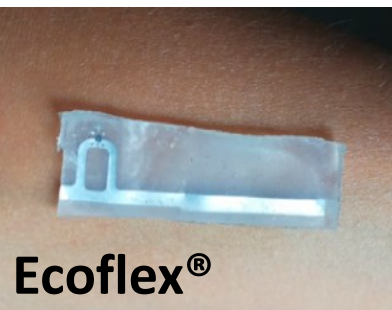
SECOND SKIN Epidermal RFID Sensors

Materials & Manufacturing

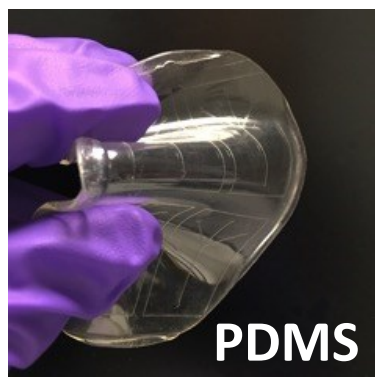
New Biocompatible Materials



Tegaderm®



Ecoflex®



PDMS



Silbione

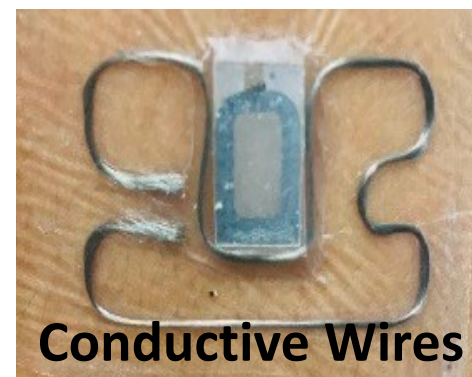
New Fabrication Techniques



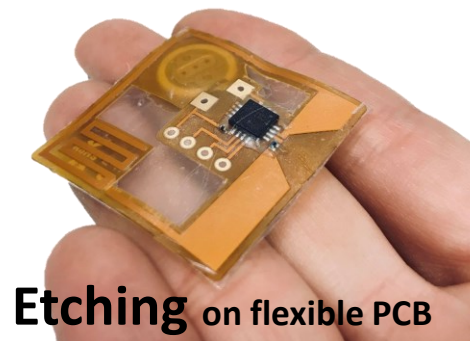
Carving of adhesive copper



Inkjet Printing



Conductive Wires



Etching on flexible PCB

Biocompatible
Stretchable

Transparent
Conformable

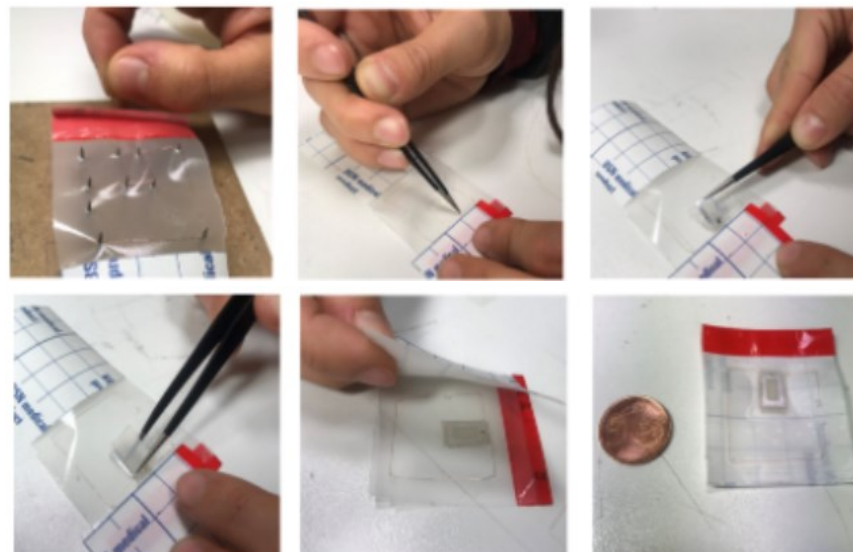
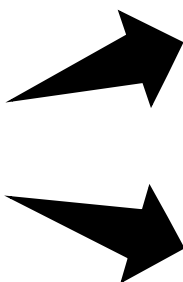
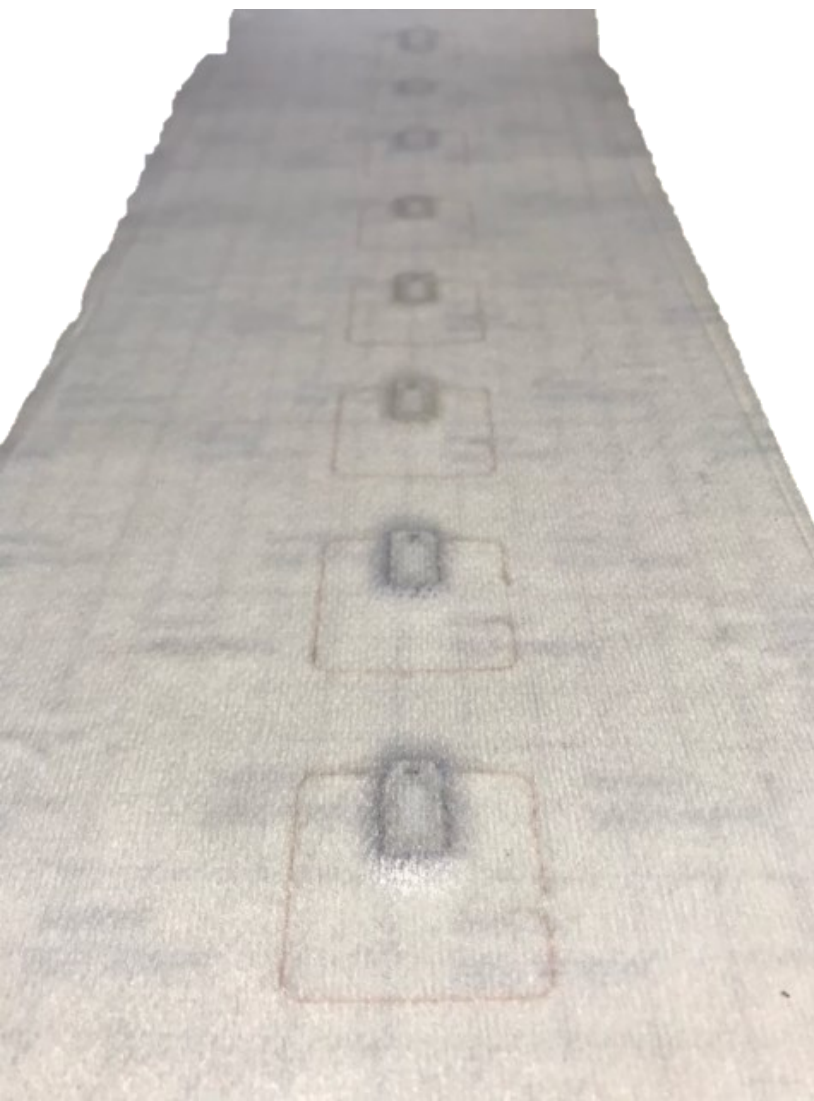
Adhesive
Breathable

