COOCK | OPEN STAD

VALUABLE ENVIRONMENTAL INSIGHTS THROUGH AN OPEN CITY APPROACH

FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF INFORMATION TECHNOLOGY
RESEARCH GROUP WAVES

WORKSHOP MOBILE ENVIRONMENTAL MONITORING MAY 4, 2021

IMEC\UGENT-WAVES

MOBILE RF EMF EXPOSURE MEASUREMENTS

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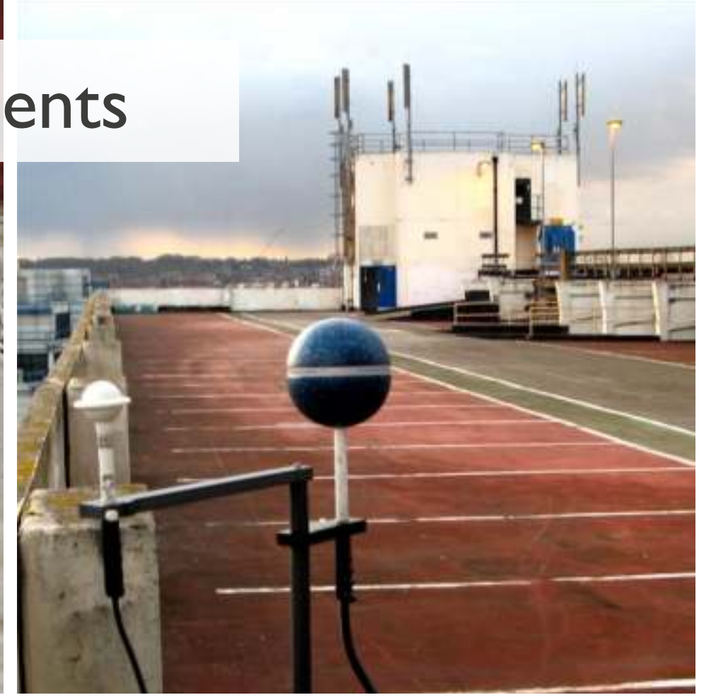
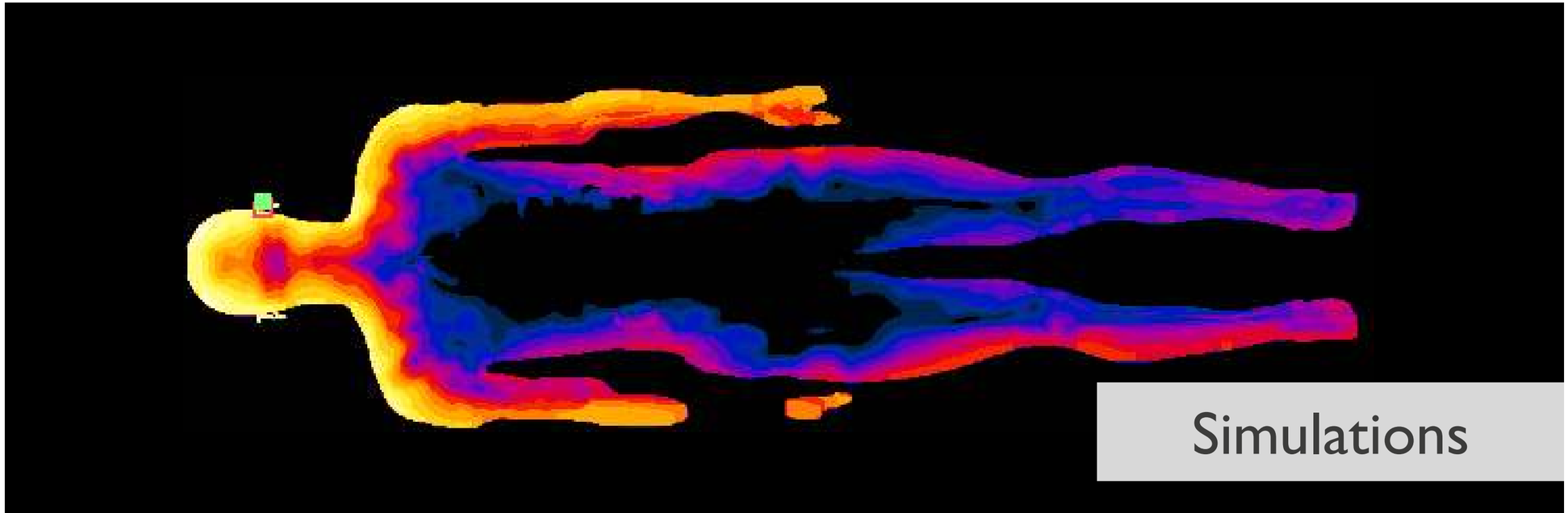
Measurements



