POSSIBILITIES FOR ONLINE MONITORING OF PERMITTIVITY CHANGES IN AGEING POLYMERS

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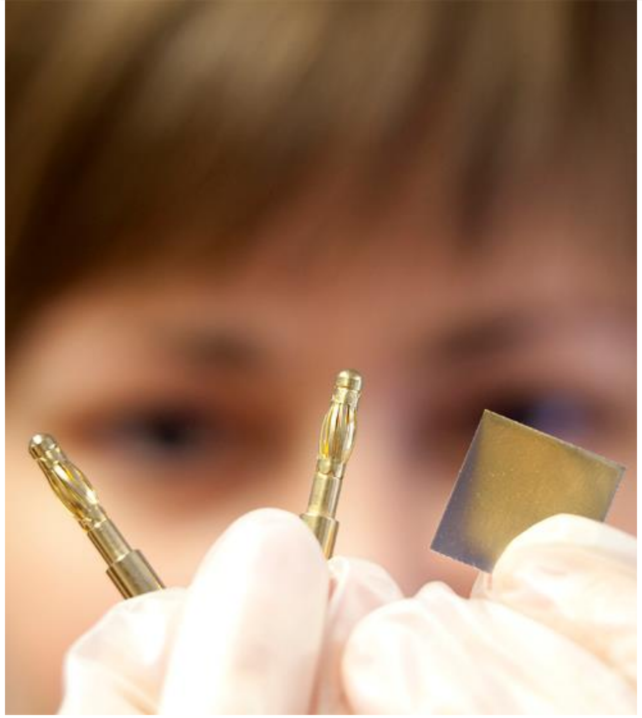
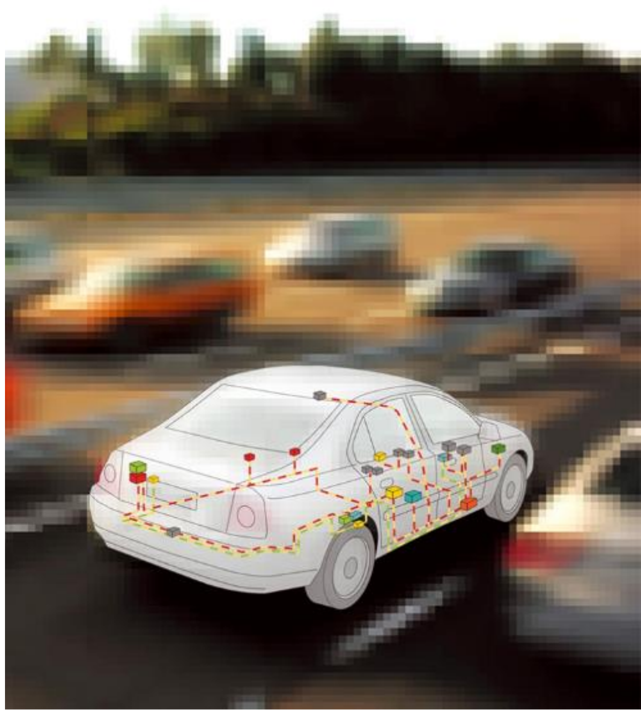
Research Institutes of Sweden

SAFETY AND TRANSPORT ELECTRONICS



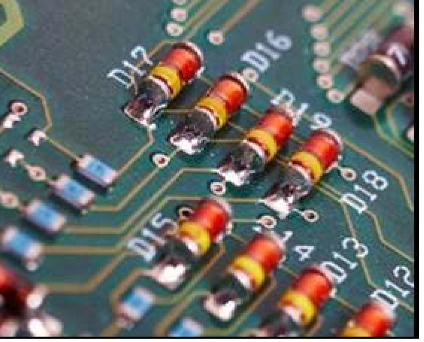


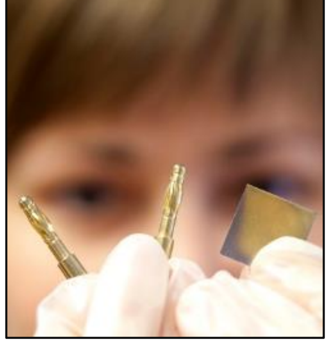
Outline

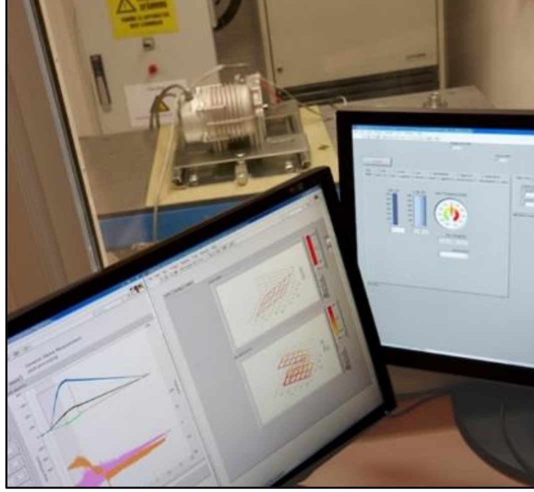
- Electronics/EMC Research
- Online monitoring of polymers
  - Permittivity
  - Antenna sensors

RISE Electronics/EMC

- Division Safety and Transport
- Unit Electronics
- Section EMC – R&D and Testing
- Groups within EMC:
    - Research (R&D)
    - Vehicle group
    - ICT group








We work with everything that contains or uses electronics.

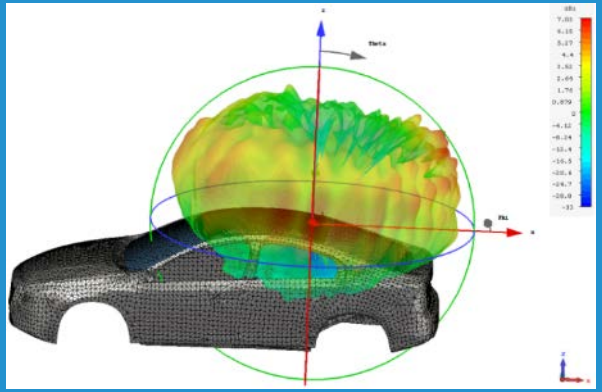
Safe and robust products – also in complex and harsh environments.