Flexible

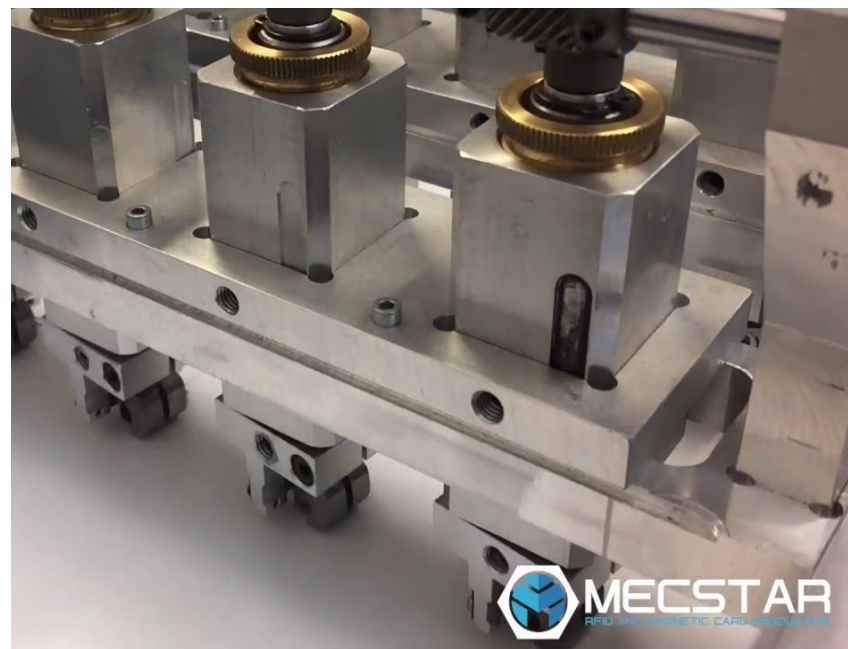


SECOND SKIN Epidermal RFID Sensors

Manufacturing



By hand



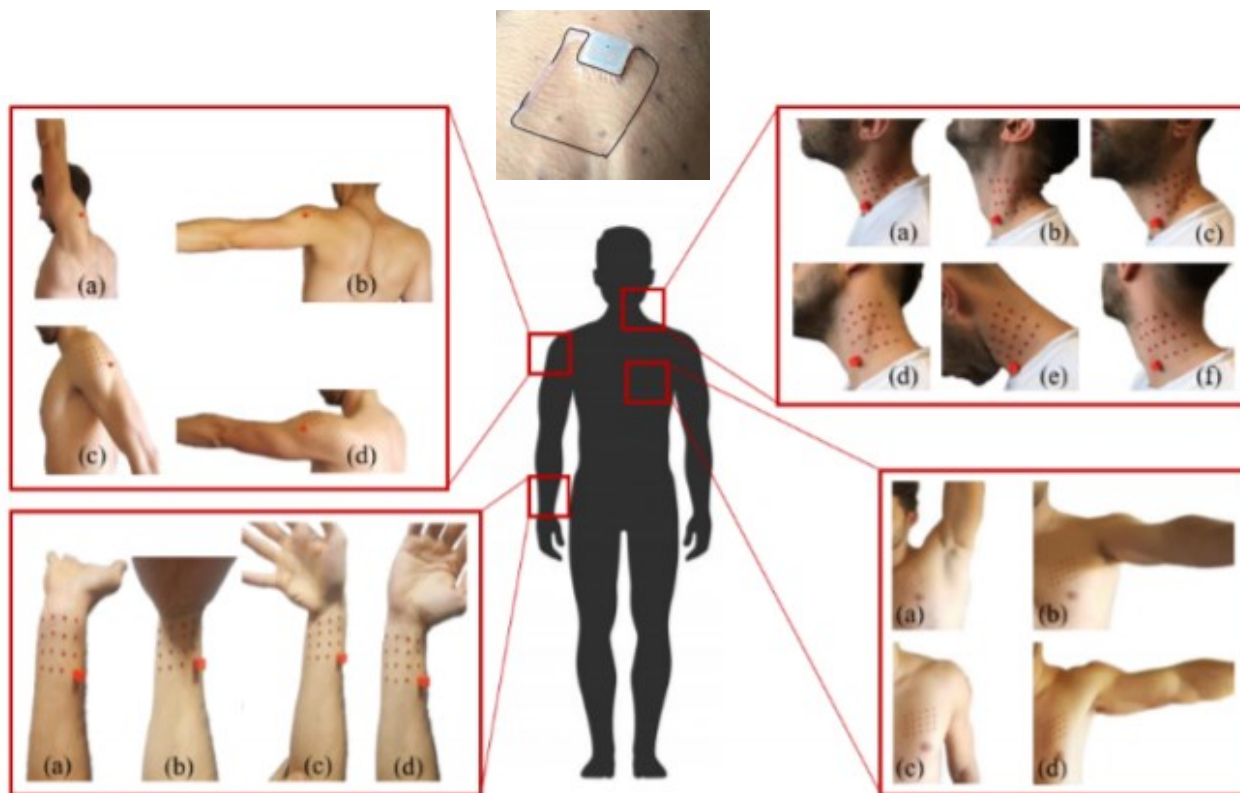
Automatic

SECOND SKIN Epidermal RFID Sensors

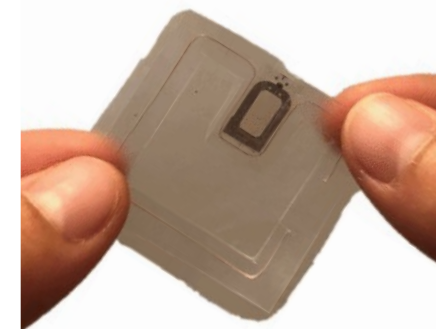
Durability & Usability

Miozzi 2020

10.1109/JRFID.2020.3001692



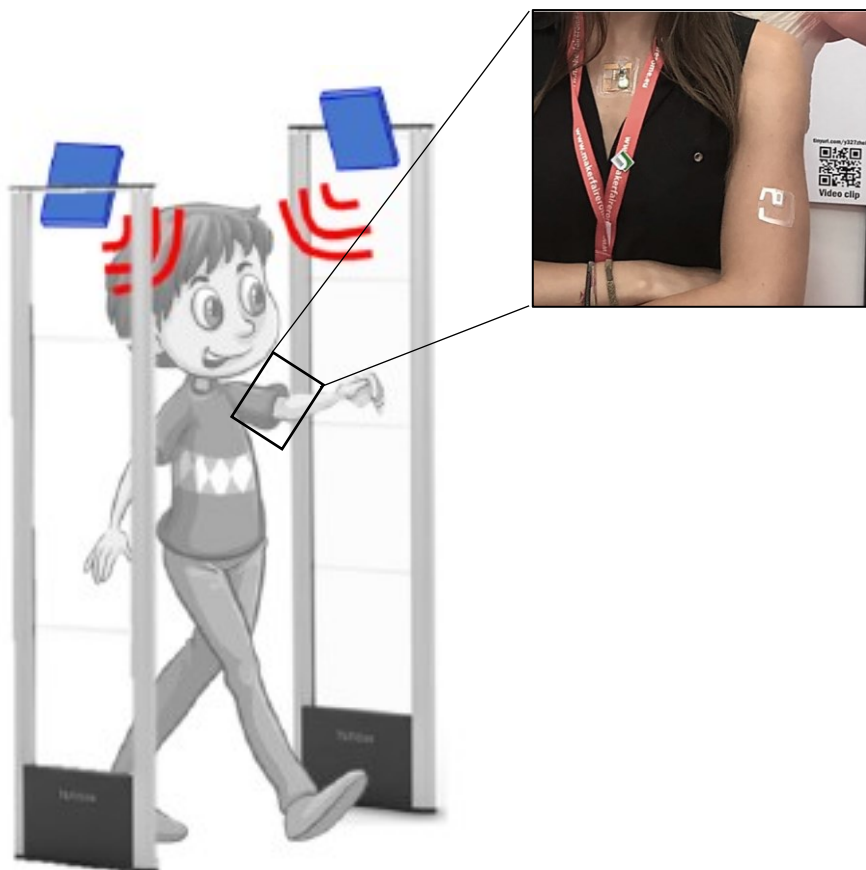
	Volunteer 1 Wire	Volunteer 2 Wire	Volunteer 3 Wire	Volunteer 1 Yarn	Volunteer 2 Yarn	Volunteer 3 Yarn
Day 1						
Day 3						
Day 7						