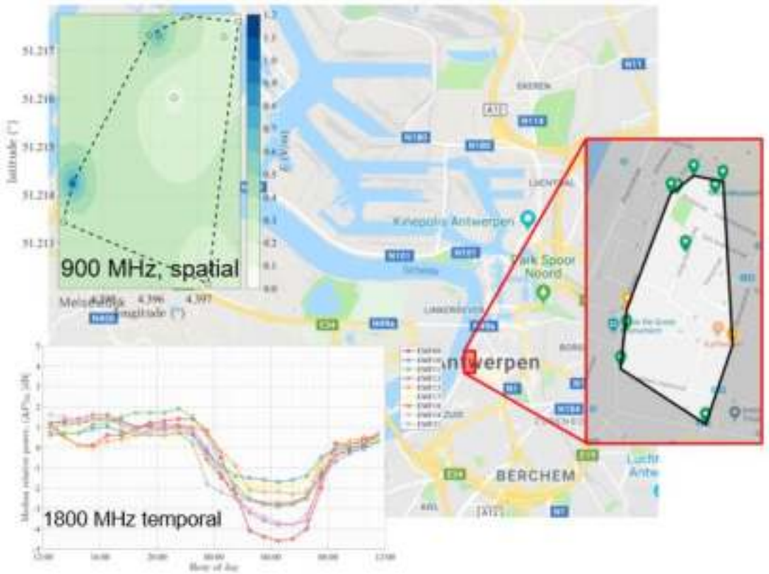
Exposure assessment and modelling



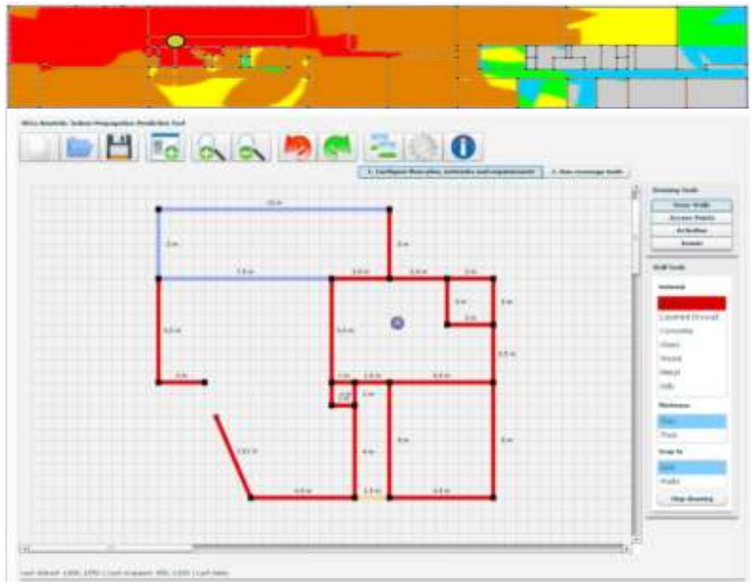
Simulations

IMEC/UGENT-WAVES
ELECTROMAGNETIC RADIATION PROJECTS

Electromagnetic Radiation



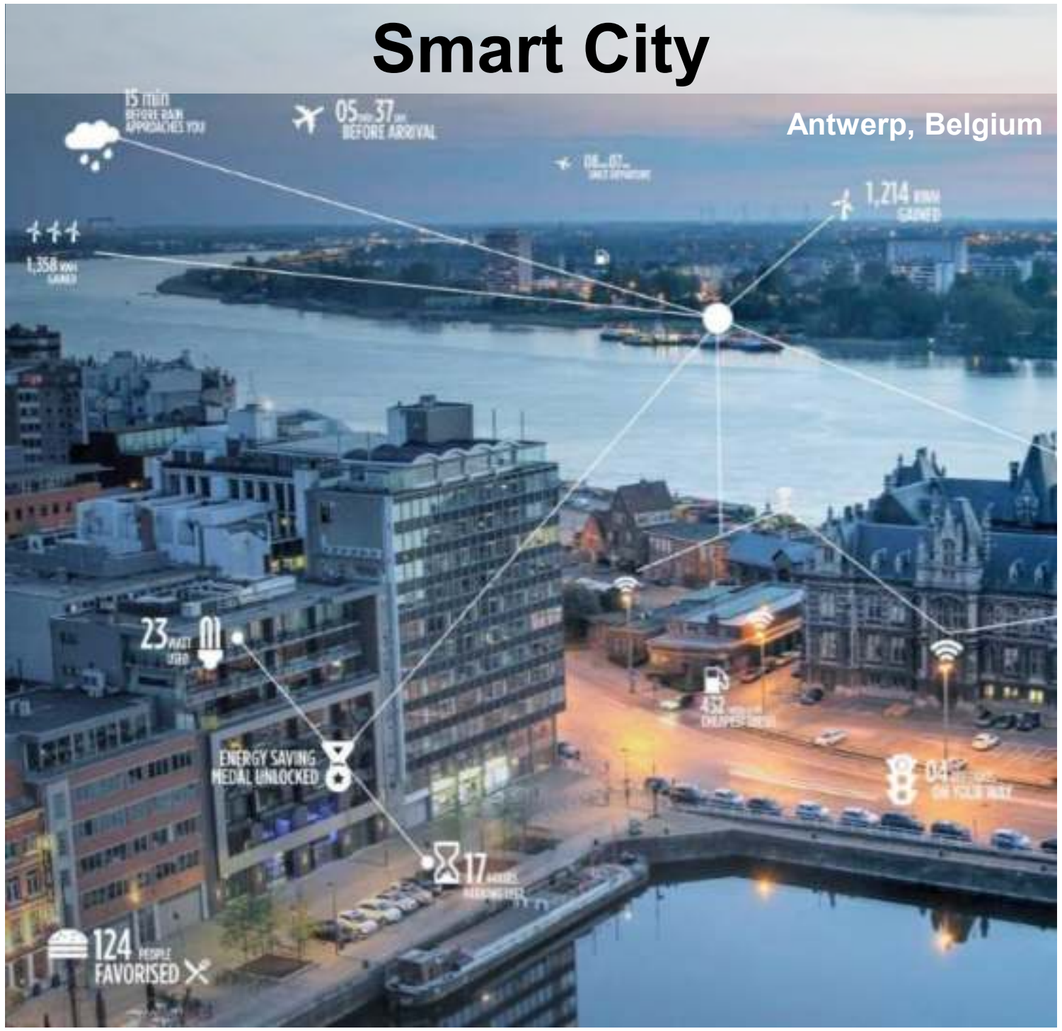
- Developing a high-resolution electromagnetic radiation map of the city of Antwerp.
- Measuring electromagnetic radiation for all major wireless networks and frequencies that these networks use: GSM, UMTS, LTE(4G), 5G & Wi-Fi.
- In Coock Open city: node for 5G radiation exposure.



- Developing a tool to predict the wireless coverage of any indoor environment for a given set of access points: the Wica Heuristic Indoor Propagation Prediction Tool (WHIPP).

Design EMF nodes: low-cost mobile nodes for radiation impact in cities

INTRODUCTION



- Enabled by:
  - Advances in network technology
  - Availibility of cheap sensor
- Strong interest in monitoring environmental parameters:
  - T, air quality, humidity, etc.
- But also need for monitoring **realistic radio-frequency electromagnetic field (RF EMF) exposure**

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NEED FOR SPATIO-TEMPORAL RF EMF EXPOSURE (1)

- **Realistic exposure assessment** is of interest to:
  - Governmental agencies: risk assessment and communication; 5G
  - Epidemiological research
  - General public and workers

- **WHO** Research Agenda
  - **Need for quantification of exposure** to widespread and emerging radiofrequency (RF) sources
  - **Public unfamiliarity** with RF electromagnetic fields (EMF) leads to concerns

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NEED FOR SPATIO-TEMPORAL RF EMF EXPOSURE (2)

- **Spatio-temporal EMF assessment**:
  - will provide data on population exposure and personal exposure
  - but, is **still a challenge**:
    - Accurate exposure maps require EMF sensors densely distributed over an area (will even increase with the advent of 5G)
    - Personal exposimeters are not suitable: high cost, battery-powered devices
  - **Mobile sensors!**

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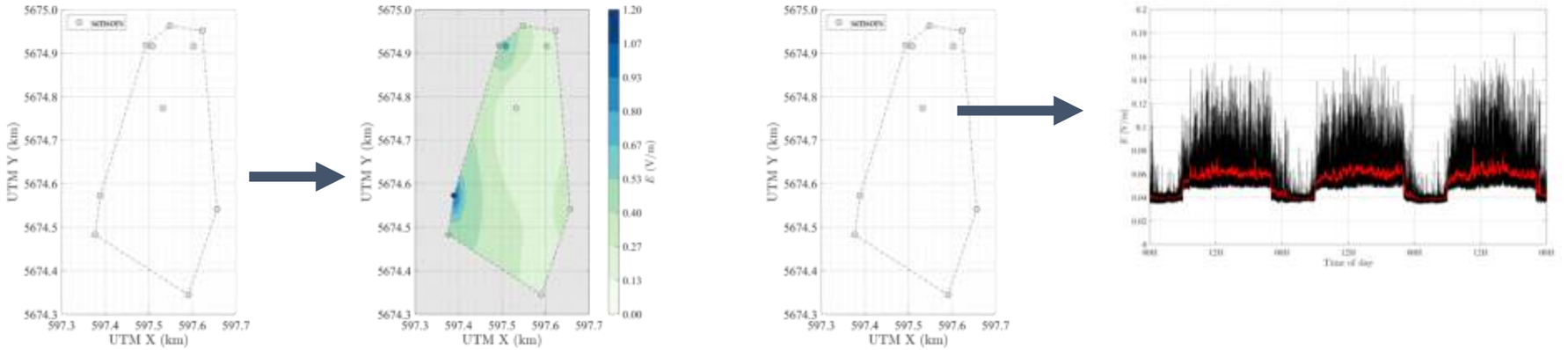
OBJECTIVES