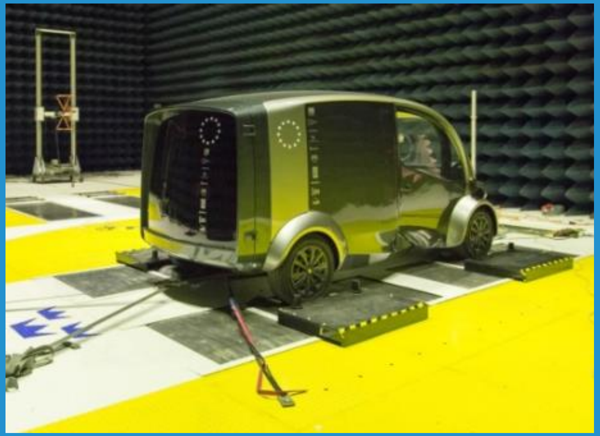




Research at RISE Electronics/EMC

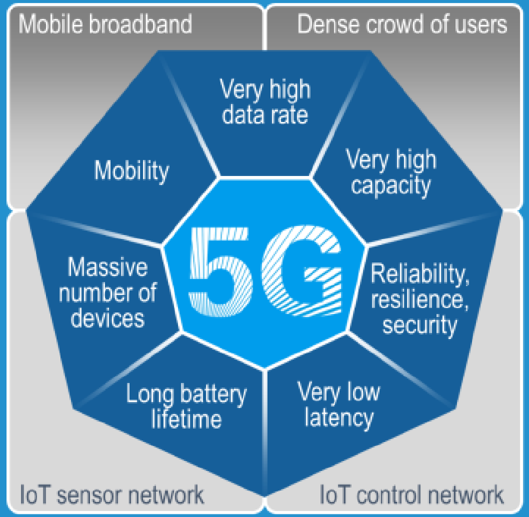
- Research group
  - 8 PhD and MSc researchers
- Ways of working
  - Research and development projects funded mainly by Swedish Innovation Agency (Vinnova) and EU
  - Collaborative projects with industry and academia
- Main research areas
  - EMC/EMI investigations, modeling and measurements
  - Methods/tools for functional testing (automotive)
  - Antenna systems and sensors
  - Wireless communication
- Tools and test facilities
  - EM calculations and system simulations
  - Semi- and full anechoic chambers (e.g. AWITAR)
  - Reverberation chambers
  - Test track (AstaZero)





Research Topics

- Automotive (V2X)
  - EMC testing and security
  - Communication (antenna systems and radio channel)
  - Radars and sensors
- 5G and IoT
  - EMC testing and security
  - Connectivity
  - Antenna systems
- EM interference (EMI)
  - EMI and intentional EMI (IEMI)
- Development of new test methods
  - OTA and reverberation chambers
  - Radiation pattern measurements
  - Fading channel emulation

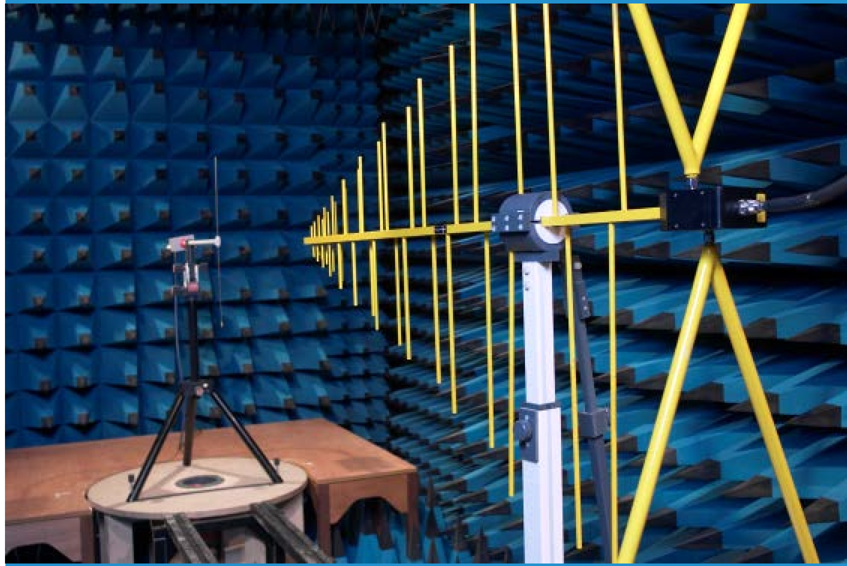


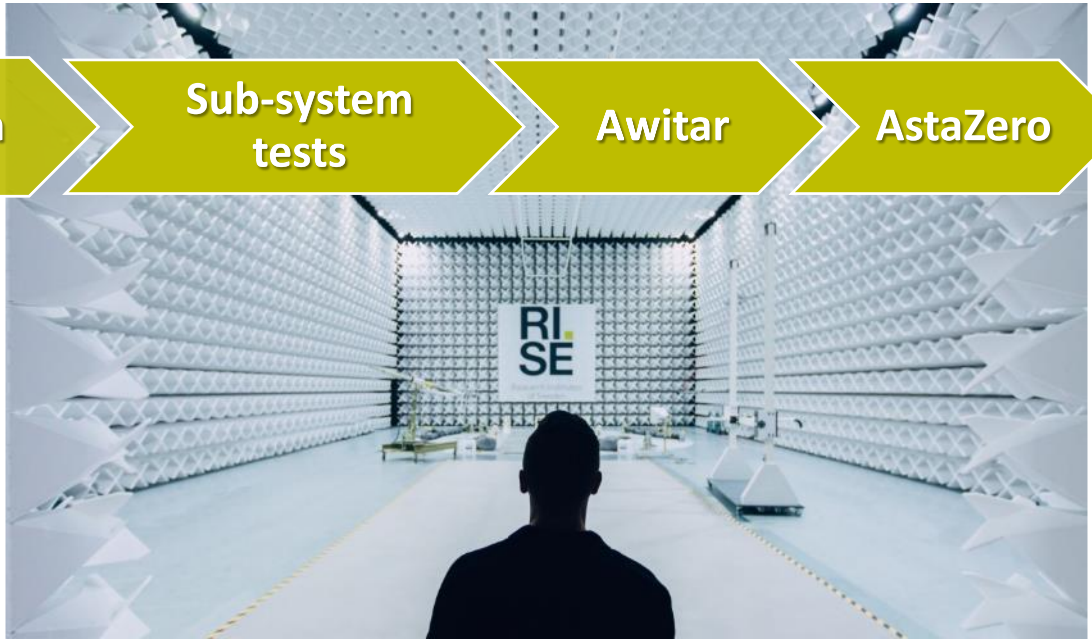
Partners and Collaborations

- Automotive industry
- Mobile communication industry
- Material and sensor companies
- Academia
- Research institutes
- Standarization bodies (ISO/CISPR, ETSI, FCC, …)
- Government and defense industry

Research on full test procedure chain

- Simulation and EM calculations
- Component and sub-system tests
- Full scale measurements in controlled environment
  - AWITAR
  - Test track AstaZero
- Drive tests on public road





Simulation → Sub-system tests → Awitar → AstaZero → Public road

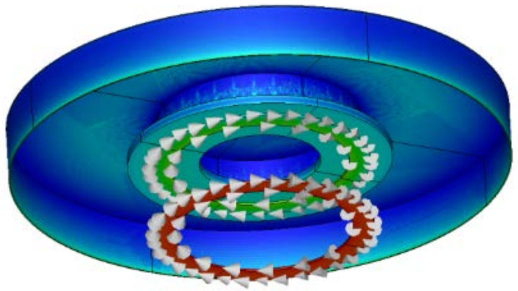
Some research activities overview

- Simulations and EM calculation
- Test environment developments
- Radar target characterization and radar target simulator
- V2X and 5G connectivity and communication