Miozzi 2020

10.1109/JSEN.2020.2968386

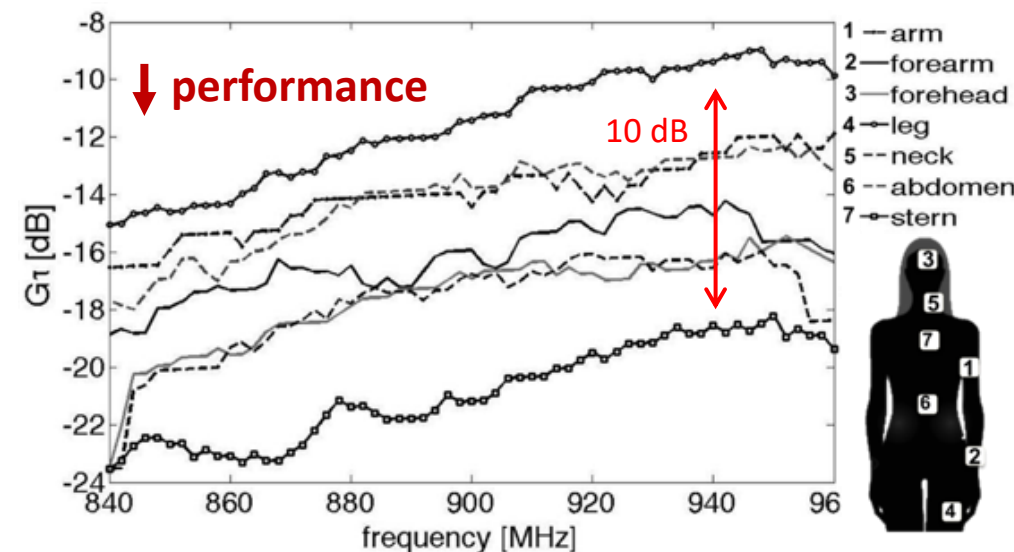
On-the-fly Collection of Body Temperature