- **Design** of fixed and **mobile** **low-cost RF EMF sensors**
- Deployment of an RF EMF exposure sensing network



Fixed EMF sensors

Mobile EMF sensors

MOBILE EMF SENSORS

ADVANTAGES-DISADVANTAGES

+ positive

- High spatial sampling
- Large areas

- negative

- Not one fixed location: sample spread over multiple locations
- Lower accuracy

Spatial exposure assessment

- Collect measurement samples per 100 m^2 to 250 m^2 tile
- Data captured to complement spatial/spatiotemporal models from fixed sensor data
- Co-kriging

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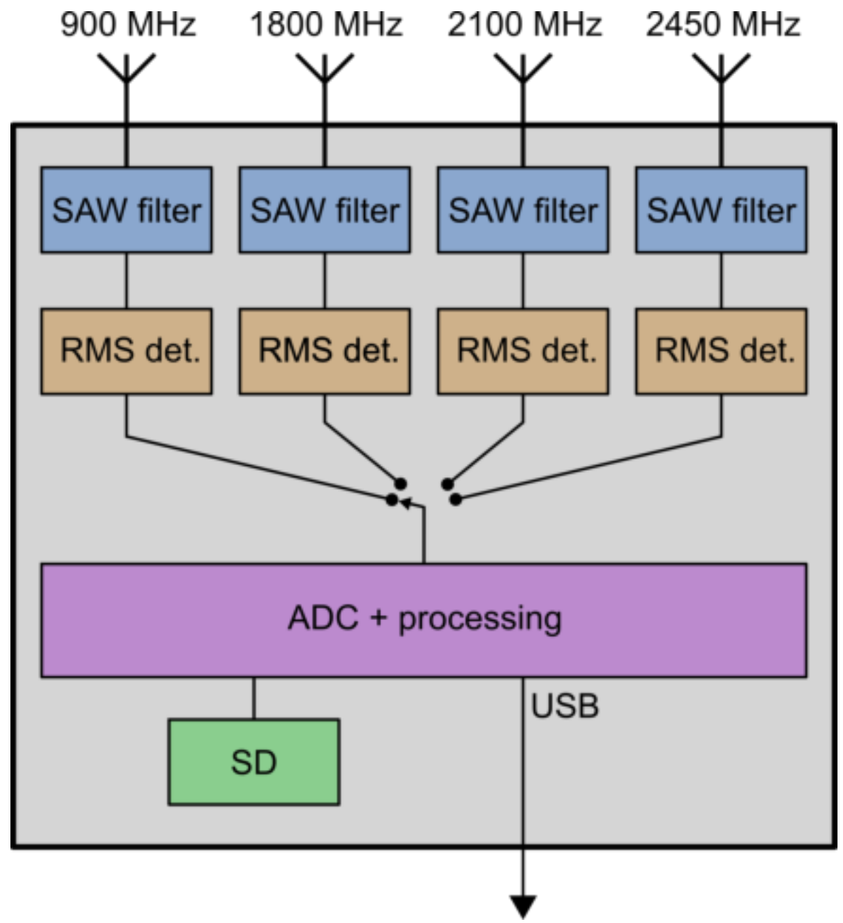
DESIGN OF EMF SENSORS V.

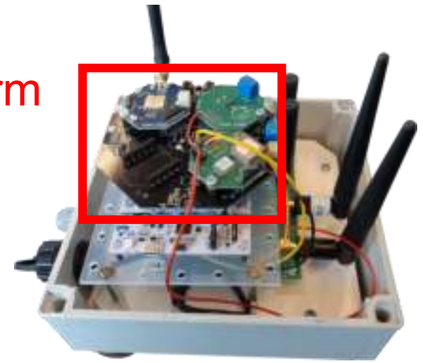
- Off-the-shelf components → low-cost
- Single antenna per frequency → increased isolation, but large size
- Interfacing to smart city network = USB
  - Fixed: towards gateway + LoRa
  - Mobile: towards Octa platform + **LoRa /NB-IoT**

5G too: 3.5 GHz and 700-800 MHz



Fixed
(x 22)

Octa platform



Mobile
(x 5)

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SPECIFICATION OF EMF SENSORS FOR WSNs

Electrical	
Frequency bands	900 MHz: 925 - 960 MHz (GSM, UMTS) 1800 MHz: 1805 - 1880 MHz (GSM, LTE) **5G too: 3.5 GHz and 700-800 MHz** 2100 MHz: 2110 - 2170 MHz (UMTS) 2450 MHz: 2400 – 2484 MHz (ISM, WiFi)
Polarization	Vertical
Detector	RMS
Sensitivity	5 mV/m
Dynamic range	70 dB
Sampling frequency (f_s): internal f_s output f_s	 5 msec 1 sec
Mechanical	
Dimensions (l x w x h)	18 x 18 x 15 cm^3
Material casing	ABS
IP class	IP66/76
Interface	USB or SD card

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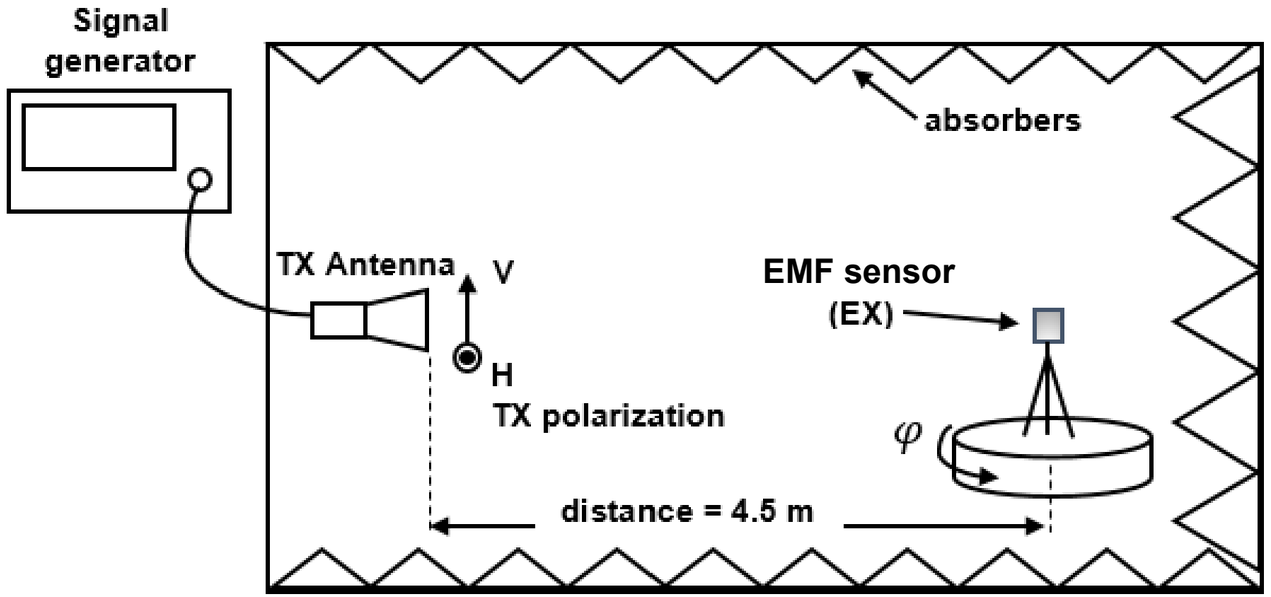
CALIBRATION