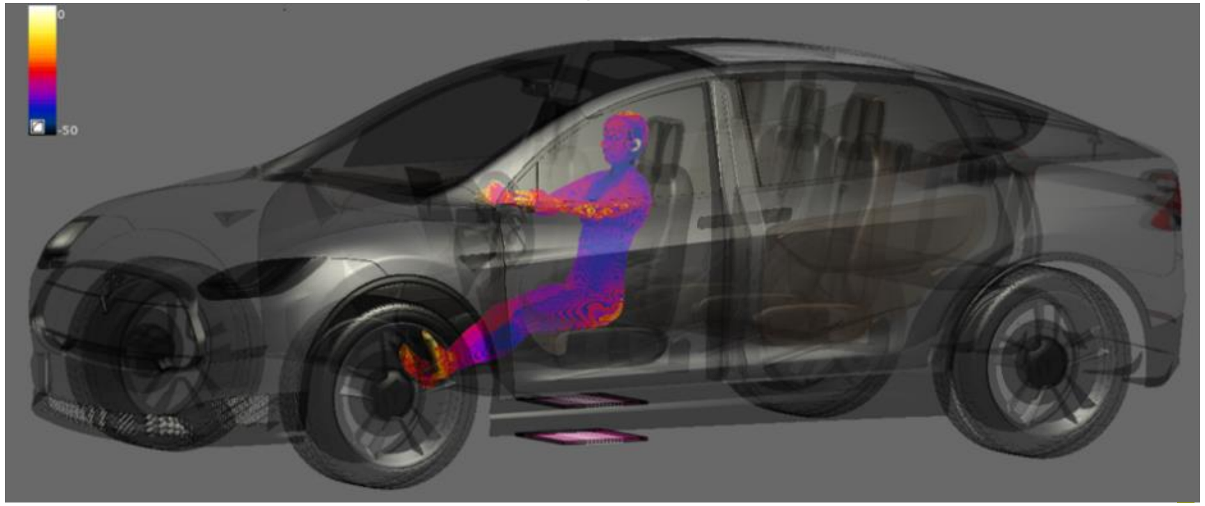
EMPIR Micev (Inductive charging)

- **METROLOGY FOR INDUCTIVE CHARGING OF ELECTRIC VEHICLES (MICEV)**
- The project aims to advance **inductive power transfer (IPT)** for the charging of EVs by developing metrology techniques for measuring IPT **efficiency** as well as reliable demonstration of compliance with existing safety standards for **human exposure**
- **Partners:** INRIM, NPL, PTB, RISE, Aalto, CIRCE, CNRS, POLITO, TU Delft, TUV-SUD, UNICAS, UNISA, SPEAG

Simulation of IPT system



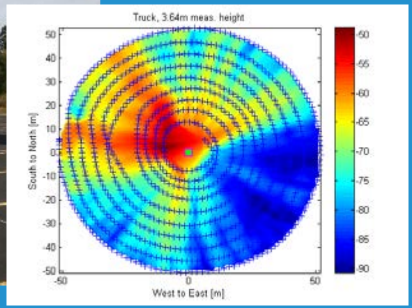
Simulation of magnetic field exposure to human from IPT system



FFI RelCommH (Finished 2015)

Reliable Communication for Heavy vehicles

- Project:
  - Vinnova FFI
  - 2 years (started: 2013-01-01)
  - ETSI TC ITS-G5 standard based on IEEE 802.11p
- Objectives:
  - Antenna prototypes
  - Diversity placements
  - Radiation pattern measurements
  - Drive tests
  - Communication analysis

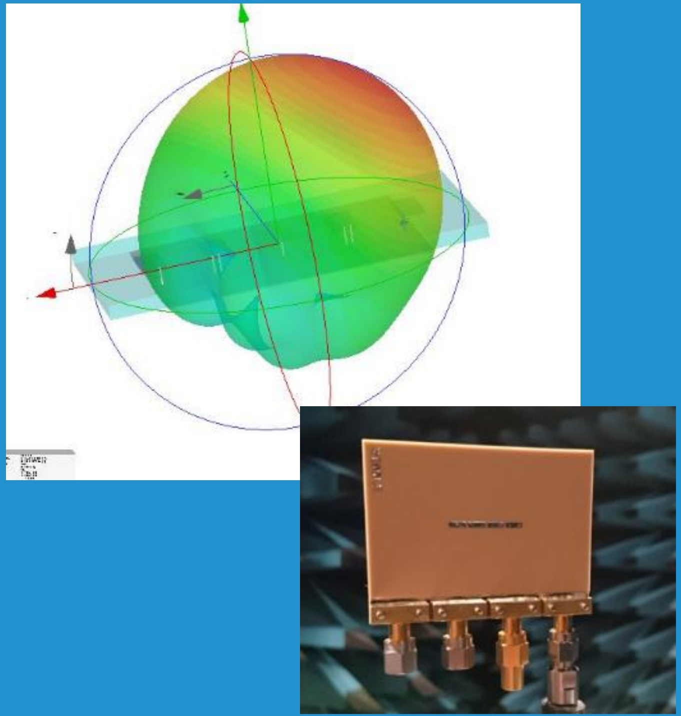


ChaseOn V2X

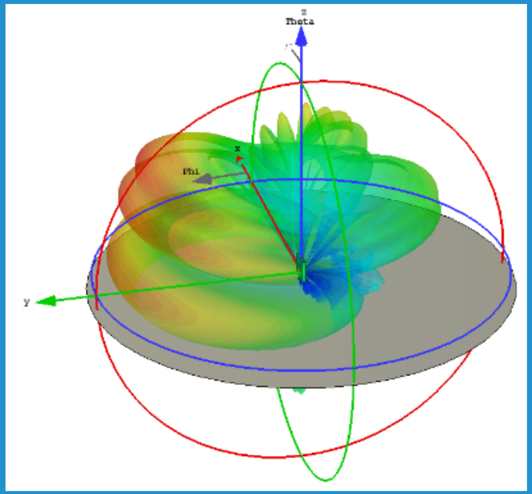
Next Generation Reliable Vehicle Communication – V2X

- Main purpose is to investigate possibilities with 5G for vehicle communication V2X (C-ITS, NR)
  - Extreme Mobile BroadBand (xMBB)
  - Massive Machine-Type Communications (mMTC)
  - Ultra reliable low latency communication (URLLC)
  - mmW communication, beamforming antennas, etc.
- 5G V2V mmW communication (NR sidelink)
  - V2N - vehicle-to-network
  - V2V (3GPP sidelink) below 6 GHz