Configurable Epidermal Data-Logger

Human Body Variability

if different users and different on-body positions



Amendola 2015

10.1109/TAP.2015.2441211

Configurable Epidermal Data-Logger

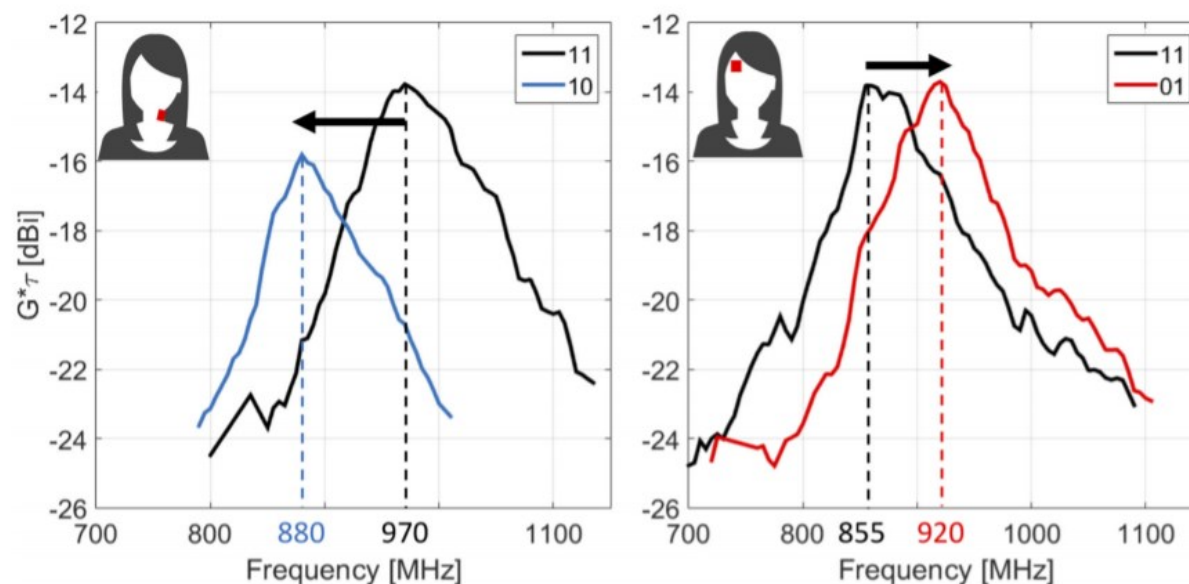
Human Body Variability

if different users and different on-body positions



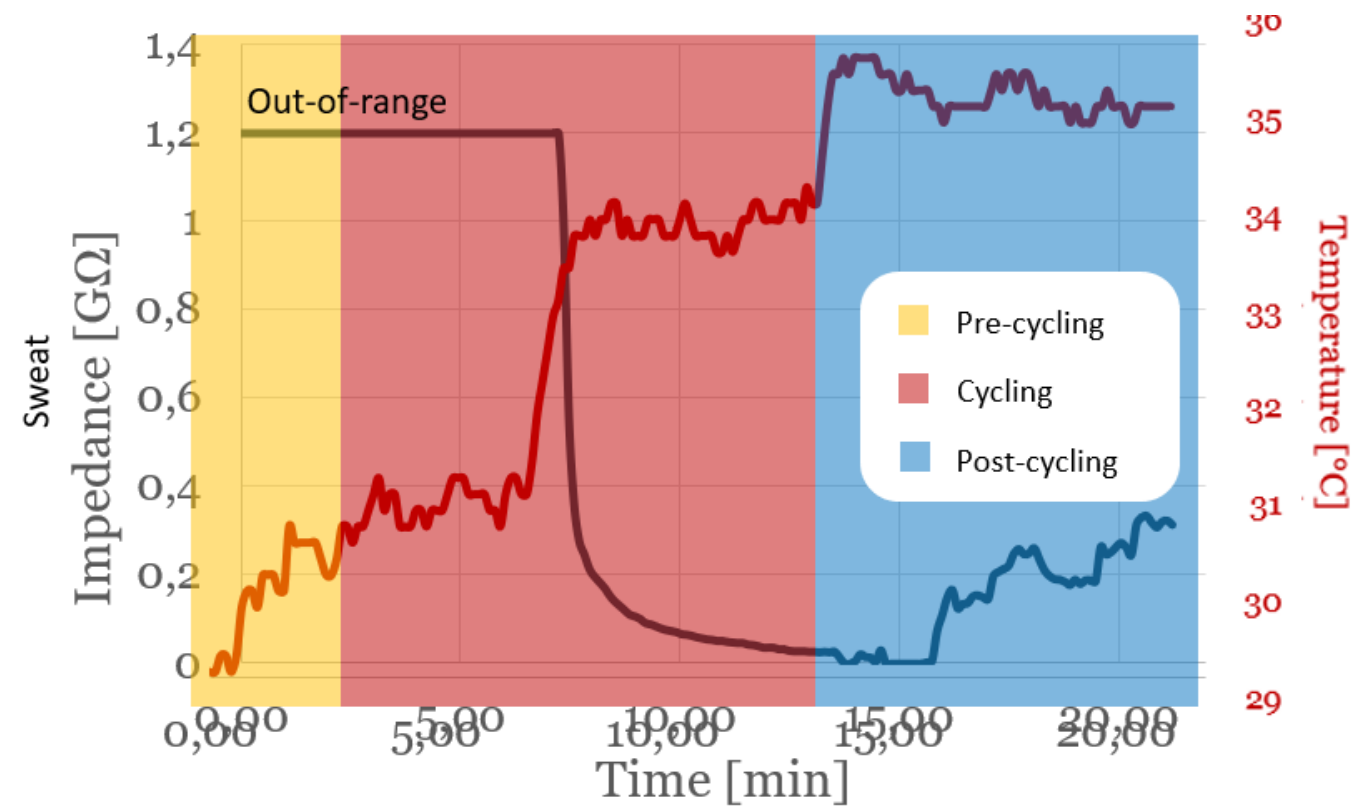