- To determine effective antenna aperture (AA)
- In anechoic chamber



1. Measurement
   - Tx: horn antenna, V- and H-pol bij 90^{o} rotation
   - Rx: (1) EMF sensor; (2) Narda NBM-550
2. Determination of AA(φ,ψ) for realistic polarization
3. Uncertainty = CI_{68} of antenna aperture

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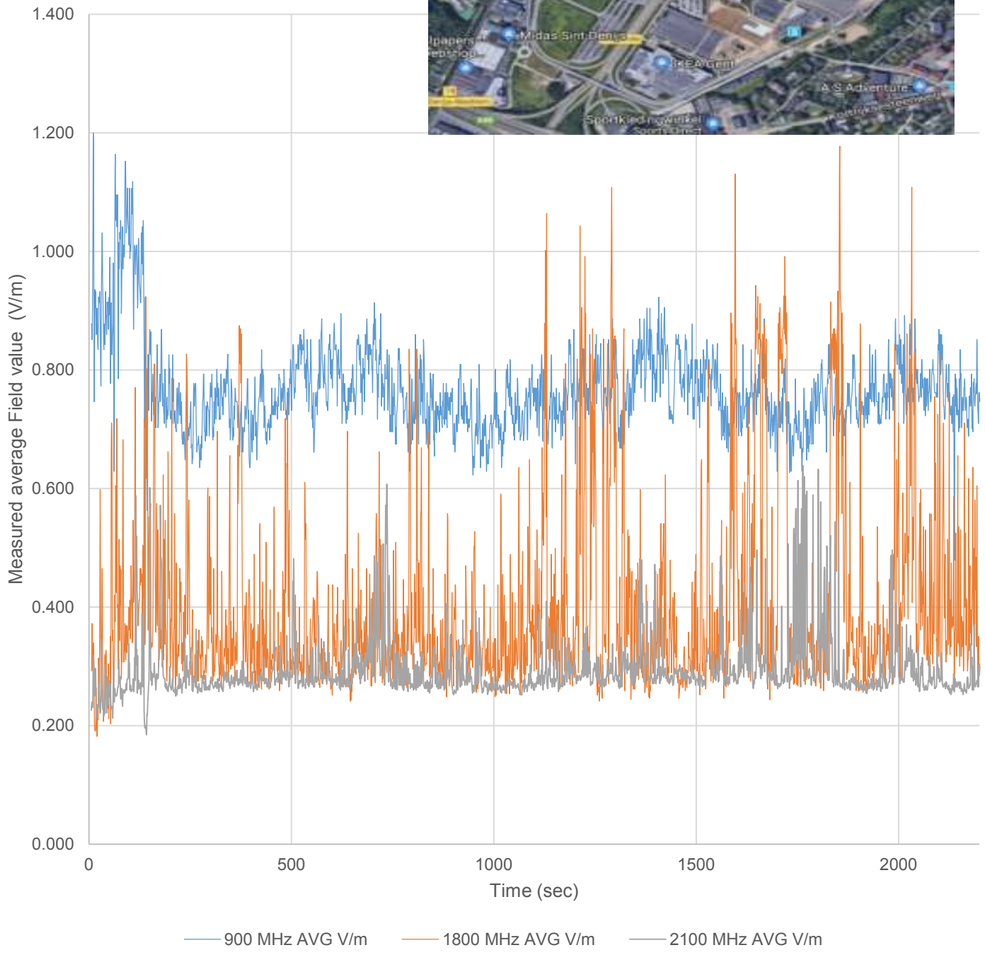
VALIDATION: FIELD TEST IN GHENT (1)



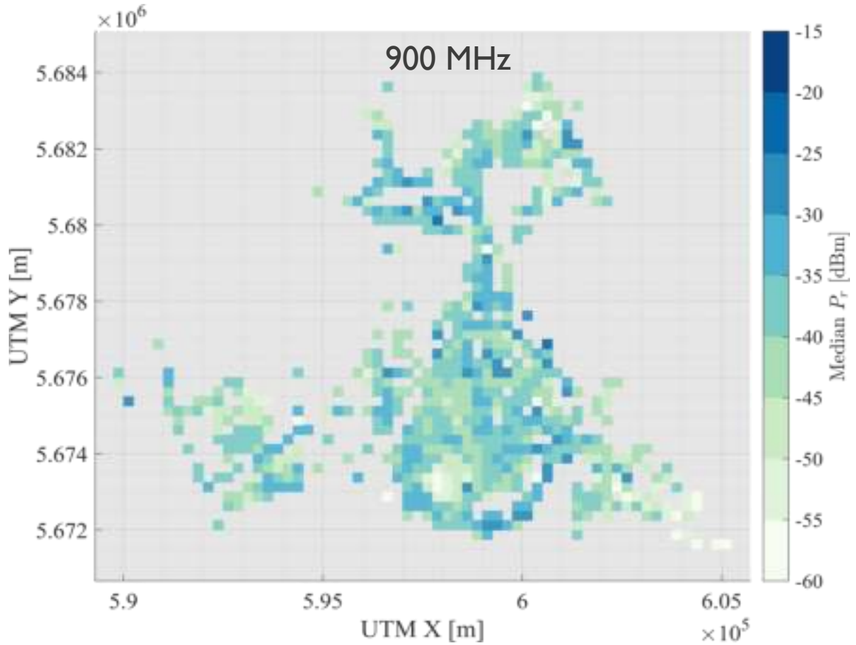
- EMF_node06
- Spectrum analyser + triaxial probe
- Freq: 900 MHz, 1800 MHz, 2100 MHz