Antenna arrays

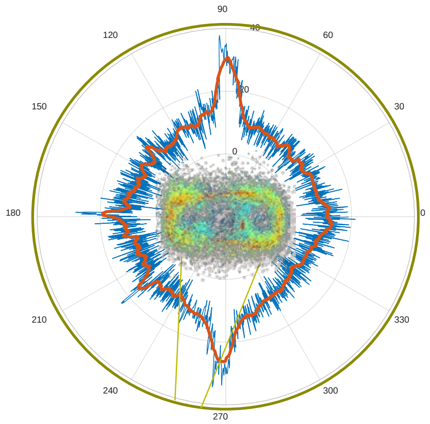


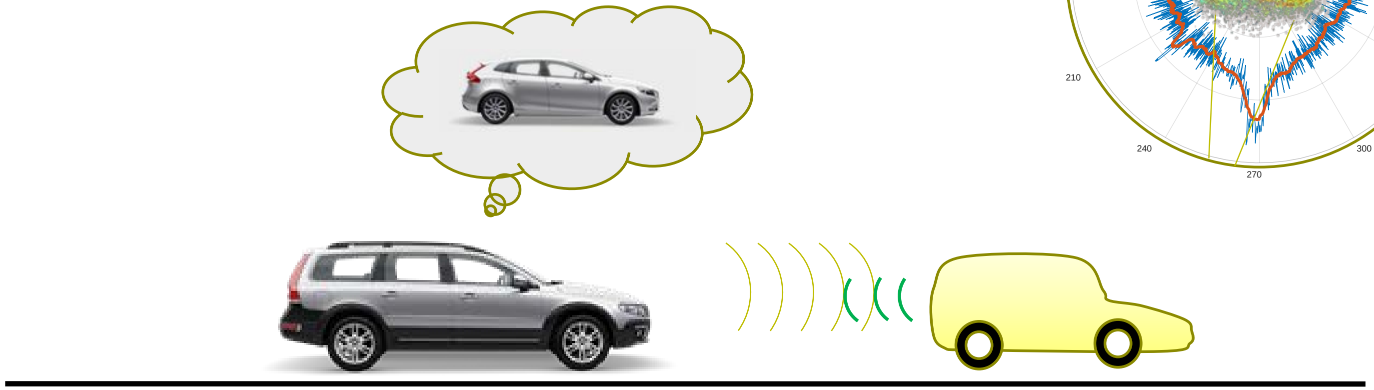
Antenna installation



FFI HiFi Radar Target (finished)

- Development of methods and hardware for radar cross section (RCS) measurements:
  - Reference objects and EM simulations
  - Measure RCS (real and soft targets)
- Methodology to construct soft surrogate targets that improve current state-of-the-art
- Input to international standardization (ISO)

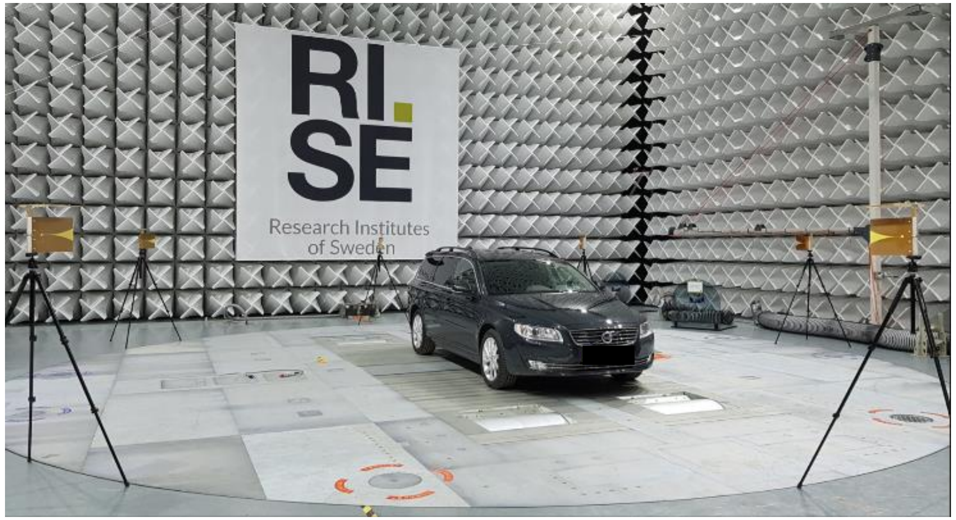


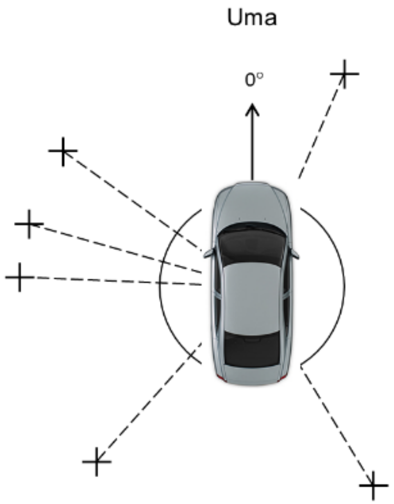


V2X communication (FFI WCAE)

Next Generation Reliable Vehicle Communication – V2X

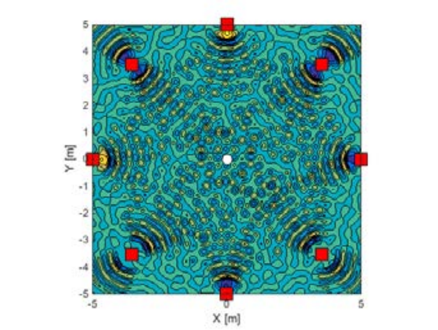
- Develop and verify multipath propagation simulator (MPS), and develop methods for active tests on 3G/LTE, Wi-Fi and 802.11p.
- Perform experiments for 3G/LTE, Wi-Fi, 802.11p.
- Continuation in Sivert with simulation of communication (5G) and evaluation/validation of OTA test methods.





RISE mainly work with:

- Antennas on vehicles:
  - Antenna pattern measurements
  - EM simulations
- OTA testing
  - Development of multi-path simulator
  - Development of OTA testing methods
  - Evaluation of OTA testing methods:



5G mmW EMC testing

- Development of measurement method in RC for mmW 5G emission test
- Target 3GPP and ANSI
- Collaboration with Ericsson S&T and ER

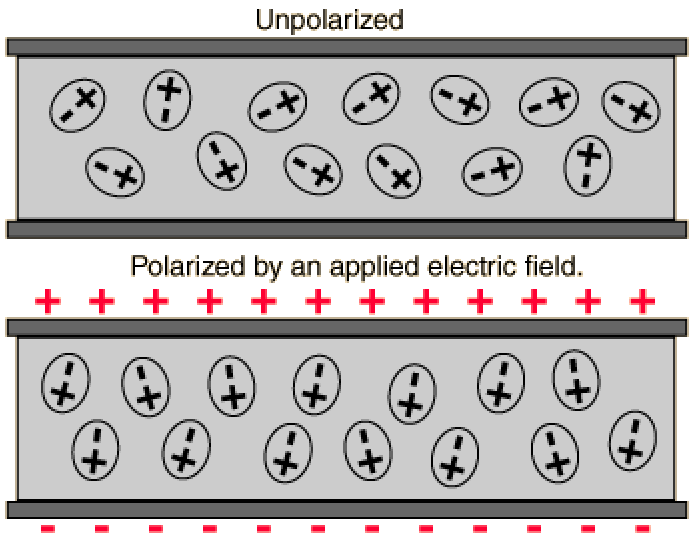
Electromagnetic Sensors

Our role in SAMPO

- WP2 - T2.1 Online condition monitoring techniques
  - Small literature study
- Expect material changes detectable through electromagnetic properties
  - Specifically permittivity