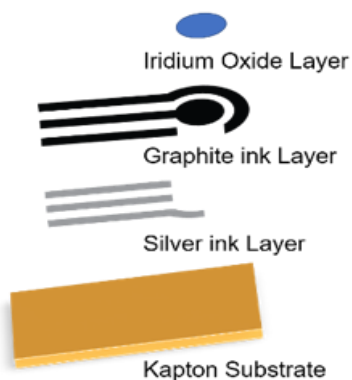
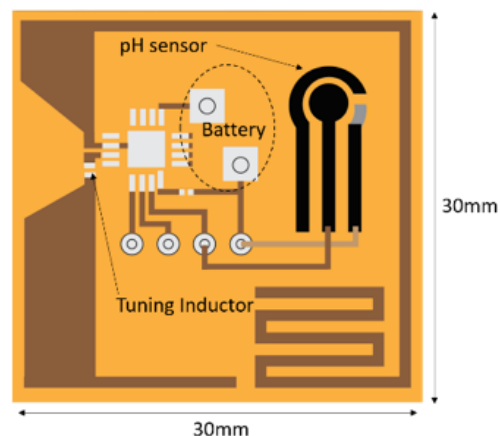
Miozzi 2019

10.1109/LAWP.2019.2901202



Antenna Tuning Unit

Continuous Monitoring of Skin Temperature and Sweat

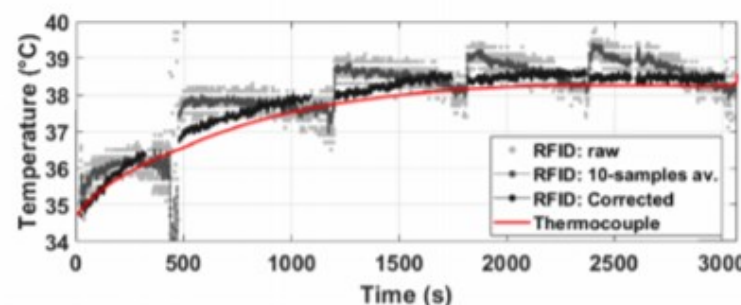
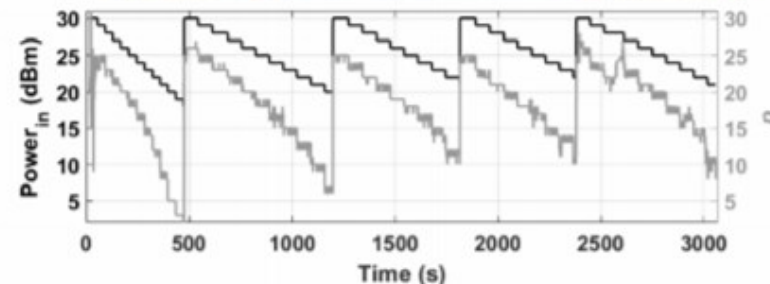
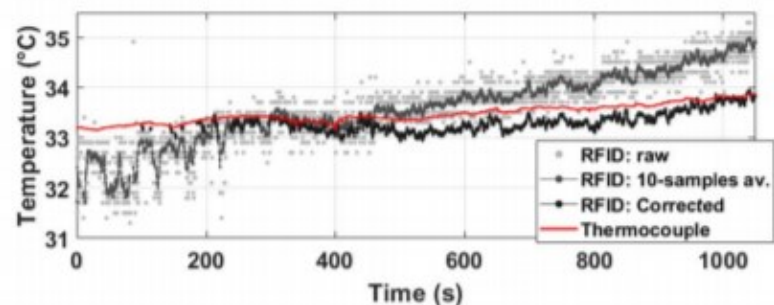
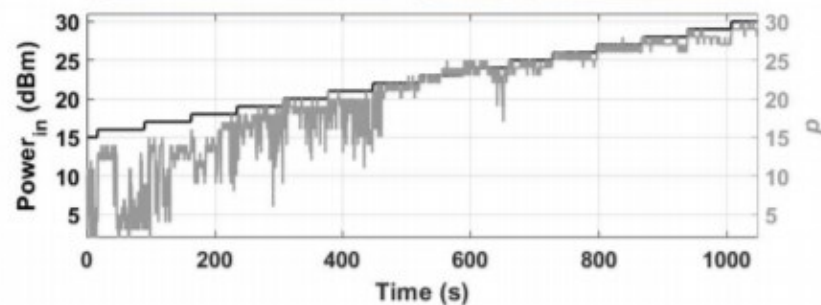