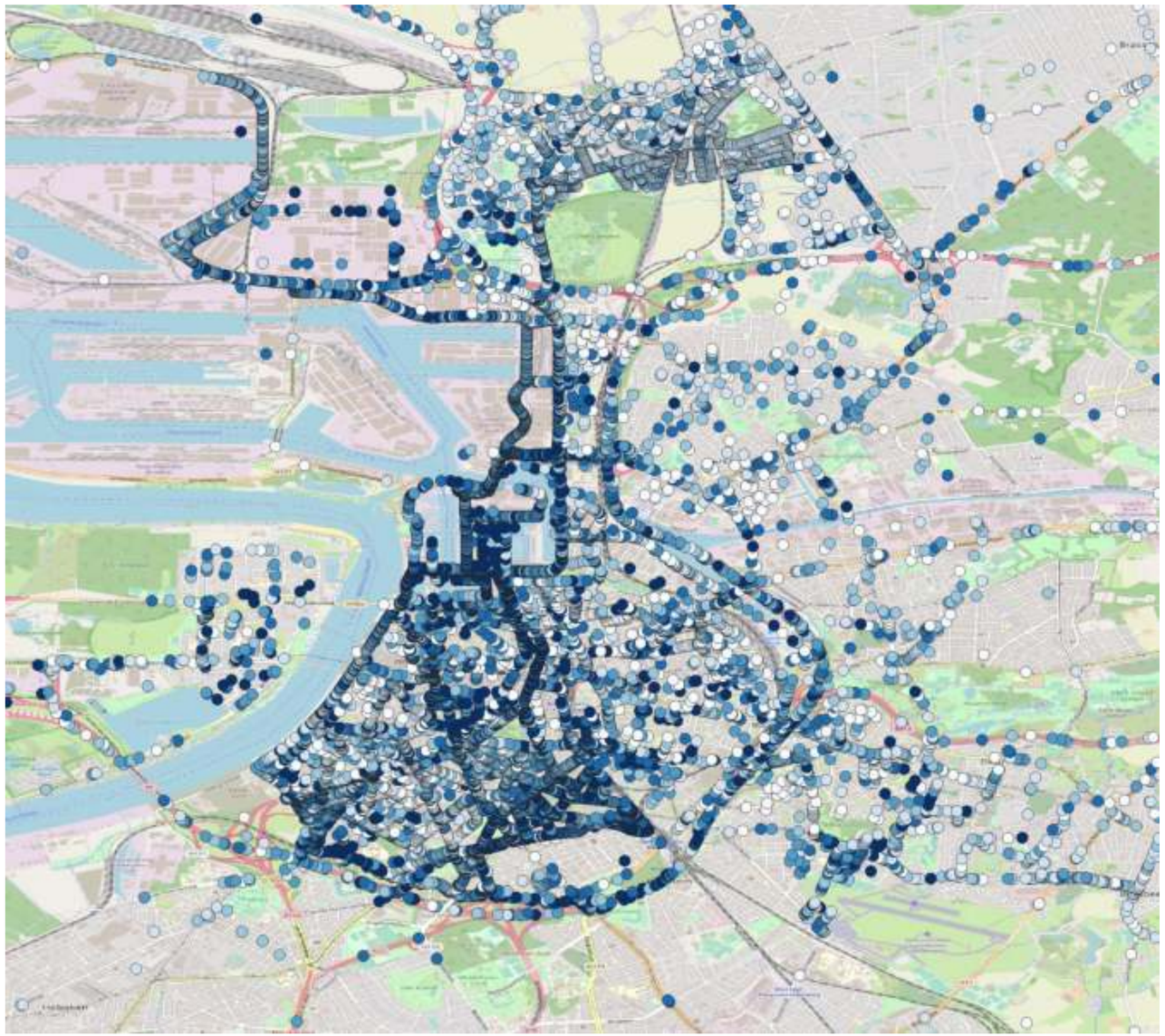
	Electric field SA (V/m)	Electric field EMF_node06 (V/m)	Deviation (dB)
900 MHz	1.003	0.768	-1.160
1800 MHz	0.468	0.400	-0.676
2100 MHz	0.182	0.292	2.061
Total electric field.	1.121	0.914	-0.889

Deviations < 3dB

RF MONITORING NETWORK: MOBILE RESULTS
IMEC CITY OF THINGS

- Mobile measurements
  - ~ 1 year of data
  - Snapped to streets (point per 20 m)
  - Averaged per point





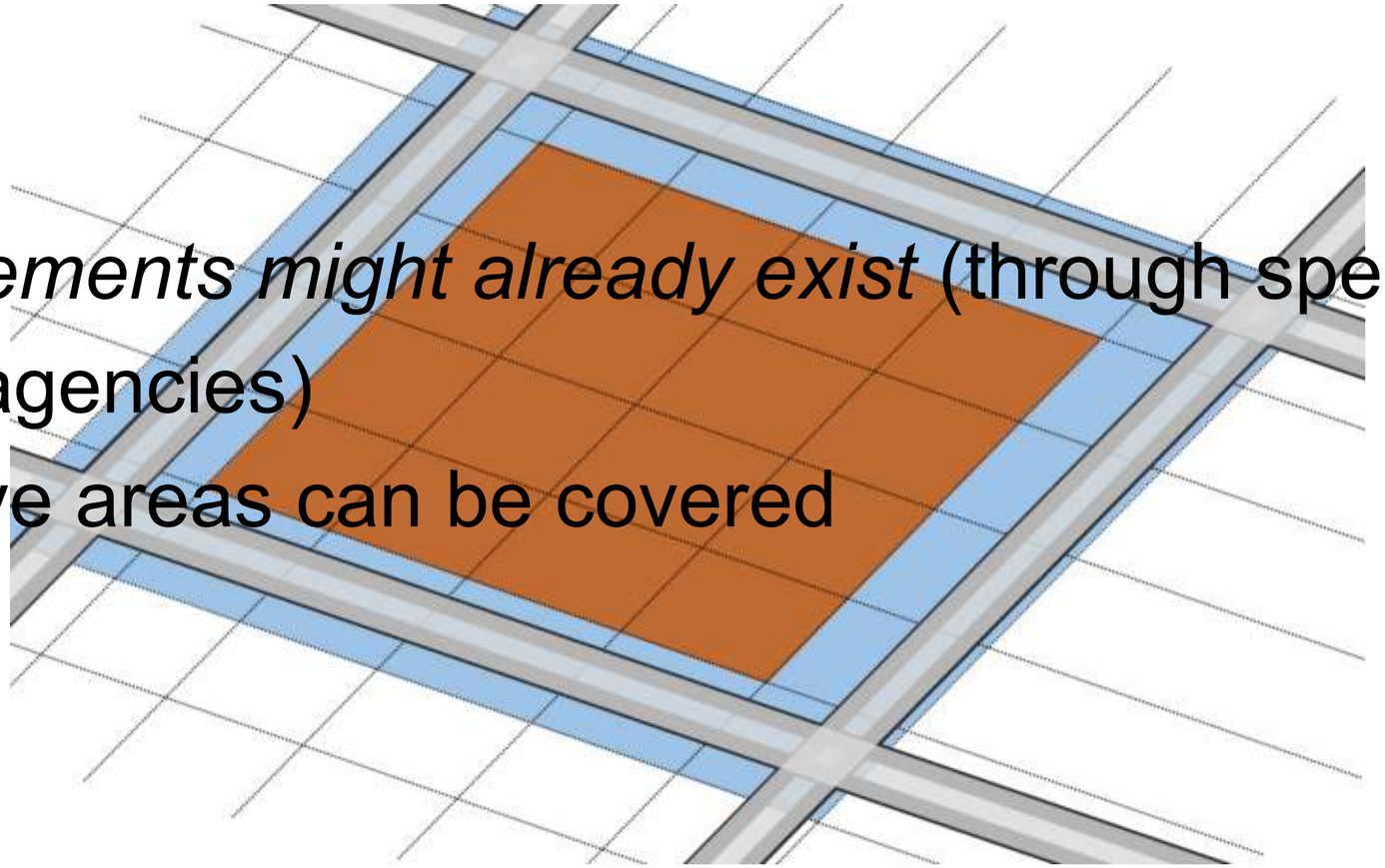
CONFIDENTIAL

Car-mounted system

CONFIDENTIAL

OBJECTIVE

Can RF measurements along roads, using a **car-mounted measurement system** used to characterize the exposure in the **area** encircled by those **roads**?