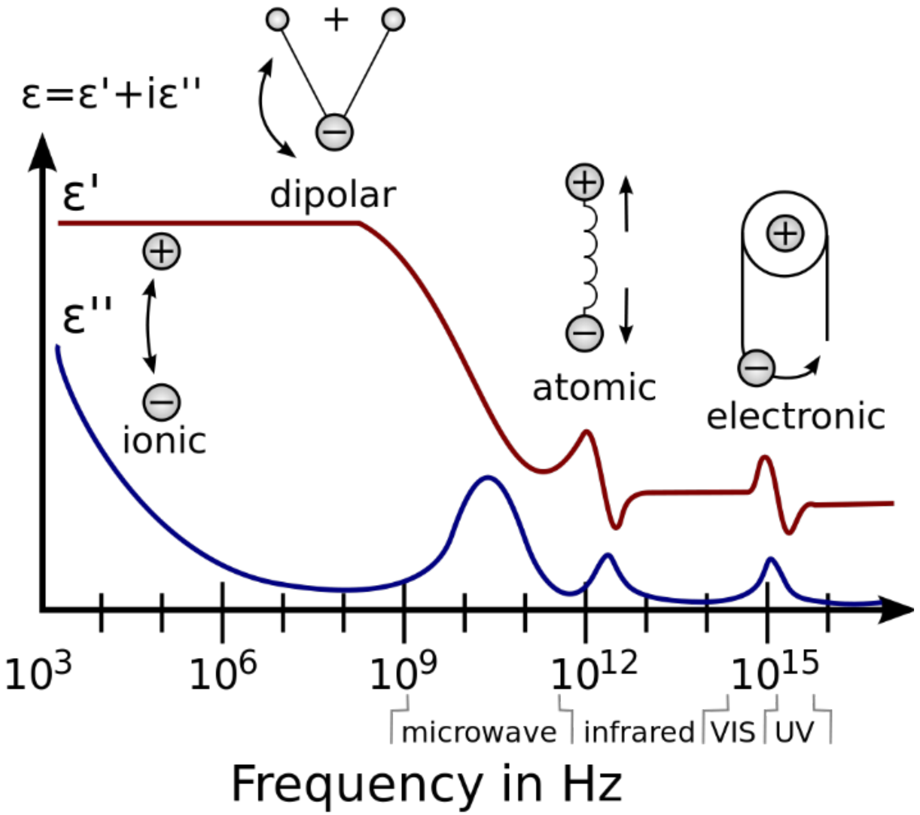
Permittivity

- “Measure of a material's ability to store an electric field in the polarization of the medium”
- Affects the propagation of electric field
  - ”Refractive index”
  - Impedance for propagating EM fields
  - Field in transmission lines/cables extends into surrounding media
    - Affects impedance of transmission lines
- Also known as dielectric constant
  - In this work it has been assumed, more or less, pure dielectrics



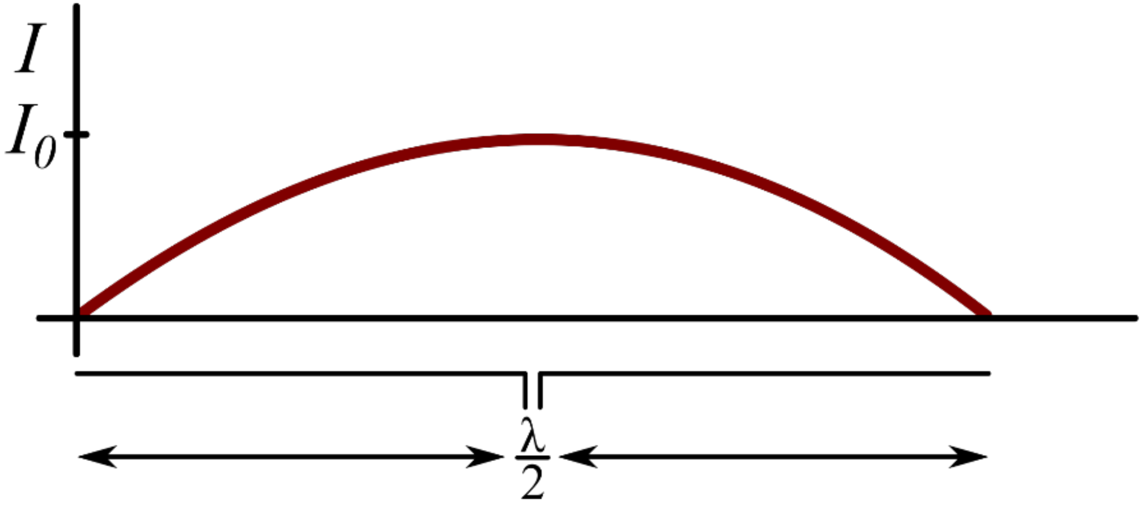
Permittivity

- Difference in impedance leads to reflections
  - Characterization materials through analysis of reflected, transmitted and absorbed wave
    - Frequency dependent
    - Dielectric/impedance spectroscopy
  - Impedance affects propagation speed
    - Also of transmission line
    - Electrical length found through time domain measurements
    - Identify positions of impedance variations through time to reflections



Permittivity and antennas

- Antennas radiate electromagnetic field
  - Typically at certain resonant frequencies
    - Example dipole
- Electrical length permittivity dependent
  - Useful e.g. for making physically smaller antennas
- Antenna sensors
  - Permittivity dependent resonance



Antenna sensors

- Example – biodegradable polymer

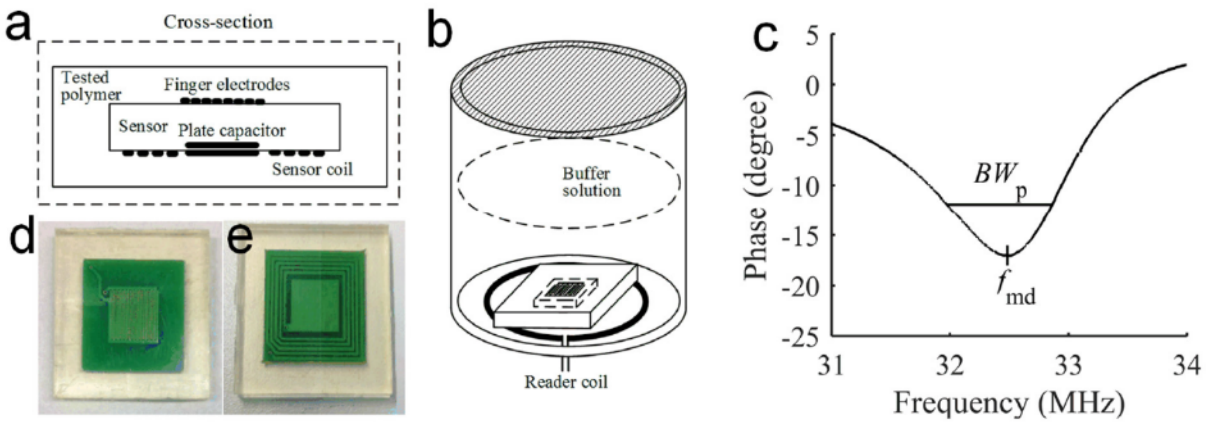


Fig. 1 (a) The cross-section of the encapsulated sensor; (b) The measurement setup; (c) A phase response and the extracted features; (d) A sensor in PLGA; (e) A sensor in PDLGA