Accuracy of Epidermal Thermometers

Thermal Correction Algorithm

Camera 2020

10.1109/JSEN.2020.3014404



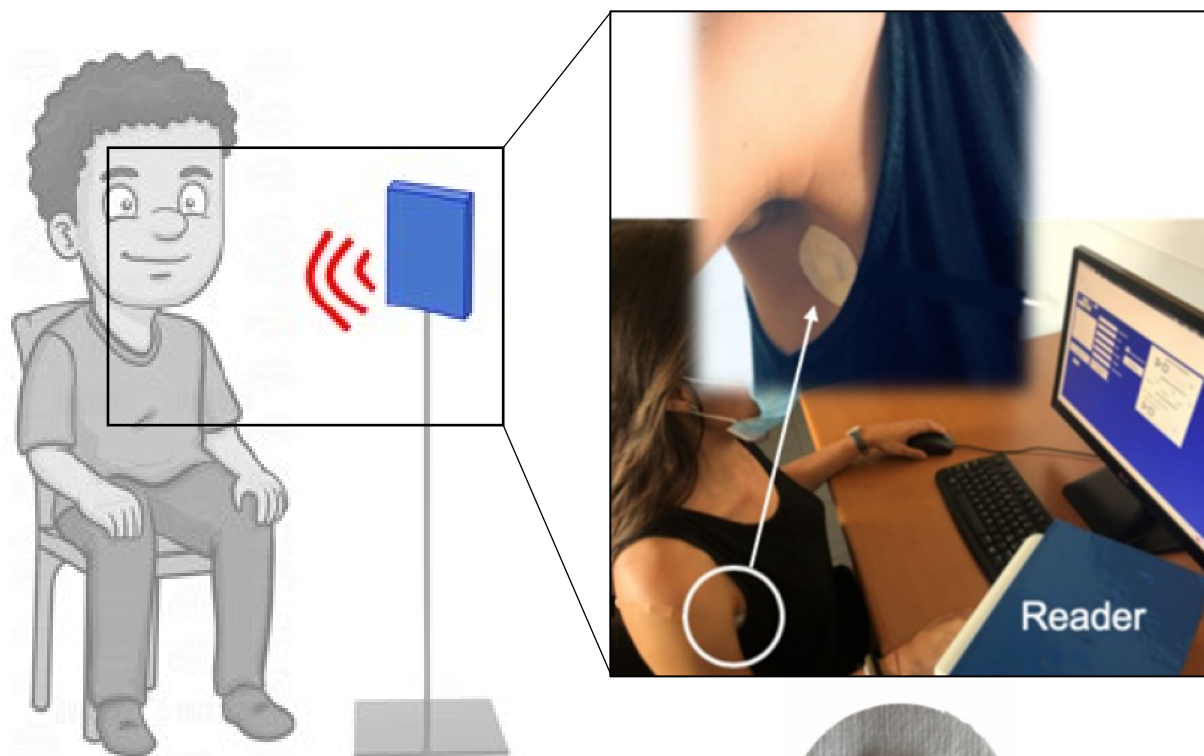
- Data independent on the reader-tag distance
- Data independent on the emitted power