Advantages:

- *Measurements might already exist* (through spectrum use control agencies)
- Extensive areas can be covered

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AREAS UNDER STUDY

Cambridge, UK

Divided in **RING** and **INNER** areas

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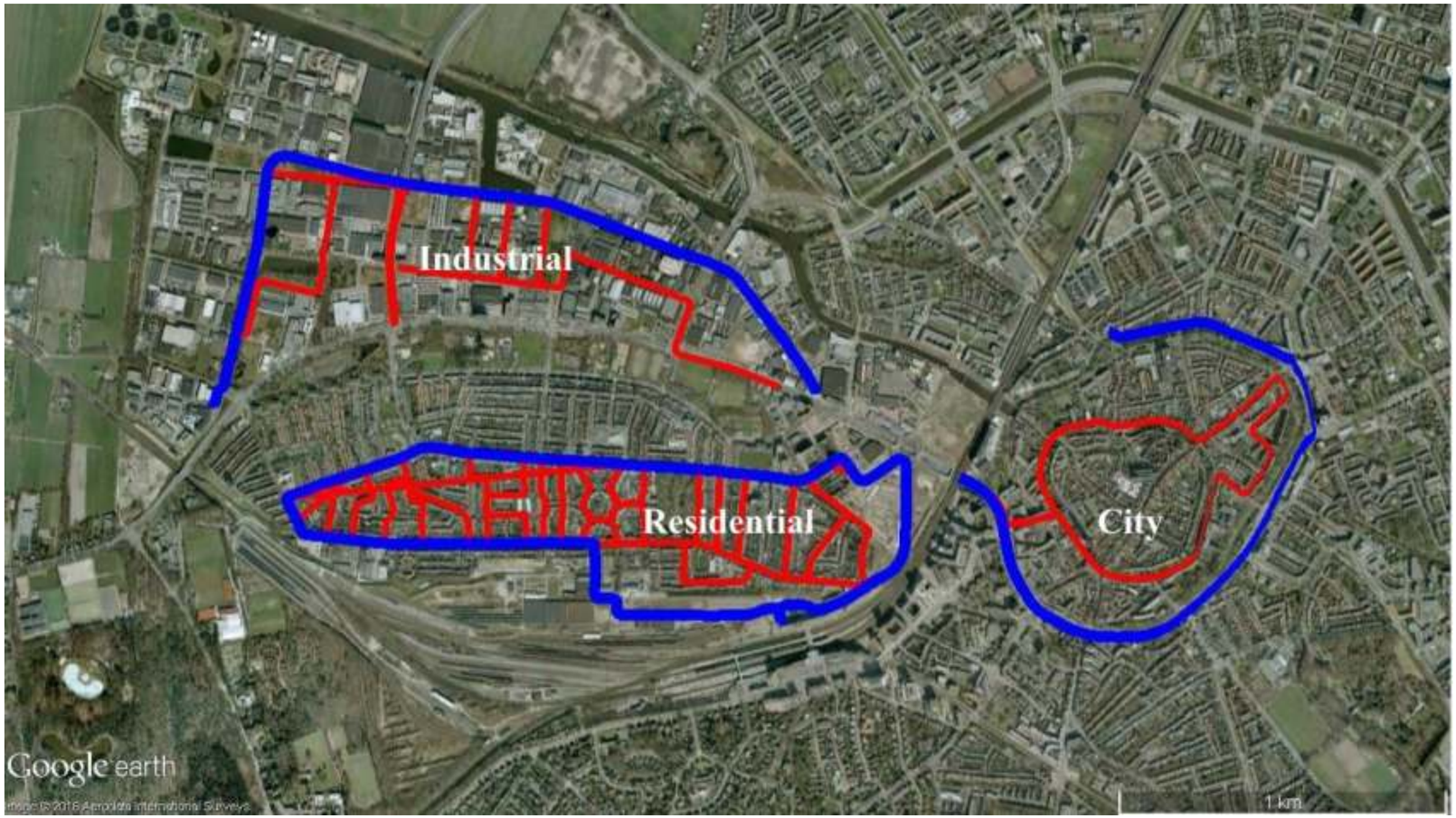
AREAS UNDER STUDY

Amersfoort, The Netherlands



Divided in **RING** and **INNER** areas

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MODELLING AND VALIDATION

The power density was interpolated (using *ordinary kriging*) on the inner-area grid bounded by the ring roads:

- **Initial model** uses only the ring data set (*R*)
- **Model is up dated** by adding inner-area (*I*) data, selected at random
- **Maximum models** are built using all available *I* (i.e., 75%) and *R* data

A random 25% subset of *I* is always retained for **validation**

Each interpolation stage was repeated 200 times using random subsets of I *for interpolation (max. 75%) and validation (always 25%).*