T. Salpavaara et al. / Procedia Engineering 168 (2016) 1304 – 1307

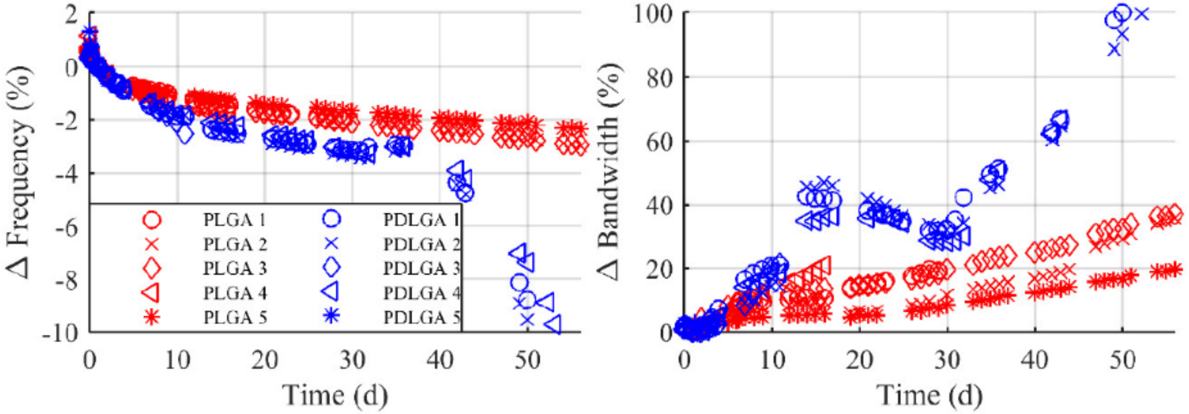
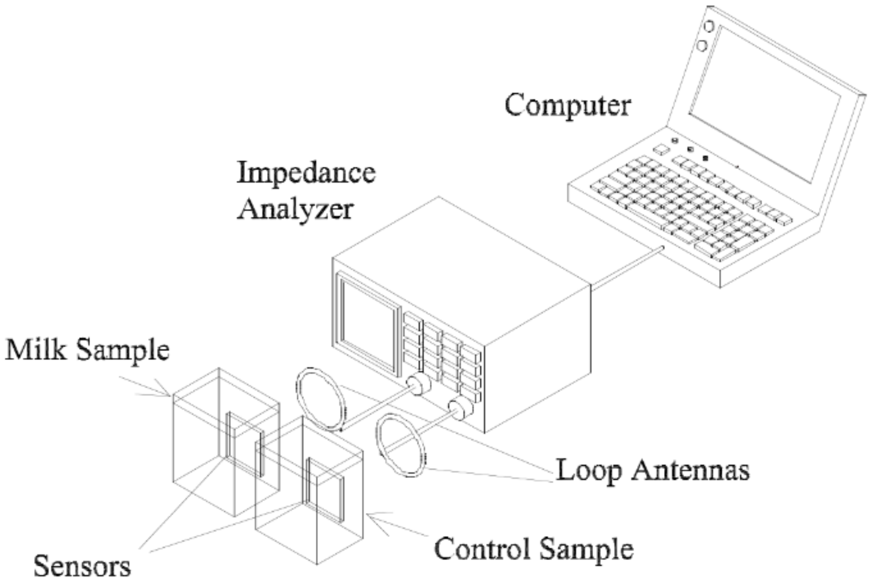
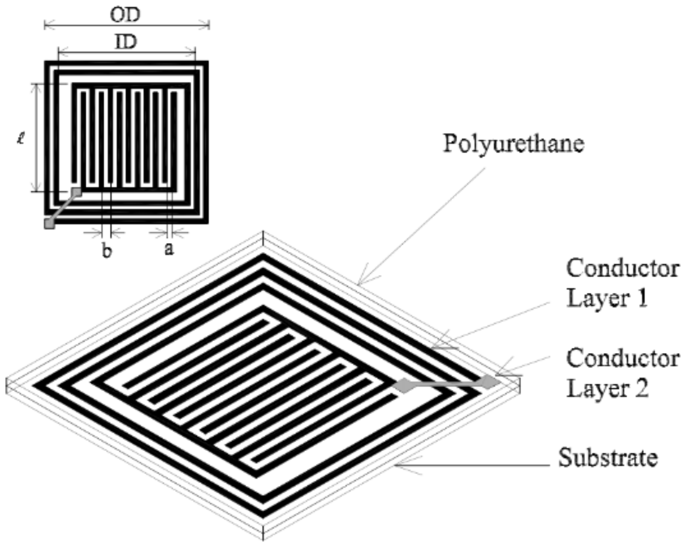


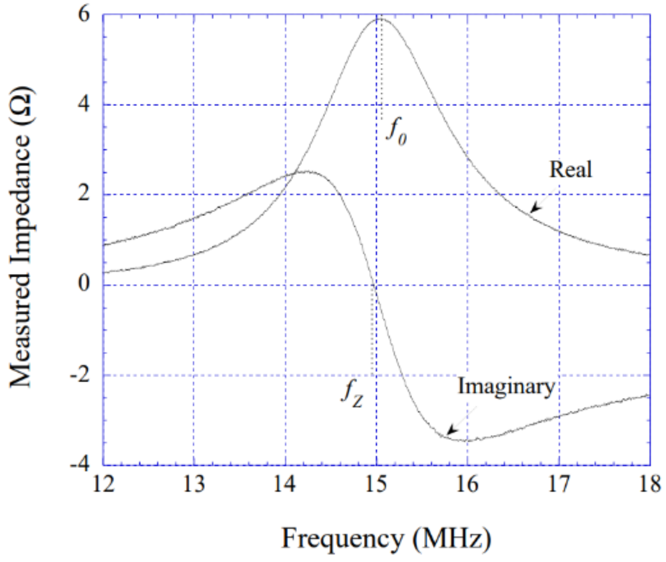
Fig. 3. The changes in the inductively measured frequency (f_{md}) and bandwidth (BW_p) of the phase-dip.

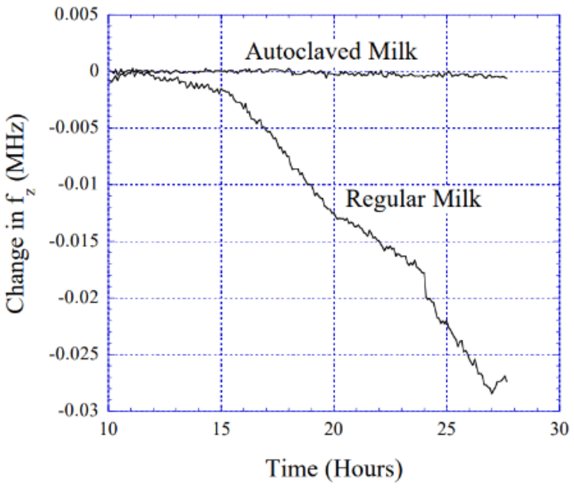
Antenna sensors

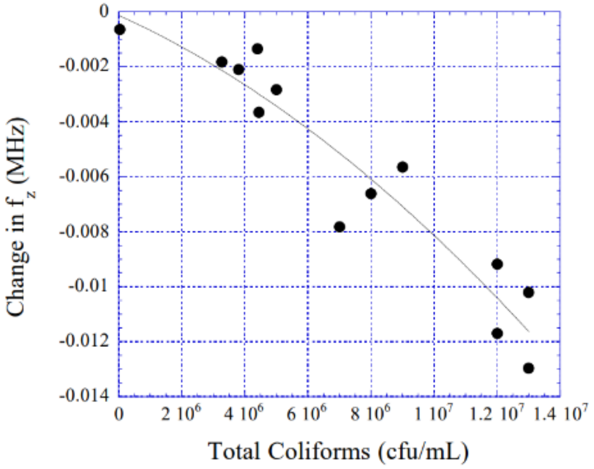
- Example – Monitoring food quality











Chemical and Biological Early Warning Monitoring for Water, Food, and Ground, Janet L. Jensen, Larry W. Burggraf, Editors, Proceedings of SPIE Vol. 4575 (2002) © 2002 SPIE · 0277-786X/02/$15.00