Accuracy of Epidermal Thermometers

Experimental Evaluation

Camera 2020

10.1109/LSENS.2020.3036486



Coat

Shirt



T_{tag}	35.9 ± 0.1	35.9 ± 0.1
T_A	36.2	36.2



Coat

Shirt



T_{tag}	35.9 ± 0.1	35.9 ± 0.1
T_A	36.2	36.2

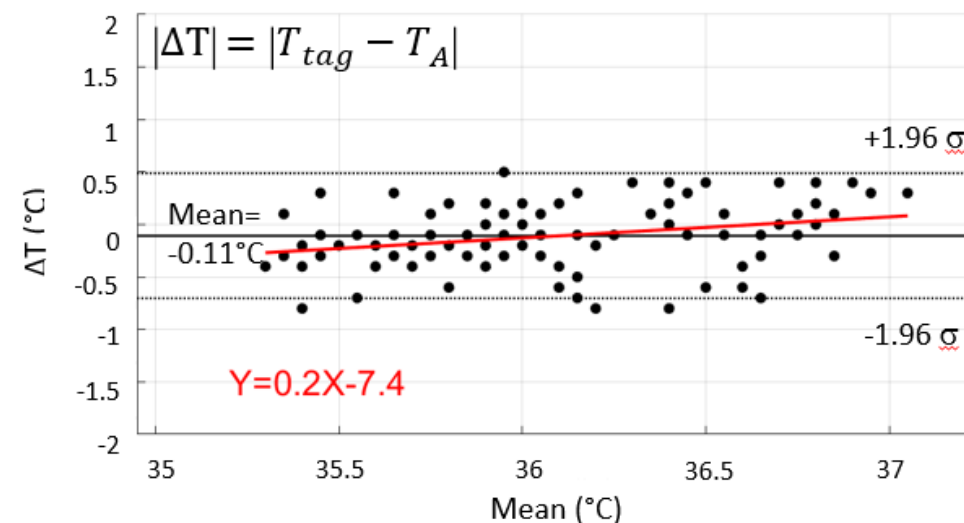
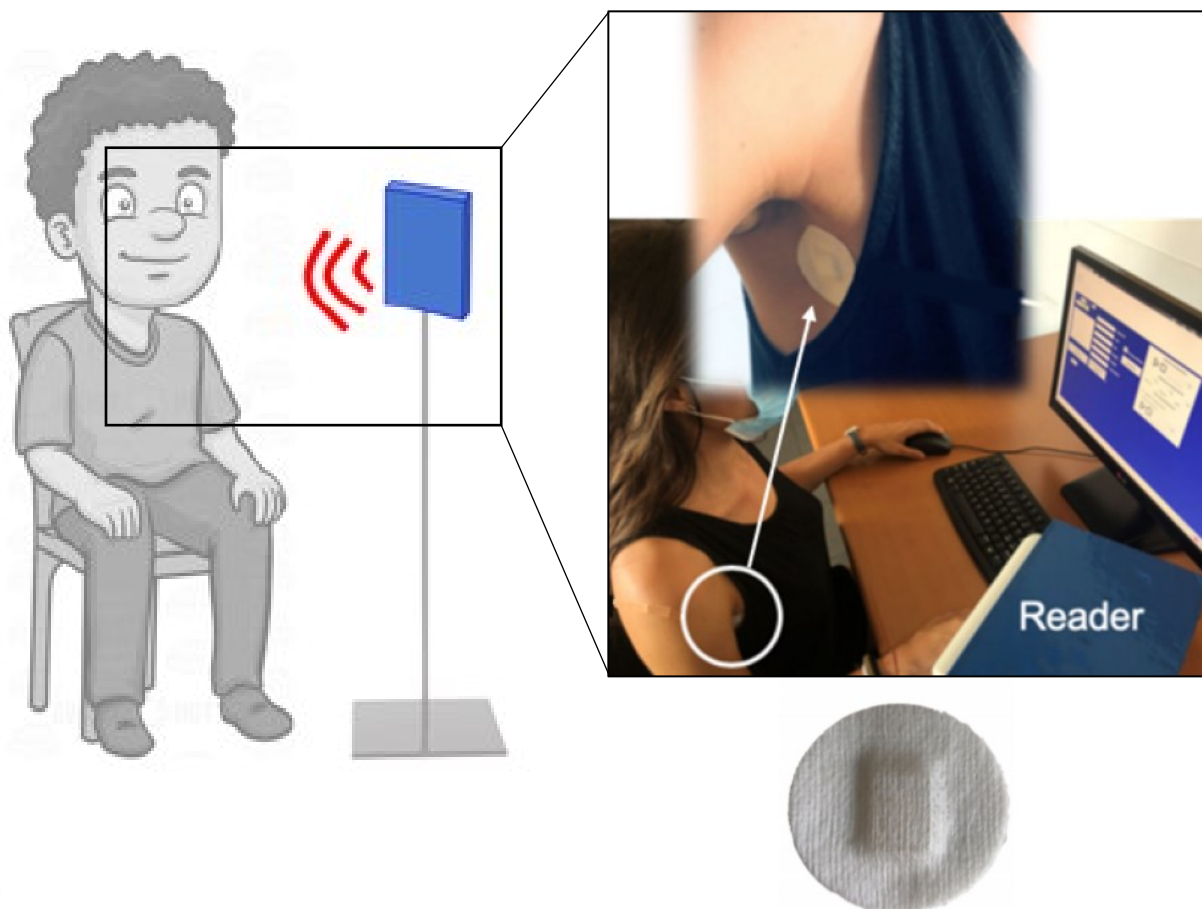
- Negligible impact of **clothing** and **external temperature**

Accuracy of Epidermal Thermometers

Experimental Evaluation

Camera 2020

10.1109/LSENS.2020.3036486



- Negligible impact of **clothing** and **external temperature**
- **Comparable** with standard thermometry systems with a user-specific calibration

Radio Finger Augmentation Devices

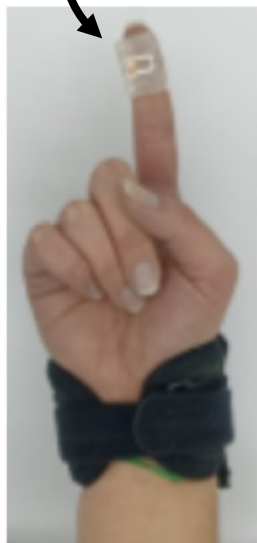
Sensory Function Regeneration and *Ultrability*