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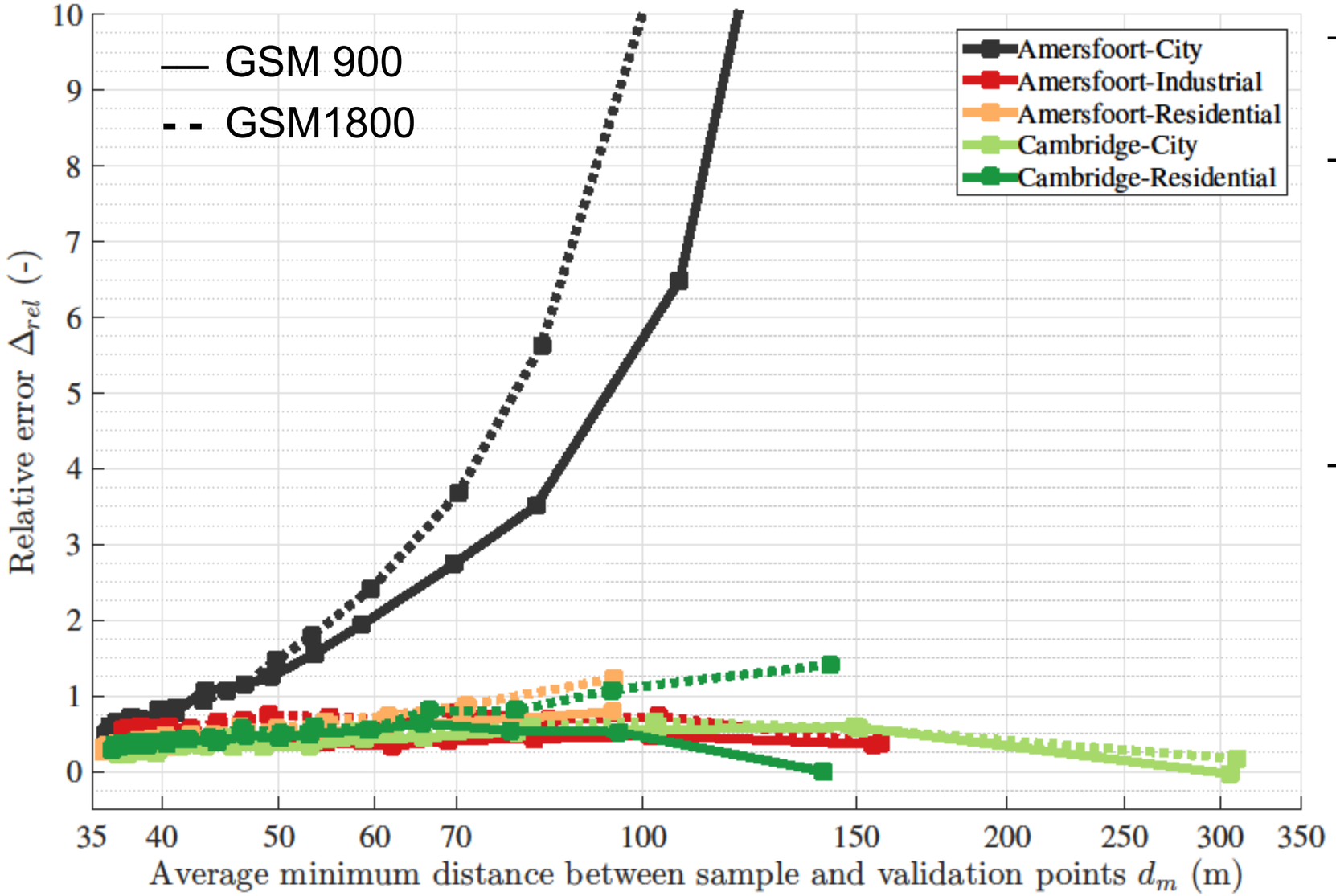
RESULTS: RELATIVE ERROR



- Rightmost point = initial model
- Error is reduced by adding samples from the inner area (*i.e., distance between samples and validation points decreases*)
- For most areas & signals, error is relatively low in any case

Adding more inner-area data points

DISCUSSION

- Overall, in areas the size and shape of Amersfoort-Residential
  - **Proposed methodology can readily be applied if the measured ring route is closed**

- **Main strength** = fact that **mobile measurements spanning nationwide road grids can be readily available**
  - on an annual basis
  - only need to be collected and interpolated
  - additional measurements might be needed

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Other mobile measurements: on-body, drone, etc.

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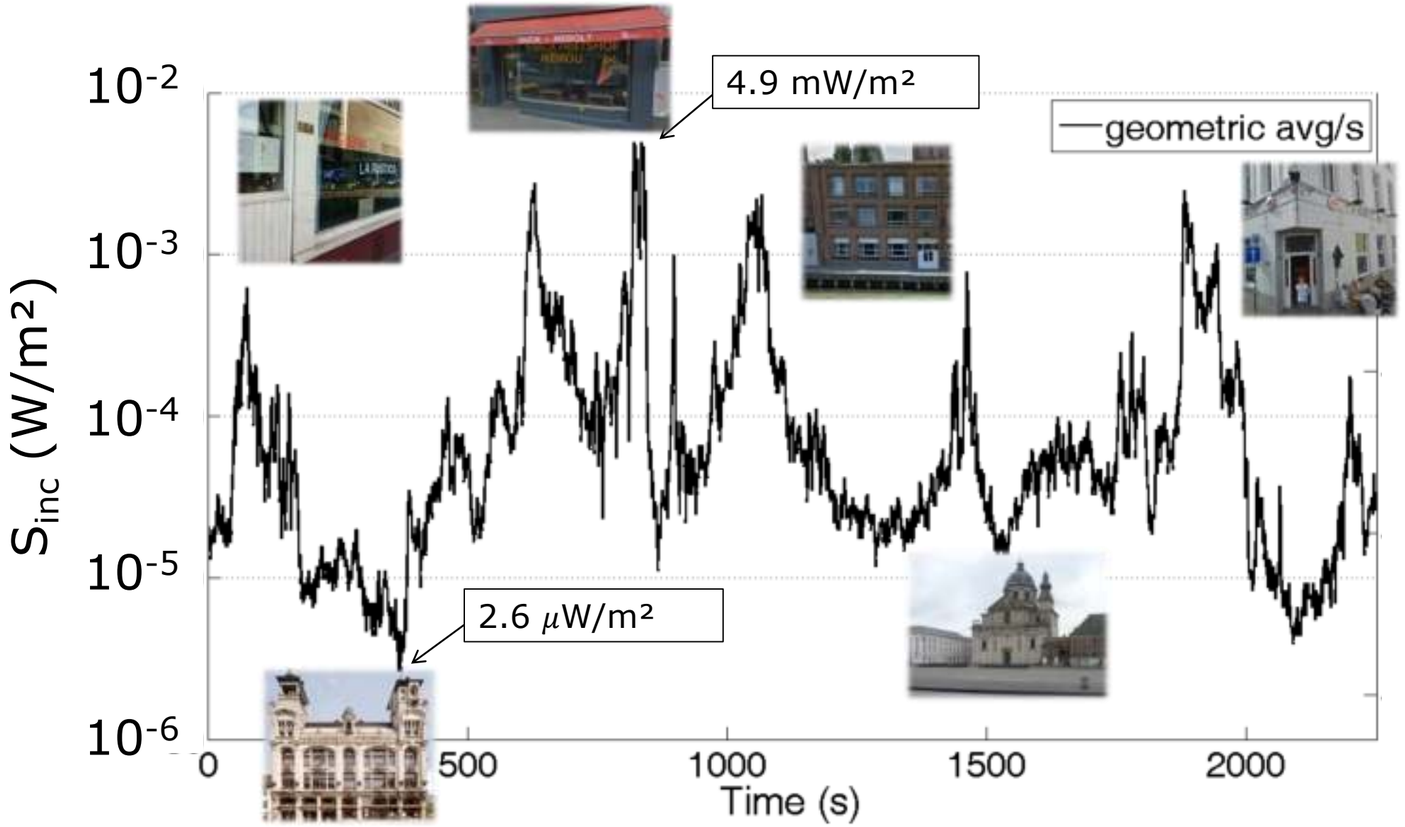
On-body- Measurements