Antenna sensors

- Example – Permittivity sensor

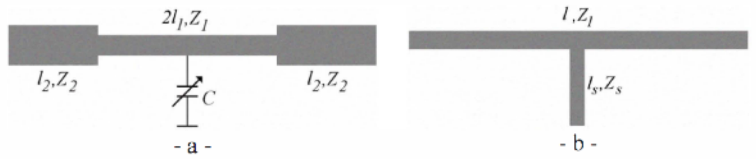


Fig. 1. (a) Capacitive-loaded stepped-impedance resonator and (b) stub-loaded resonator.

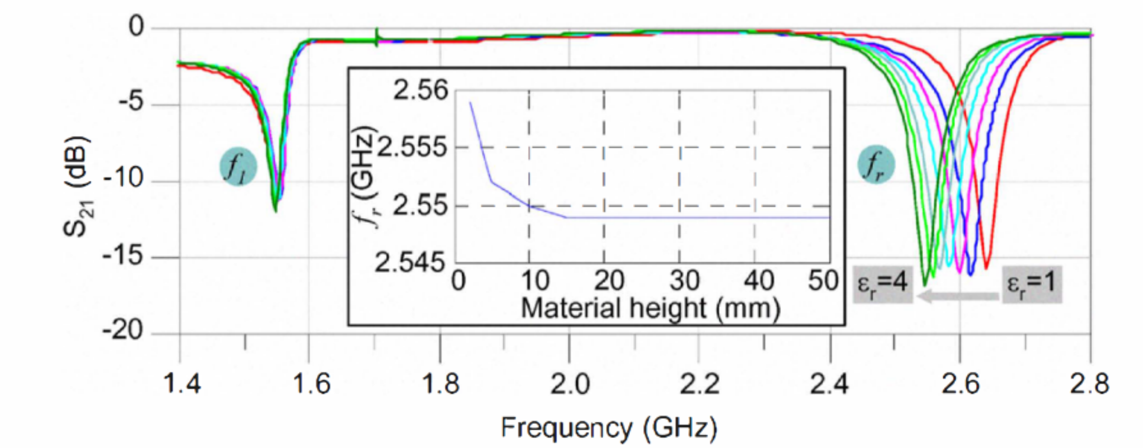


Fig. 3. Simulated thru line that connects the two antennas loaded with the dual-band resonator. 25-mm thick material swept from $1<\varepsilon_r<4$.

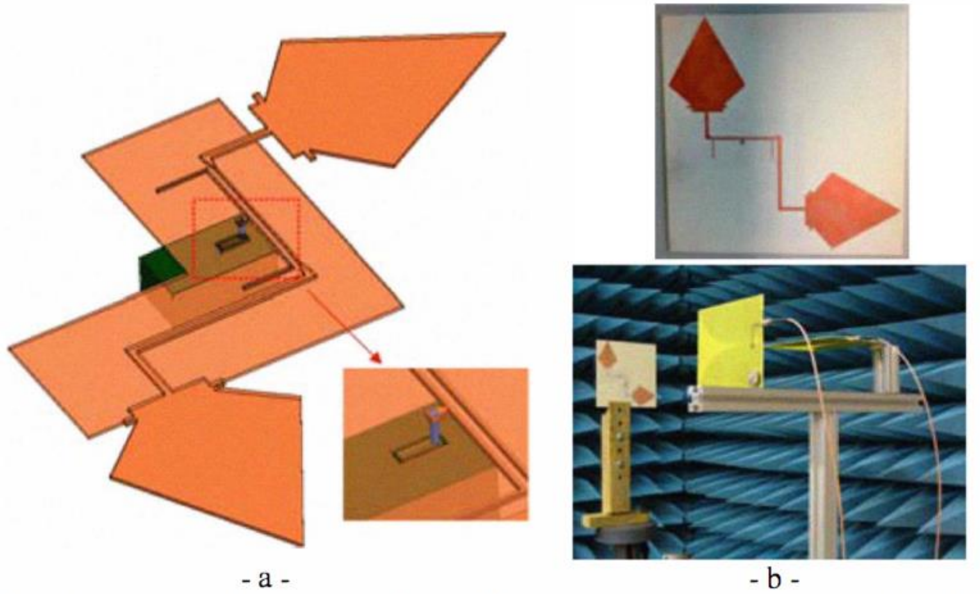


Fig. 2. Sensor topology (a), and tag and measurement system photographs (b). Tag size: 14x14 cm.

Girbau, David, Antonio Lázaro, and Ramon Villarino. "Passive wireless permittivity sensor based on frequency-coded chipless RFID tags." *2012 IEEE/MTT-S International Microwave Symposium Digest*. IEEE, 2012.

Combine with controlled ageing

- Essentially dielectric characterization
- Sample exposed to environment
- Measure during ageing process
- Possible to correlate ageing of polymers with permittivity change
- Material specific
- Unknown mechanisms?

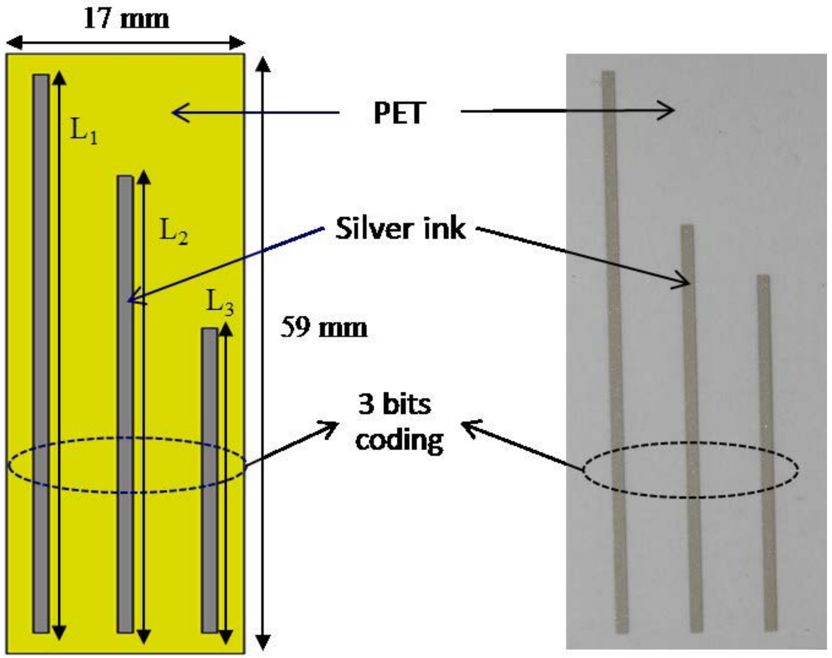
Combine with microcalorimetry

- Correlate
  - Specific material changes
  - Permittivity changes
- Miniaturization of sensor
- Needs simple structure – unaffected by ageing
- Preferably interrogate from outside sample container