Bianco 2020

10.1109/TAP.2020.2995315

Identification of liquids



Bianco 2020

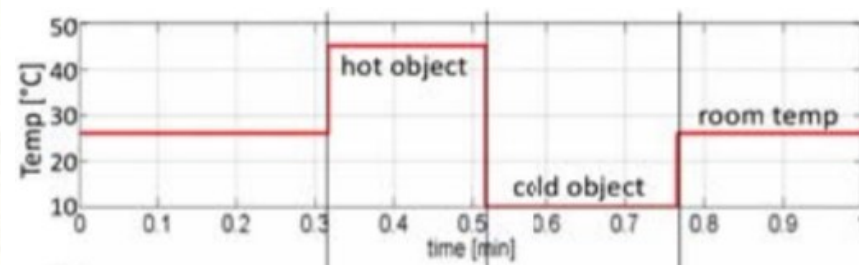
10.23919/SpliTech49282.2020.9243753



Object temperature

Amendola 2019

10.1109/RFID-TA.2019.8892012



Identification of gestures



Amendola 2018

10.1109/TAP.2018.2876703

Beyond SECOND SKIN

Technological Boost



Beyond SECOND SKIN



Dual-SKIN

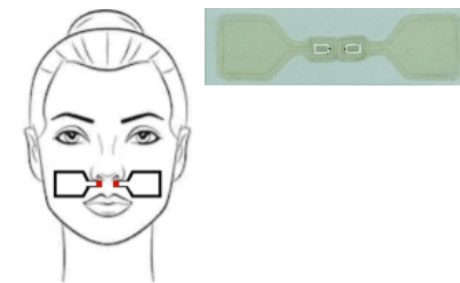
*Dual-sensor wireless and flexible skin thermometers
for fast and reliable detection of feverish states*



- Improve accuracy
- Multi-parameter monitoring



Occhiuzzi 2020
10.1109/JSEN.2020.3031664



Miozzi 2021
10.1109/RFID52461.2021.9444377

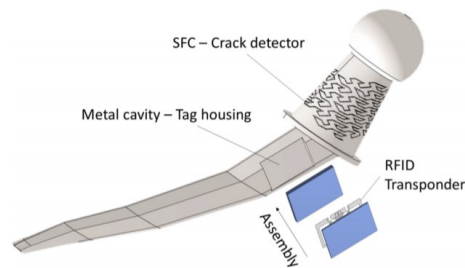
Beyond SECOND SKIN

Radio Finger Augmentation Devices



Naccarata 2021
URSI GASS 2021

Implantable Prostheses

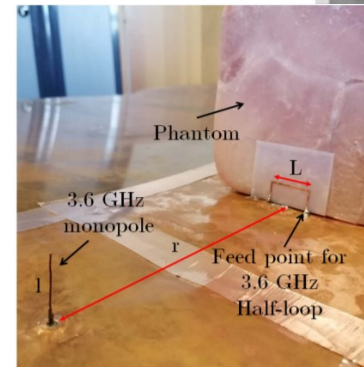
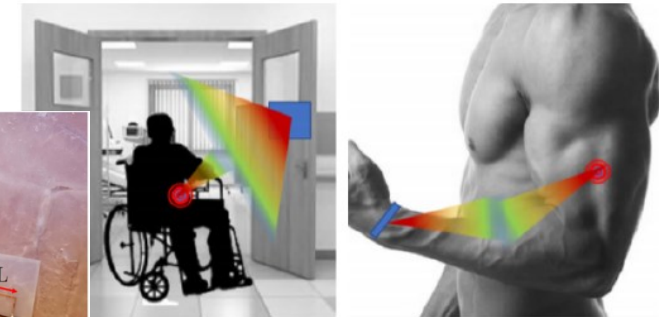
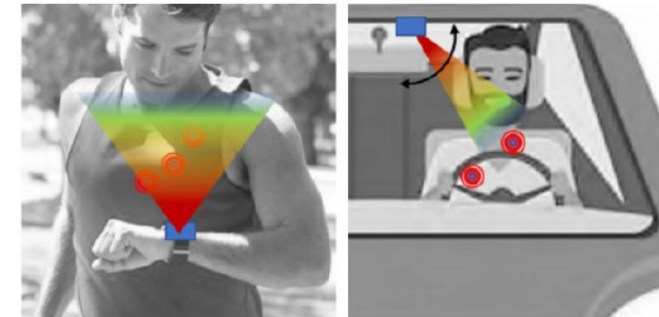


Nappi 2021
10.1109/JERM.2021.3108945



Avaltroni 2021
10.1109/JSEN.2021.3097448

5G-RFID Epidermal Sensors

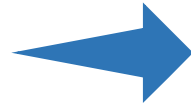


Amato 2020
10.1109/JRFID.2020.2998082

SECOND SKIN

Conclusions & Beyond





UHF RFID Epidermal Sensors

Strengths

- Biocompatible and comfortable
- Reduced dimensions
- Innovative materials and manufacturing techniques
- Low-cost
- Battery-less
- Remote reading through fixed or wearable readers
- Data processing and correction

Benefits

- Temperature
 - Pressure (i.e. sense of touch)
 - Perspiration
 - pH and sweat
 - Gestures
- ↓
- Personalized diagnostics





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Thank you!

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