Route in Ghent, Belgium

- 3 km
- urban area
- sample rate = 1 Hz

Measurements

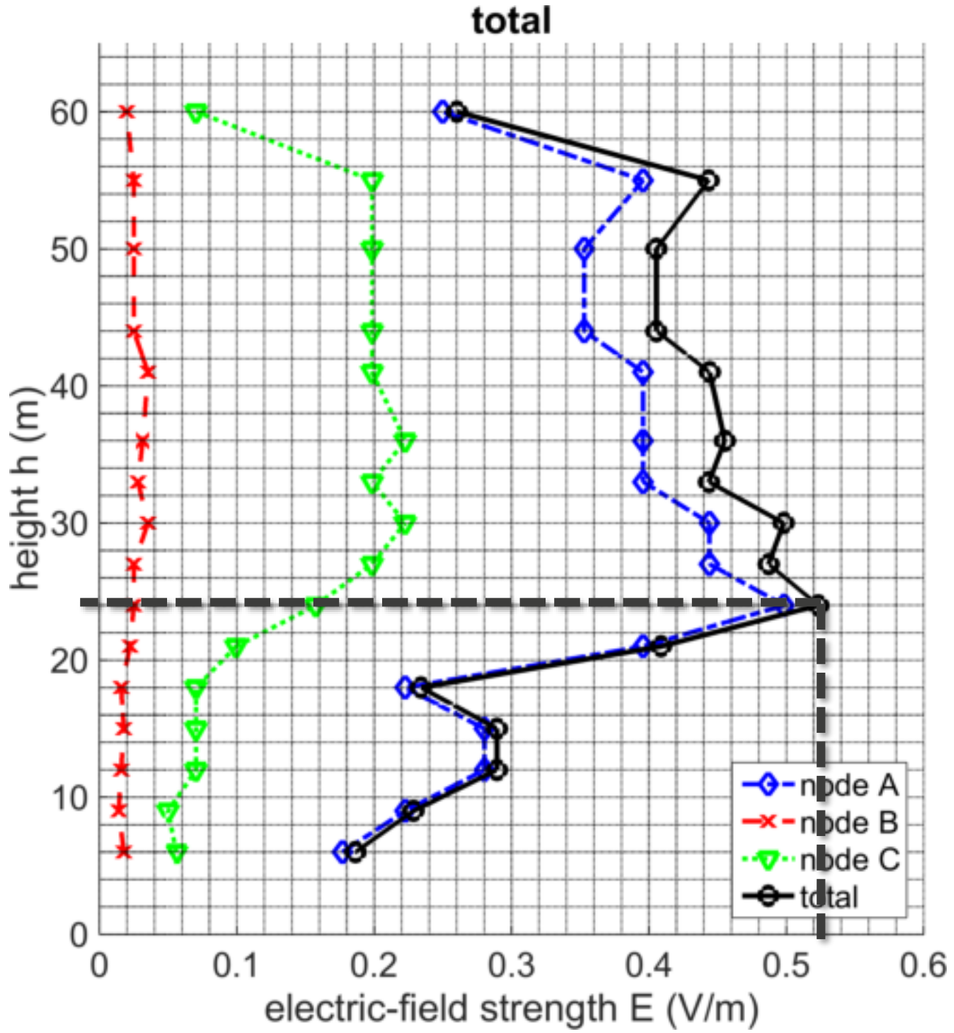


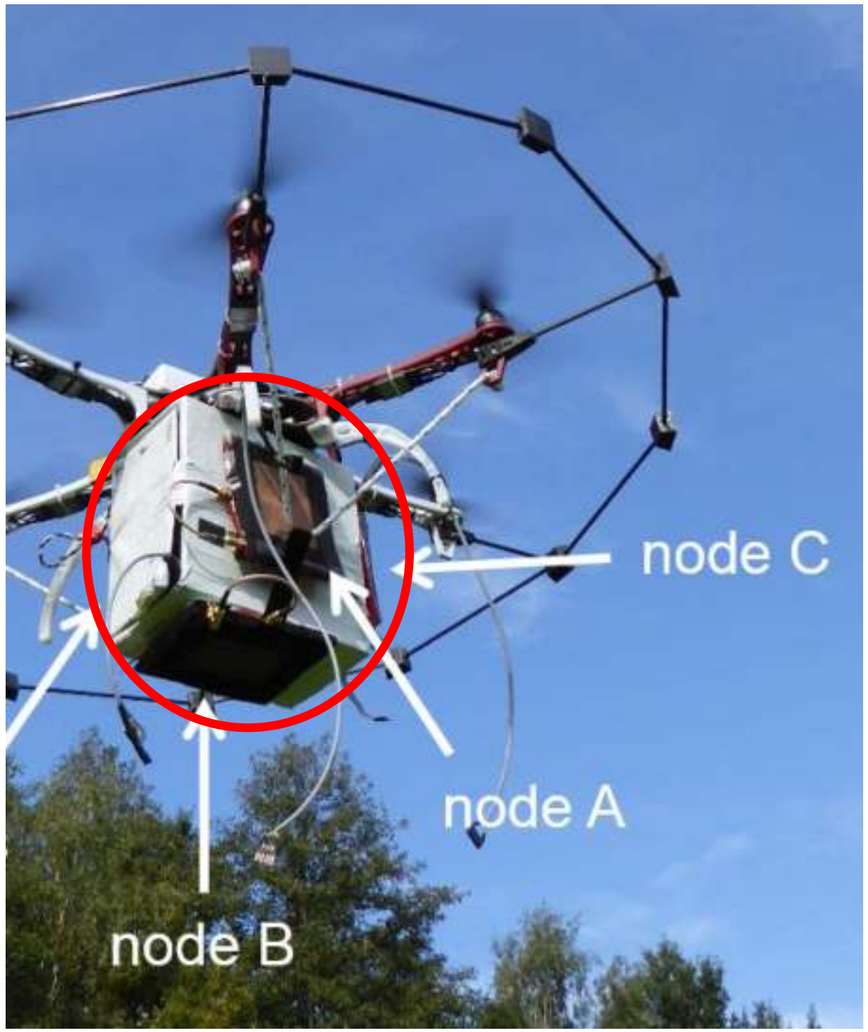
	p_{25}	p_{50}	p_{75}	p_{95}
S_{inc} ($\mu W/m^2$)	21	47	120	830

Reference Levels*
$4.6 \times 10^6 \mu W/m^2$

*general public

DRONE-BASED 3D PROPAGATION AND EXPOSURE MEASUREMENTS





CONCLUSIONS AND FUTURE

- Low-cost 5G EMF sensors for wireless sensor networks
- Deployed EMF exposure sensing network Antwerp:
  - **mobile EMF sensors** were installed in Antwerp
  - Modelling of route and inner area field exposure
  - **Mobile: on car, on-body, app on mobile phone**

- **Next:**
  - Mobile nodes: larger scale + 5G
  - Exposure data in Digital Twin of imec
  - Spatial and temporal analysis
  - Combining EMF data from fixed and mobile data to assess the spatio-temporal EMF exposure in a smart city environment

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Acknowledgment: This research is part of '**DENCITY**' and **COOCK-Open City**, VLAIO funded projects