Combine with microcalorimetry

- Chipless RFID
  - Simple resonance structures
  - Can be designed for frequencies of specific interest
  - Might need reference signal (independent of ageing)

Example simple chipless RFID



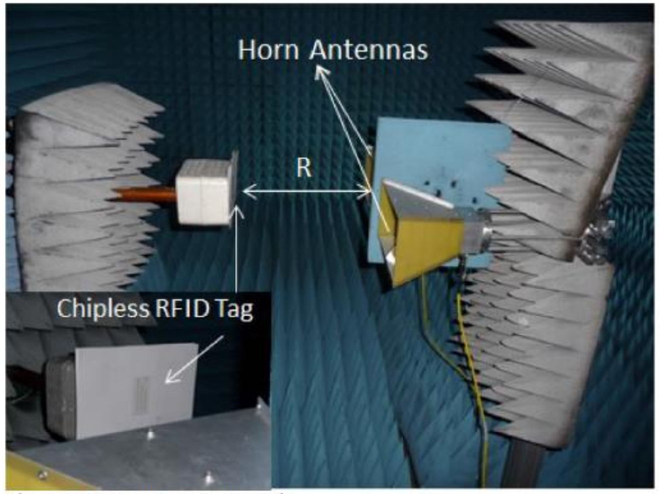


Fig. 4. Measurement set-up used.

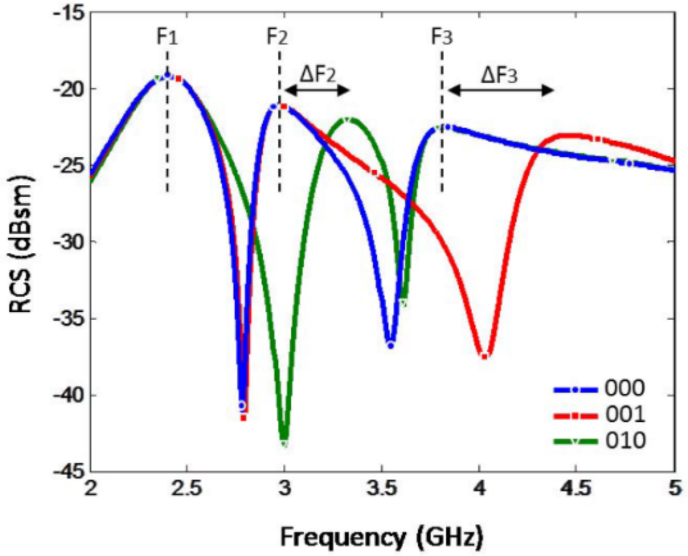


Fig. 3. Simulated RCS of the reference tag with lengths L_1=55 mm, L_2=45 mm, and L_3=35 mm; ID '000' in blue color. Frequency shifting: RCS of the tags corresponding to the IDs '001' in red and '010' in green.

Nair, Raji, et al. "A fully printed passive chipless RFID tag for low-cost mass production." *The 8th European Conference on Antennas and Propagation (EuCAP 2014)*. IEEE, 2014.

Chipless RFID

- Sensor circuit can be made simple
  - Free standing antenna
  - MUT as substrate?
  - Robust

- “Radar-like” approach
- Found similar approach
  - JS McCloy *et al.* @ Pacific Northwest National Laboratory
  - Specifically changes due to radiation

Concluding remarks

- Response clear enough?
- Design of interrogating unit?
- Effect of ambient conditions
  - Monitor long term trends?
  - Couple to reference structure
  - Sensitive to movement
- First step: Investigation under lab conditions
  - Feasibility
  - Identify frequency regions of interest
  - Not necessarily same set-up as *in situ* monitoring
    - System similar to LIRA

THANKS!

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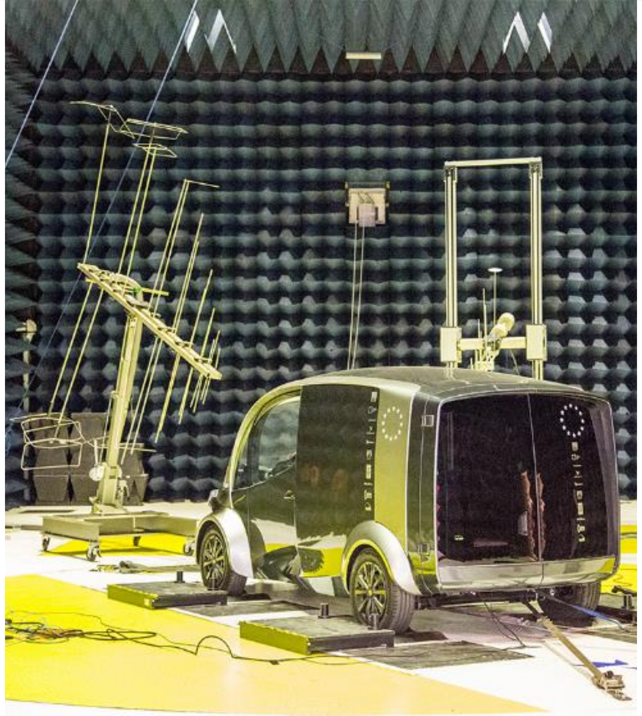

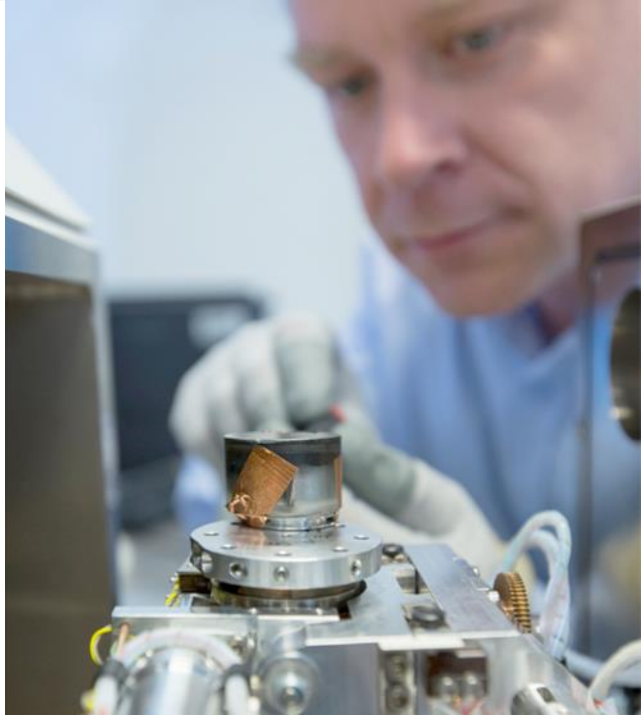

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